WAVE AND FLOATING WIND ENERGY

OPPORTUNITIES FOR SHARING INFRASTRUCTURE, SERVICES AND SUPPLY CHAIN

WES_LS09_ER_Wave_Wind_Sharing

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Wave Energy Scotland Executive Summary

Reasons for commissioning

The competitive, stage gate process of the Wave Energy Scotland (WES) Novel Wave Energy Converter programme has delivered two large-scale proof of concept wave energy devices, which have been successfully demonstrated in EMEC's Scapa Flow test site. These technologies show a promising trajectory towards commercialisation, supported by the suite of sub-systems and enabling technologies emerging from the other WES programmes, namely Power Take-off, Control Systems, Structural Materials and Quick Connection Systems.

WES is working to support the next steps in this commercialisation pathway, delivering on its original objectives from the Scottish Government – to bring forward commercially viable and cost competitive wave energy technology for Scotland.

In that context, three key drivers initiated this study:

1. Conceptual studies have shown that partnerships with floating offshore wind technologies and projects could provide a route to MW-scale wave devices and further cost of energy reduction, but these have not yet been thoroughly analysed from cost, feasibility and wider benefits perspectives
2. The EVOLVE project clearly demonstrated that the generation profile of wave energy is complementary to wind and solar[1], making it a valuable part of a high-renewables-penetration energy system and reducing the need for energy storage deployment
3. The magnitude of the ScotWind leasing round and the size of the supply chain required to deliver it, as well as the requirement for significant domestic content, creates a potential opportunity for supply chain sharing which could benefit both wind and wave developers

WES commissioned this study to gather evidence upon which to build a strategic scale-up pathway, and to make a case for doing so in partnership with Scotland's planned growth in floating wind capability and deployment.

WES Objective

The objective of this study was to understand the potential technical, economic and socioeconomic benefits of various levels of sharing of infrastructure, space, supply chain and services between wave energy and floating wind energy developments. Aware that such a partnership would need to be mutually beneficial, WES required consideration of sharing scenario benefits from the perspectives of both parties (wind and wave). The study set out to evaluate local, project and technology level benefits to complement the national energy system benefits of a broad energy mix recently characterised by the EVOLVE project[1].

[1] https://evolveenergy.eu/project-outputs/

Summary of results

The key results of the study, from a strategic perspective are:

1. All scenarios reduce the cost of energy, by significant amounts for both wind and wave energy
2. Benefits are available through cooperation, co-location or co-development of floating wind with both individual MW-scale wave devices and multi-absorber wave energy platforms
3. The wind and wave sectors can accrue the majority of the cost benefits without considering fully hybrid, combined wind and wave platforms, which are potentially unattractive from a development risk perspective in the near to medium term
4. Integration of wave energy and sharing of supply chains between wind and wave energy makes a strong contribution to the local content of a floating wind project
5. Sharing with floating wind is a path to the delivery of a world-leading wave energy industry and subsequent export opportunities

Strategy Development

WES will continue to build technology development and commercialisation strategies based on integration of wave technology with floating wind. The strategy will include the delivery of cross-sector workshops and innovation activities and WES welcomes the engagement of developers, supply chains, government and technology providers.

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List of Abbreviations

AEP	Annual Energy Production
BoP	Balance of Power
CAPEX	Capital Expenditure
CLV	Cable Laying Vessel
CTV	Crew Transfer Vessel
CSA	Cross Sectional Area
DCO	Development Consent Order
DECEX	Decommissioning Expenditure
DEVEX	Development Expenditure
DTS	Distributed Temperature Sensing
FLS	Fatigue Limit State
FOU	Foundation Package
FOWT	Floating Offshore Wind Turbine
GCP	Grid Connection Point
IAC	Inter Array Cable
LCOE	Levelised Cost of Energy
MCE	Major Component Exchange
MEQ	Main Electrical Equipment
VAr	Volt-Ampere Reactive
MW	Mega Watt
NGESO	National Grid Electricity System Operator
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OFCA	Offshore Cables
OFFGE	Offshore Grid Entry Point
P/Q	Power/Reactive Power Performance Curve
PTO	Power Take-off
OFGEM	Office of Gas and Electricity Markets
OFTO	Offshore Transmission Owner

OMA	Operations and Maintenance Agreement
ONCA	Onshore Cables
OnSS	Onshore Substation
OPEX	Operational Expenditure
ORE	Offshore Renewable Energy
OSS	Offshore Substation
OWF	Offshore Wind Farm
SOV	Service Operation Vessel
T&I	Transport and Installation
TRL	Technology Readiness Level
TSO	Transmission System Operator
ULS	Ultimate Limit State
WEC	Wave Energy Converter
WES	Wave Energy Scotland
WTG	Wind Turbine Generator

1 Introduction

Wave Energy Scotland (WES) commissioned OWC to investigate the potential benefits that could be realised both to the wave energy industry and floating wind projects through the sharing of assets and/or deployment and operational activities. The overarching aim is to explore ways to fast-track or improve commercialisation potential of wave energy technology, given WES's remit as a funding body for wave energy technology research.

The report first introduces the rational for the project, core objectives and scope of work before detailing the approach to definition and selection of sharing scenarios, the evaluation of cost and wider benefits of these scenarios and the assessment of their feasibility. The report concludes with a clear output of the sharing opportunities that have the greatest potential along with a proposed roadmap for implementation of these and recommendations for next steps. It is hoped that this report will provide a basis to warrant further research and development of co-development activities in Scotland and other markets and ultimately contribute to bringing wave energy technology to the point of commercial viability.

1.1 Context

The energy market in the UK is currently undergoing a transitionary period with increasing prices of fossil fuels, heightened demand, and challenging targets to meet to achieve net zero pathways. Particularly with the backdrop of the current international energy crisis, the demand for all forms of renewable energy sources is increasing dramatically.

At present, wave energy technology cannot effectively compete in the UK electricity market with offshore wind and other renewable technologies. The industry is relatively immature with high costs that have not yet had the opportunity to reduce through increased deployment numbers and the associated learning. Furthermore, the lack of ringfenced government support with respect to commercialisation and route to market has made it harder for the industry to develop at speed, and alternative or supplementary commercialisation pathways are being considered.

Since its formation WES's focus has been on addressing the technical challenges facing wave energy through both competitive technology development workstreams and strategic landscaping and tool development studies to support this sector. In order to progress further, wave energy needs to move towards commercial projects and therefore private investment.

One opportunity for the wave energy industry to achieve this is to identify scenarios in which wave energy could complement other technologies. In particular, floating offshore wind has been identified as a promising sector to align with. An interesting point to consider is the ability for floating wind turbines to cope with the significant wave conditions that coincide with the ideal deployment locations for Wave Energy Converters (WECs), given the floating wind technology has yet to be deployed in such conditions. The opportunities for wave and wind sharing will hinge on whether common ground can be found for both technologies, leading to economic and/or wider benefits for the energy developers and the local industry.

The wave and wind resources in Scotland are among the best in the world. Scotland is the world leader in floating wind and plays a significant role in wave energy development with deployment sites at EMEC. This makes WES ideally located to engage with this opportunity. The benefits for Scotland would include greater renewable energy production; local socio-economic benefits; and the establishment of a new industry sector with technology, services and IP export potential.

1.2 Project Objectives

Given the context described above, the overall objective of this study is to assess whether floating wind projects can provide an opportunity to fast-track wave energy towards commercial viability and in so doing help establish the industry. This objective is framed in the context of the ScotWind floating wind projects currently at the early stage of development as a real opportunity that could potentially be utilised by WEC developers. This will provide a sound basis to investigate the specific hypothesis, but at the same time enable broader conclusions to be drawn of relevance to the wider industry through maintaining generality in the assumptions. The study will identify and analyse the most efficient and mutually beneficial means of integrating wave energy systems into floating offshore wind systems through the sharing of physical infrastructure, supply chains and services.

The overall aim of this study can be broken down into several separate objectives. These include:

- To identify the benefit of co-development of wave and floating wind energy, at first at a generic level for both sectors, and then focusing on the benefits that wave can bring to the emerging floating wind industry.
- To identify any cost reductions and market benefit associated with co-development, in a way that is easily communicable and enables fair comparison, i.e. focusing on the key metric of LCOE. The assessment will focus on analysing opportunities for shared use of array resources (e.g., substations, export cables, IACs etc.), through comparison of combined WEC and Wind Turbine Generator (WTG) array configurations. It will also include the assessment of opportunities for development, supply chain, Installation and O&M synergies (e.g., shared manufacturing facilities, installation vessels, ports, etc.).
- To identify wider benefits of integrating the technologies, such as, but not limited to:
    - Opportunities for power profile smoothing due to different temporal outputs of WECs and WTGs

    - Opportunities for load reduction on Floating Offshore Wind Turbines (FOWTs) by using WECs
    - Benefits to supply chain development
    - Local technoeconomic benefits for Scotland including jobs and positioning as a market leader for both wave and floating offshore wind sectors
- To identify feasibility and technical challenges related to the co-location or integration of the technologies, assess their impact, and identify potential solutions.

1.3 Project Methodology

The approach and high-level steps that will be followed are shown in Figure 1-1, where the tasks to be performed in the different parts of the project are also presented.

In order to account for all of the configurations and sharing options, the first step consists in a longlisting exercise (Section 3.2.1), leading to the combining of different sharing options into specific sharing scenarios definition (Section 3.2.2), which are evaluated throughout this study.

The first level of evaluation is the economic one, through an LCOE modelling exercise (Section 4), which is conducted with the required level of detail and sensitivity to meet the objectives of this study, so that all the scenarios and sharing options defined can be modelled in the costing exercise. This requires a customised LCOE tool, which can combine the desired elements of wind and wave projects. Baseline scenarios (no sharing) are developed to enable comparison with the sharing scenarios, and the results to be ranked in terms of the level of cost reduction compared to the baseline cases.

A second level of evaluation investigates the wider benefits that the sharing scenarios provide to the industry, job creation and supply chain, as well as to less quantifiable topics such as electrical benefits to the grid infrastructure, and production performance improvements induced by combination of the technologies. This is covered in Section 5. This enables a more qualitative assessment of potential benefits to be covered to complement the outputs of the techno-economic model.

The cost evaluation and the wider benefits are then combined into a scoring matrix analysis with weighted criteria to identify a selection of 4-5 scenarios that are then assessed from a feasibility perspective (Section 7), to achieve the final conclusions and provide recommendations to the industry and future studies. A final iteration of ranking, combining the feasibility, wider benefits and cost results provides the basis for the final conclusions of the study.

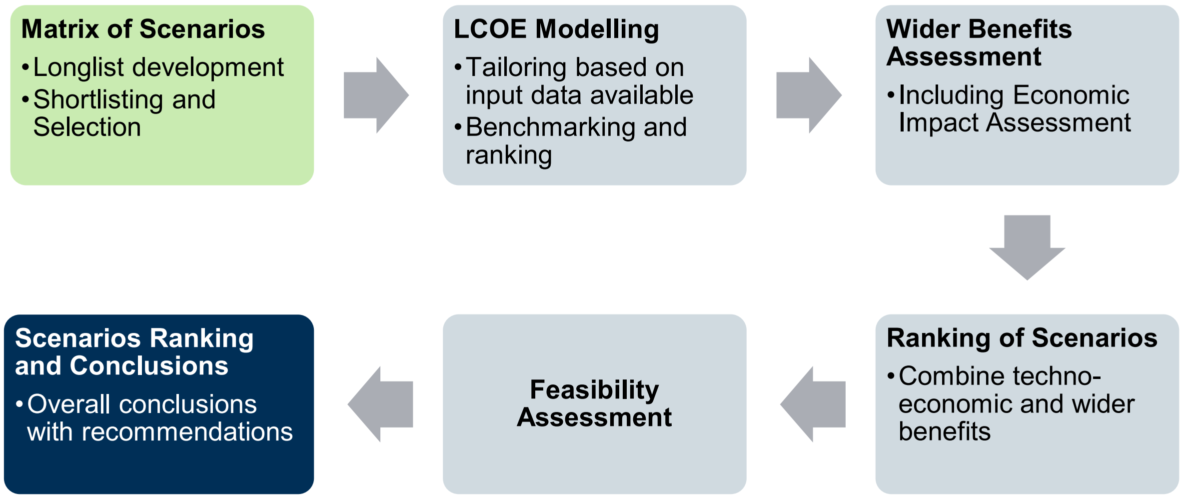


Figure 1-1 – High-level approach to meet project scope

1.3.1 Assumptions and limitations

The nature of this study requires the assessment of technologies with relatively low maturity in the market and across a broad range of sharing configurations. This means that multiple assumptions need to be made as a first step for investigating this topic. Therefore, the results of this report should be viewed as high-level, indicative conclusions towards understanding the benefits that sharing projects could bring. Further studies are recommended to develop the level of detail for the most promising options and to provide validation of the results of this study. The core assumptions and limitations are presented primarily in the following sections:

- Section 3.1.4, explaining the assumptions related to the wind and wave baseline scenarios
- Section 4.4 and 4.5, regarding the LCOE modelling and conclusions

2 State-of-the-Art & General Considerations

2.1 Wave Energy

Ocean energy converter technology originates in the 19th century and it regained some interest in the 1970s and again at the end of the 20th century, with significant research efforts made particularly in the coastal European countries and particularly the UK. About 12 MW of devices have been installed in Europe since 2010, although currently active wave energy devices have a cumulative capacity of about 2-3MW and are mainly focused on research and demonstration projects. Therefore, there is no fully commercial wave energy converter in operation.

The wave energy sector is still in development, with no technology being yet able to claim commercial maturity but for very specific applications. Compared to other types of Offshore Renewable Energy (ORE) technologies, the wave energy sector is characterised by the large quantity of concepts being actively developed. The concepts being developed bear little in common, with different working principles and target deployment areas.

Aside from a few examples, most of the Wave Energy Converters (WECs) tend to be resonant devices, or at least to have a hydrodynamic response and therefore performance which is strongly dependent on wave period. Depending on their working principle, this characteristic tends to constrain the potential size of the prime mover of most WECs, and one cannot expect future WECs to continue scaling upwards in the same manner as we have seen in wind turbine size evolution. Therefore, in the context of mixed and/or collocated wind and wave farms, it should be expected that the WECs will have to be more numerous than the Floating Offshore Wind Turbines (FOWT) to achieve a similar level of installed capacity.

2.2 Floating Wind Energy

Floating offshore wind has grown incredibly rapidly in the last decade. Since the late 2010s, the global floating wind project pipeline has increased significantly from just under 20 GW to more than 100 GW. The advent of floating wind has come about as the relatively shallow offshore sites have started to be consumed and offshore wind looked to continue to expand in support of Net Zero targets across the world. This led to the exploration of deeper water regions and the development of foundations that could support large offshore turbines in such locations. Floating foundations, moored to the seabed, provided a feasible solution to enable deeper water (typically >60m) sites to be exploited. Floating foundations could also be favoured for challenging shallow-water seabed geographies where fixed-bottom solutions are economically unviable for deployment.

The floating wind sector started with a few small-scale demonstrators installed in the EMEA region – Unitech Zephyros (formerly known as Hywind Demo) and moved into active pilot-array deployments such as the Windfloat Atlantic (25 MW) and Kincardine (48MW) projects, as well as small-scale commercial deployments; Hywind Tampen (88MW) which has just started to export power, at the end of 2022, with full operations expected in 2023. Anticipated worldwide installed capacity in 2030 is 14GW rising to 46GW by 2035 [1]. The vast majority of this early development will be focused in Europe with South Korea and the US's West coast (California) following closely behind.

From the recent ScotWind leasing round there is a considerable amount of floating wind potential in the planning stages (approximately 17 GW). Within the UK, floating wind activity also exists in the Celtic Sea such as Erebus, Valorous and other 100-300 MW projects, with the former being the only one at the more advanced development stage (although still pre-construction). Floating wind capacity in the UK is anticipated to increase as The Crown Estate (TCE) is expected to launch a leasing round for the Celtic Sea in 2023 targeting 4-5 GWs. In the Americas, the recent leasing auction, held by BOEM in December, saw five developers being awarded the seabed rights for five areas off the coast of California with a total capacity of 4.6 GW. All awarded projects are expected to enter construction within the next decade. The US also has some floating wind potential off the coast of Maine. The University of Maine was the first to introduce a "US made" floating wind concept, the VolturnUS, a concrete-based floater. The University of Maine has partnered with key offshore wind developers; RWE and Mitshubishi, promoting a 10-11 MW demonstrator which is expected to enter operation in 2023. A small-scale array (<250 MW) is also pursued by the local government in collaboration with the University of Maine. In the APAC (excl. China) region, the key market is South Korea with the city of Ulsan being the first mover to introduce legislation promoting floating wind developments. Numerous projects have already been proposed off the coast of Ulsan, as the city targets 4.6 GW of installed capacity by 2030. Notably, the local administration has collaborated with the South Korean government promoting floating wind specific legislation with the view of allocating 6-8 GW of floating wind capacity in the coming years.

State of the art in floating offshore wind is currently represented by the Kincardine-phase 2 – semi-submersible foundation – and the Hywind Tampen – spar-buoy foundation. The main difference between these floating architectures is linked to the floater's dimensions. The spar-buoy type foundation is realistically restricted to Norway and other regions with deep port infrastructures that could allow for the WTG integration within a safe haven (port), whereas semi-subs are not so restricted. However, the disadvantage of the semi-submersible structure is linked to the architecture's complex design and ballast system(s) which are required for active stability during both the towing-installation and operation phases. Another topology is the barge. Barges also achieve stability through buoyancy. So far, three barge demonstrators have been deployed; two in Europe and one in Japan. A fourth floating architecture is the Tension Leg Platform (TLP) which achieve stability through mooring tension. Currently, there is no operational demonstrator nor a pilot-array project using this architecture. However, a pilot-array project, the 25.2 MW Provence Grand Large project in the French Mediterranean Sea, is at the final construction stages with deployment of the three TLPs anticipated in 2023.

Given the current progression of the floating wind market and the fact that most of the proposed floating wind technologies are based on the semi-submersible architecture, the majority of the proposed projects in the pipeline are expected to deploy semi-subs (Figure 2-1).

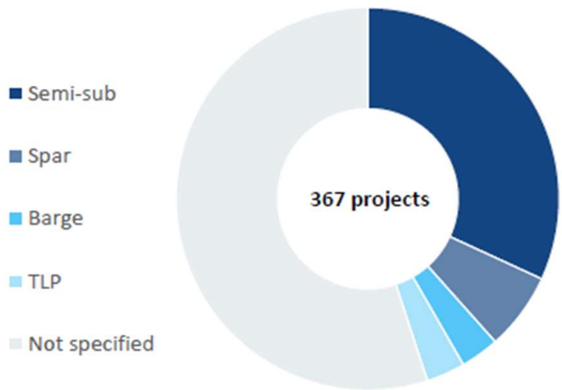


Figure 2-1: Selected floating wind foundation architecture for all projects in 4C's database [1]

Typical project considerations for the selection of a floating wind project are centred around the site conditions. Key primary parameters are the wind and wave climate considerations that need to be integrated during the design process of the floater, and geotechnical conditions that should be taken into consideration when selecting the mooring system (mooring line and anchoring). These factors are seen to drive foundation, mooring and installation costs, significantly impacting upon project economics. Secondary considerations are linked to manufacturing of large foundations, transport and installation challenges as well as to O&M activities.

2.3 Wave-wind Co-location

Offshore wind and wave resources often coexist in the same locations, which would allow for the combination of wind and wave energy technologies. However, the limited technological maturity and commercial attractiveness are the major obstacles for such joint development. Currently there are no existing wind and wave co-located farms worldwide.

2.3.1 WECs within the wind farm

In addition to the concern about the high number of WECs required and the relatively low installed capacity, WEC spacing constraints are particularly important in the context of collocated wind and wave farms, especially when layouts with WECs inserted between FOWTs are considered. For wave energy farms, the literature is relatively scarce on this subject. A study on the numerical simulations of farms composed of generic WECs [2], recommends that a spacing of 10 to 20 times the characteristic length can be used for the WEC to avoid any hydrodynamic interactions between systems.

Another study, see [3], shows that for a Wavebob type point absorber, distances of 78m (approximately 4 times the diameter) between WECs, could be sufficient to ensure average interaction factor of around 1. The interaction factor of a WEC array measures the output of the farm to the output of a single WEC in the same location. Values above 1 mean that WECs interact positively, values under 1 mean that the WECs interaction is negative, i.e. that the product of a single WEC multiplied by the number of WECs deployed is higher than the actual farm production. In practice, it is difficult to obtain interaction factors significantly above one when considering the full resource at a potential deployment site. In another investigation [4] the authors conclude that array interactions in the order of only 3% to 5% (production losses through WEC array interaction) were suggested in irregular waves, albeit uncertainty in measurement makes it difficult to reach statistical significance for the tests performed. These two latter studies would suggest that WECs could be spaced more densely than suggested in the original numerical analysis [2], if required.

This is an active area of research and it will be important to understand fully the interaction effects and appropriate spacing for different device types and configurations, including clustered devices and those on a shared platform design.

2.3.2 WECs outside of the wind farm

Previous works were also conducted on the potential impact of placing WEC arrays on the outside of a Wind farm, with potential benefit regarding the overall energy density deployed in a given area, and regarding a decrease of the significant wave height within the wind farm. Some studies [5] [6] have focused on a specific case in Denmark with WEC types which would favour such impact. One of the main benefits identified in these studies is the gain in accessibility of the wind farm which will favour better O&M and availability. The impact of the WEC indeed allows in such cases to have access to the site in marginal conditions with small reduction of the significant wave height. More details are provided in Section 5.3.

2.3.3 WECs collocated on WTG platforms

Finally, much of the work on collocating wind and wave energy has been done by trying to integrate these technologies in the same platform. The leader in this sector in Floating Power plant[1] which has been developing their concept since 2014 and were the first to test at large scale a wind and wave combined platform. Marine Power Systems[2] is also developing a concept based on a floating platform able to support multiple WECs, a WTG, or a combination of both technologies. Both entities are emphasizing potential gain in terms of stability of power supply as the wind and wave resource are only weakly correlated [7] [8]

Further to this development by private entities, numerous academic studies [9] [10] [11] [12] [13] have been completed regarding the design of potential wind and wave platforms. The

[1] https://floatingpowerplant.com/products/

[2] https://www.marinepowersystems.co.uk/

authors are not only focusing on the maximum production of the combined wind and wave platform, but on holistic approach by which the additions of WECs to a FOWT are used to dampen the motion of the platform and allow higher wind energy production and/or lower fatigue stress on the WTG. More details are provided in Section 5.3.

3 Scenarios Definition

The definition of Scenarios follows the methodology presented in Figure 3-1. This section will cover the baseline scenarios for wind and waves and then describe the combined scenarios, and the selection of scenarios for the techno-economic, wider benefits and feasibility assessment.

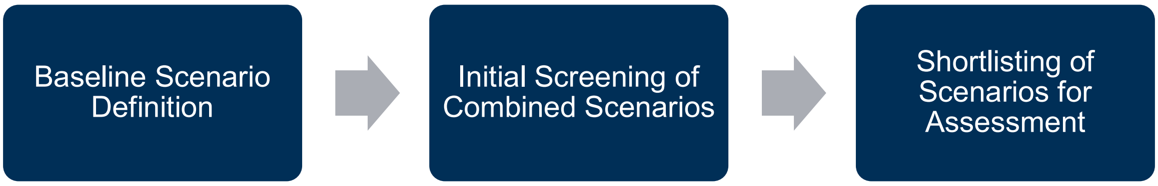


Figure 3-1 Scenarios Definition Methodology

3.1 Baseline Scenarios

The first step in the scenario definition process was to define baseline scenarios for the wave and wind concepts in order to provide a point for comparison for the cost reduction assessment of the different sharing scenarios. The idea of the baselines is to generate a stand-alone wave project and a stand-alone floating wind project with consistent assumptions to ensure a fair comparison. These base cases should also be realistic with respect to the industry context to ensure applicability of the analysis to future commercialisation of the technology.

For the floating wind concept, in view of the aim of this study which is designed with applicability to the opportunity presented by ScotWind in mind, the focus for the baseline assumption is on the typical characteristics of ScotWind round 1 projects in favourable areas for wave energy technologies, and any future projects awarded in the Spatial Marine Plan areas, especially where there is already additional space available for further leases.

The wave resource for the base case needs to be at least ~20kW/m for existing/first generation wave technology. This then enables the ScotWind sites to be screened for suitability for wave-wind co-generation alongside bathymetry checks for floating wind suitability as well as the types of project leases that have already been awarded and specified as floating technology.

3.1.1 Site Characteristics

Figure 3-2 provides a high-level view of the wave power across Scottish waters. The ScotWind floating wind sites compatible with wave energy are NE1, N2, N3 and possibly N1 although this is generally a slightly shallower site.

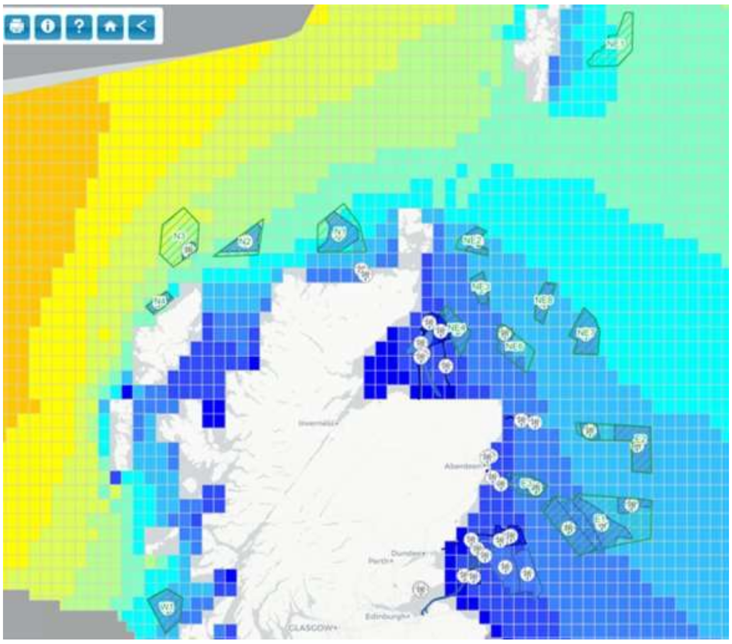


Figure 3-2: Wave power map of Scotland (source: Marine Scotland)

Site characteristics assumptions, broadly based on the above sites (strong waves & wind, deep water) are provided in Table 3-1. Note that some of these assumptions are simplified compared to the specifics of the ScotWind sites to ensure applicability to other geographic locations and to avoid complexities in the modelling that have no relevance to the cost reductions that can be achieved through sharing assets and activities.

Parameter	Value
Mean Wave Power	40kW/m
30yr Mean Wind Speed	11 m/s
Tides/currents	Negligible
Seabed	Sand, deep bedrock
Water depth	80m

Table 3-1: Site characteristics for baseline scenarios, broadly applicable to ScotWind sites

3.1.2 Wave

For the wave project base case, the following assumptions are applied. The associated values are provided in Table 3-2.

- Scottish/UK supply chain and labour rates are generally assumed
- The targeted commercial operation date is 2033
- Examples of ports considered for installation include Orkney Ports (e.g. Lyness) as there are less stringent port requirements for smaller project and smaller devices. Examples of ports considered for O&M include Scrabster and Scapa/Orkney ports

 Confidential

- Grid connection options considered are North Scotland, Shetland, and Stornoway. The distance to GCP (grid connection point) is roughly based on North Scotland as this is the lowest risk option, but not fully representative to avoid grey area between HVAC and HVDC switch-over.
- North Scotland grid charges assumed (no differences between scenarios). It is assumed that there will be no grid connection CAPEX required (no sole assets designated in connection agreement)
- The WEC technology is assumed to be a taut moored point absorber with energy capture in 6 degrees of freedom
- A project size of ~100 MW is assumed with WEC capacity assumed to be ~800 kW given that devices are generally in the range of 250-1500 kW. Sharing with floating wind is anticipated to be more challenging for smaller devices
- Gross capacity factor is assumed as 35% as this is cited as typical for a commercial project
- Wave resource assumed to be 40 kW/m

Total capacity	100 MW
Quantity	125 (0.8 MW each)
Technology	Point absorber
Mooring	Taut (polyester/chain)
Anchoring	VLA
Transmission	HVAC, 1x 132 kV
IACs	33 kV (feasibility of this is discussed in Section 7.1.8)
Distance to GCP	90 km (off), 10 km (on)
Distance to O&M port	100km
Distance to Installation port	150km
Development	6 years
Construction	3 years (including pre-construction/fabrication/supply activities)
Operation	25 years

Table 3-2: Summary of key assumptions/project parameters to frame WEC base case project

3.1.3 Wind

For the floating wind project base case, the following assumptions are made to align with the objectives. The associated values are provided in Table 3-3:

- Scottish/UK supply chain and labour rates are generally assumed
- Examples of ports considered for installation include Nigg, Scapa Deep Water (not built yet), and Lerwick as these have known suitability for floating wind. Examples of ports considered for O&M include Scrabster, Scapa/Orkney ports and Lerwick
- Grid connection options considered are North Scotland, Shetland, and Stornoway. The distance to GCP is roughly based on North Scotland as this is lowest risk option, but not fully representative to avoid grey area between HVAC and HVDC. North Scotland grid charges assumed (no differences between scenarios). It is assumed that there will

be no grid connection CAPEX required (no sole assets designated in connection agreement)

- A medium sized project of ~500MW and WTG capacity of 15MW assumed. Higher capacities not selected because floating projects are less mature, and the deployment area has harsh site conditions.

Total capacity	500 MW
Quantity	33 (15 MW each)
Technology	Steel semi-submersible
Mooring	Semi-taut (polyester/chain)
Anchoring	Suction piles
Transmission	HVAC, 2x 220 kV
IACs	66 kV
Distance to GCP	90 km (off), 10 km (on)
Distance to O&M port	100km
Distance to Installation port	300km
Development	9 years
Construction	3 years (including fabrication)
Operation	25 years

Table 3-3: Summary of key assumptions/project parameters to frame floating wind base case project

It is important to note that the baseline scenarios are derived to provide a basis for comparison of cost reduction/sharing scenarios. Current assumptions will not result in lowest absolute LCOE values, and we do not intend to focus on these, rather on the relative difference in LCOE between scenarios. However, the results are scaled to benchmark them against typical values anticipated along the timeframe being modelled. Absolute LCOE numbers should not be relied upon.

3.1.4 Assumptions and Limitations

The following points are important to note in terms of the development of the base cases and their envisaged use:

- Baseline scenarios have been derived to provide basis for comparison of cost reduction/sharing scenarios
- Current assumptions will not result in lowest absolute LCOE values, as it is not the aim of the study, but rather on the difference in LCOE between scenarios
- Absolute LCOE numbers should not be relied upon. Relative difference should be considered as indicative
- Sensitivities will help demonstrate applicability in a wider range of situations so that the baseline is less specific to the north Scotland characteristics, especially with respect to distance to shore
- Timeline is optimistic for wave, but selected to align better with ScotWind projects
- When comparing scenarios to the baseline, the output is a combined LCOE metric for the individual wave and wind baseline projects. This will mean that in the wave-wind sharing scenarios we will not need to differentiate between costs associated with the

wave as opposed to the wind part of the project, where the ownership assumption is a fully integrated project

- Direct comparison between the wave base case and wave scenarios will be possible in other cases, but we will need to make assumptions around how costs are apportioned (one off payment or leased arrangement, at cost price or with a premium applied)

3.2 Sharing Scenarios

3.2.1 Initial Identification and Screening

In order to comprehensively assess the wind and wave sharing scenario options, a matrix of sharing opportunities was created. This matrix was initiated by first defining all the different assets and activities that are associated with the development of wind and wave projects (Table 3-5), to ensure coverage of all aspects of project development and technology. Then, the possible spatial configurations (Table 3-6) of a combined wind and wave project were identified. Following this, a long list of potential sharing scenarios was defined by considering which project aspects could feasibly be shared within each spatial configuration. Given the many different project aspects that have potential for sharing and the multiple different spatial configurations of projects, the matrix method helped to provide clarity. This approach ensured the creation of a comprehensive list and enabled easy identification and assessment of the potential impact of scenarios, as well as supporting the definition of combined scenarios.

The initial matrix developed was in the following format:

		Project Aspects/Assets/Activities				
		A1	A2	A3	...	An
Scenarios & Spatial Configurations	S1	-	-	-	-	-
	S2	-	-	-	-	-
	S3	-	-	-	-	-
	...	-	-	-	-	-
	Sn	-	-	-	-	-

Table 3-4: Format of initial sharing scenario matrix

The project aspects that have been identified as having a potential for sharing are outlined in Table 3-5. These aspects are further broken down into individual resources or tasks that can be shared between projects. These make up the column titles of the matrix shown in Table 3-4.

Project Aspects		
ID	Title	Assets/Activities Shared
1	**Transmission System Procurement /Fabrication**	Inter-Array Cables (IACs), Export Cable, Offshore Substation, Onshore Substation, Grid Infrastructure
2	**WEC/WTG & Foundations procurement /Fabrication**	Floating Platform Fabrication, Procurement/Supply Chain
3	**Mooring & Anchors Procurement /Fabrication**	Mooring Fabrication, Anchor Fabrication, Procurement/Supply Chain
4	**Assembly, Transportation and Installation**	Port Facility, No. Vessels per Day
5	**Operations and Maintenance**	Port Facility, Service Operation Vessel (SOV) Charter + Operations, Personnel, Inspections, Monitoring
6	**Project Decommissioning**	IAC, Export Cable, Foundations, Offshore Substation (OSS), Mooring and Anchor Removals
7	**Site Characterization**	Measuring Equipment, Environmental Campaigns
8	**Leasing & Consenting**	Local Initiatives, Leasing Phase, Consenting Phase
9	**Project Management**	Project Management

Table 3-5: Project aspects available for sharing

The list of potential sharing configurations that have been identified is shown in Table 3-6. These make up the row titles of the matrix shown in Table 3-4.

Spatial Configurations	
ID	Title
0	**Baseline reference – Different projects**
A	**Projects in same region**
B	**Adjacent project boundaries**
C	**Adjacent project boundaries – WECs peripheral**
D	**Adjacent project boundaries - Versatile platform**
E	**Co-located projects - Independent IACs**
F	**Co-located projects - Combined IACs**
G	**Co-located projects - Hybrid platform**

Table 3-6: Spatial configurations

It is important to note that, in this report and throughout the project, the word “Scenario” is related to the combination of spatial configuration and project aspect, asset or activity shared.

Having identified the project aspects available for sharing, and the possible spatial configurations, the next step was to refine the potential sharing scenarios. The process for determining the final scenario set followed the logic set out in Figure 5. The final scenario definition took into account the levels of sharing working up from separate projects to a fully integrated WEC-WTG project. This coincided with the different spatial configurations and specific assets to be shared. This shortlist eliminated all options that were deemed incompatible (e.g IAC sharing was automatically ruled out if projects were on completely different sites). Once the compatible spatial and asset sharing configurations were identified these were then explored with respect to the compatible options for additional sharing within the development, installation and O&M phases. In some cases, this resulted in more than one scenario for the same spatial and asset sharing option.

Finally, consideration was given to the appropriate ownership and project development model/split between the wave and wind developers. This enabled clearer definition of the cost benefits to each party within the different scenarios during the LCOE modelling as well as supporting the feasibility assessment. The WTG project developer was assumed to be the primary developer in most scenarios, having the larger project and access to the seabed lease. For some scenarios with partial sharing, our ownership model makes a simple assumption of the WEC developer buying participation to the WTG project rather than being part of the development from the outset. This should reduce risk associated to the WTG project as well as ensuring cross-benefits of colocation are realised. Fully shared scenarios assume a single developer due to the difficulty in apportioning responsibilities to two owners separately for the WEC and WTG aspects. Ownership and cost splits between WTG and WEC developers are explored in the wider benefits and feasibility sections further, given the uncertainty in how individual projects would wish to proceed in this respect.

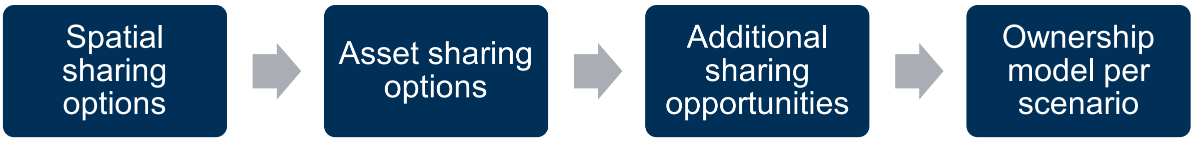


Figure 3-3 Final scenarios definition process

3.2.2 Overview of Sharing Scenarios

Having identified the baseline scenarios and following the long list of sharing options through the screening exercise, the next step was to shortlist the different sharing configurations that could be achieved. The categories, assets, or activities which characterise the different scenarios are shown in Table 3-7. The largest cost reductions and benefits are expected for asset sharing mainly, rather than the other categories, however all of these needed to be included in the definition of scenarios in order to have a clear configuration description useful for the Wider Benefits and Feasibility Assessment section of this study.

Table 3-7: Categories of sharing opportunities

Category	Description
Spatial	Geographical position of wind or wave farms
Assets	Sharing of substations, transmission, electrical system, floater, or other equipment.
Development	Synergies in the project development phase, activities like consenting, site surveys, engineering phases, etc.
Supply Chain	Savings due to modularity or economy of scales
Installation	Synergies regarding vessel mobilisation and utilisation, as well as port usage

O&M	Sharing of vessels or personnel for maintenance activities
Ownership	Ownership of the project and potential split between wind and wave developer liabilities

The full list of sharing configurations considered is presented in

Table 3-8. Figures are used to aid understanding of each option. The icons used are shown in the following key.

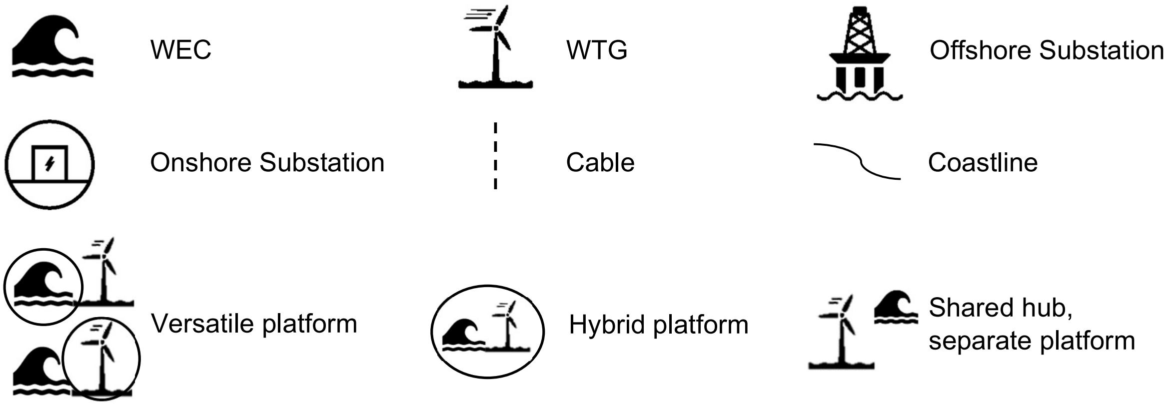
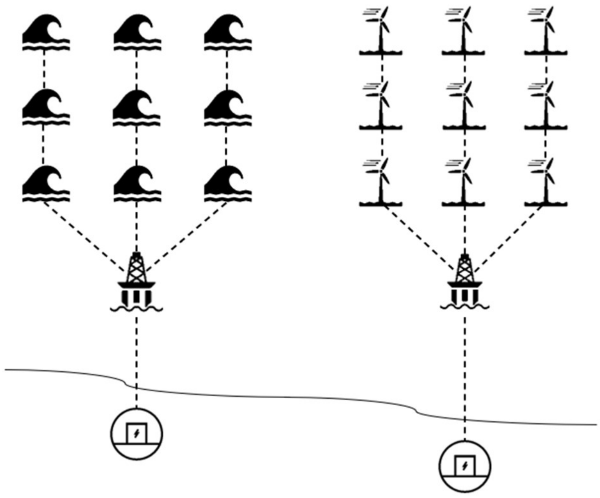
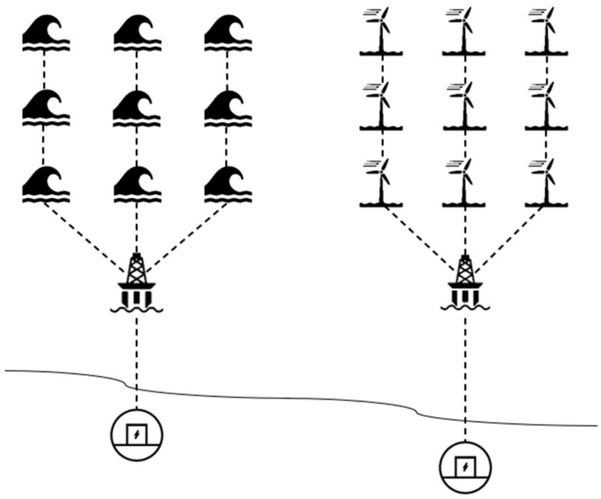
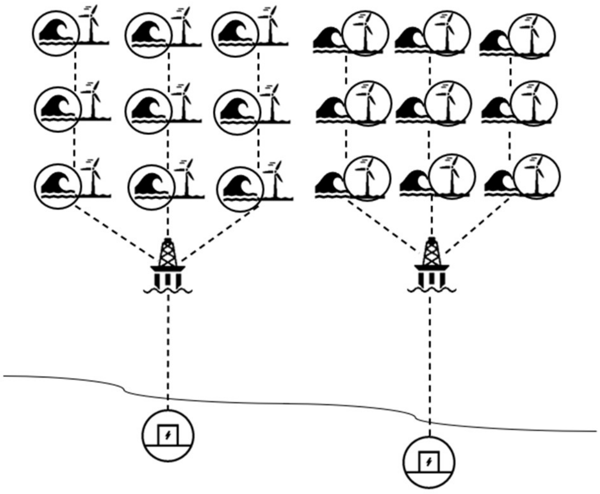
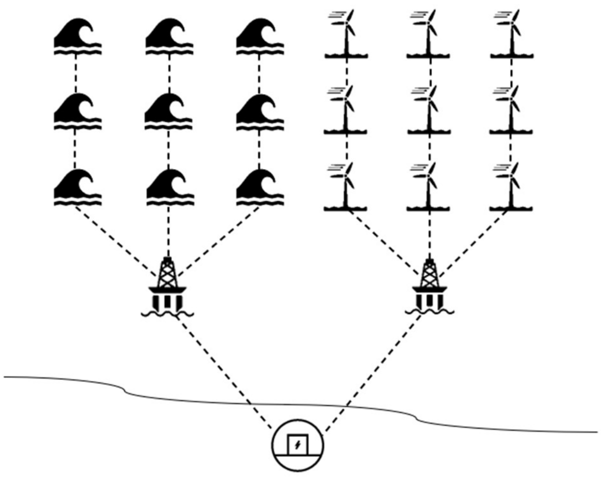
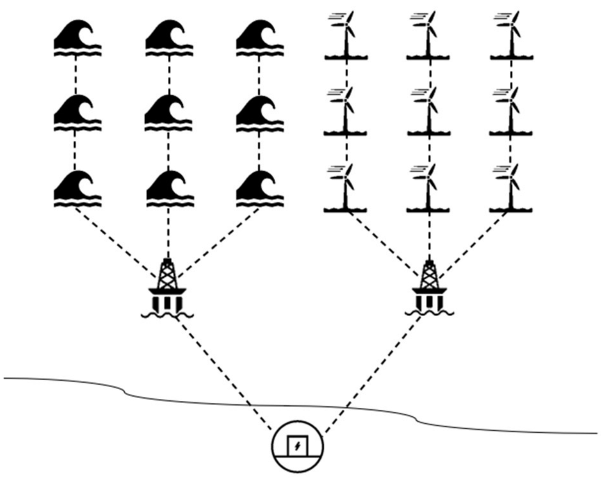
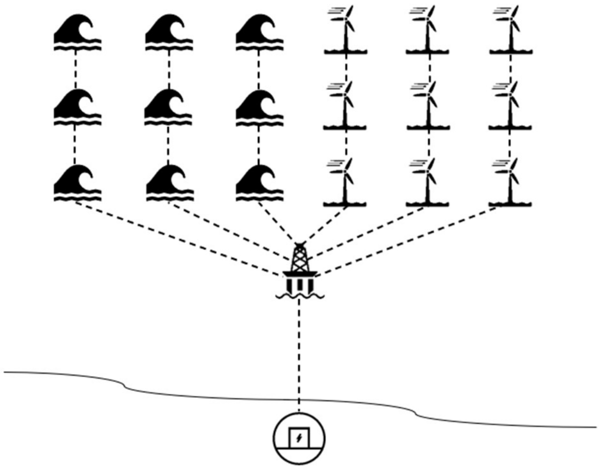
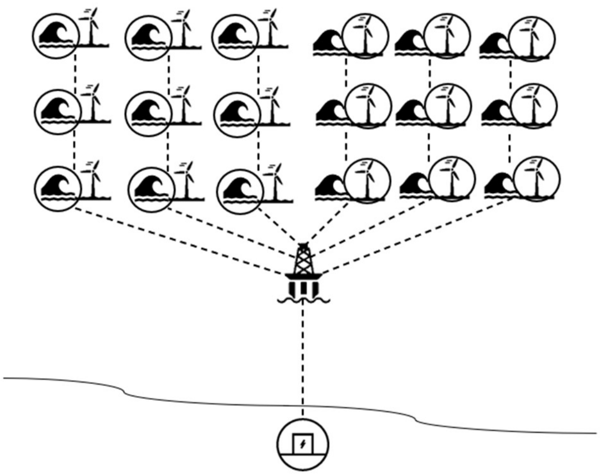
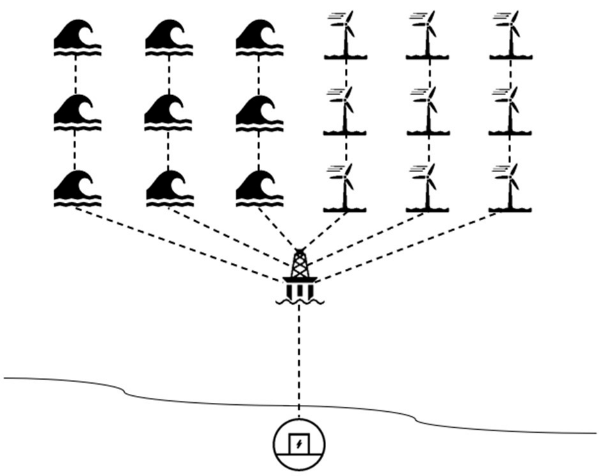
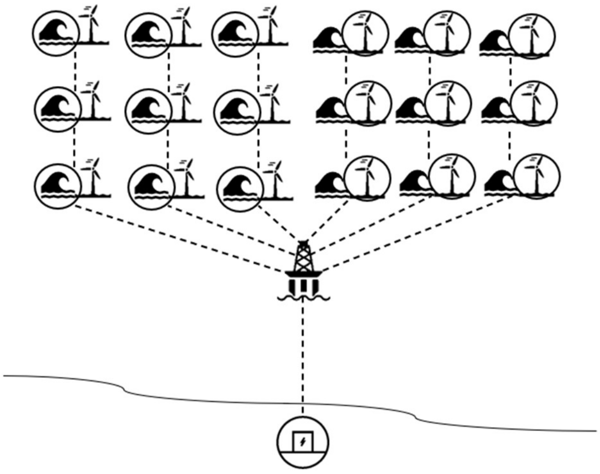
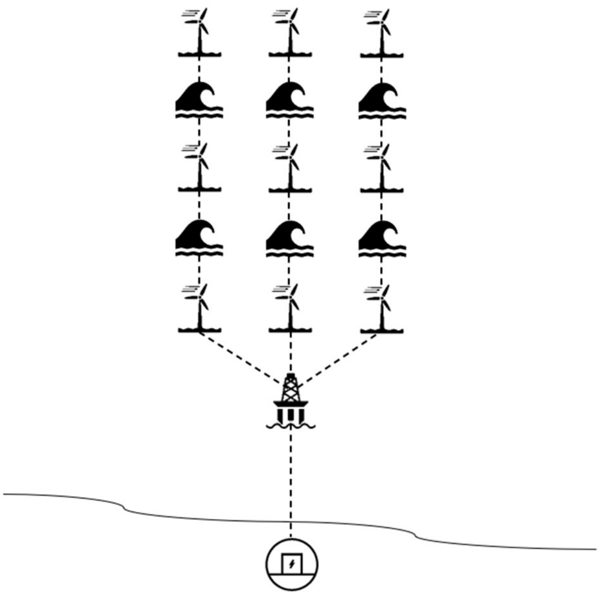


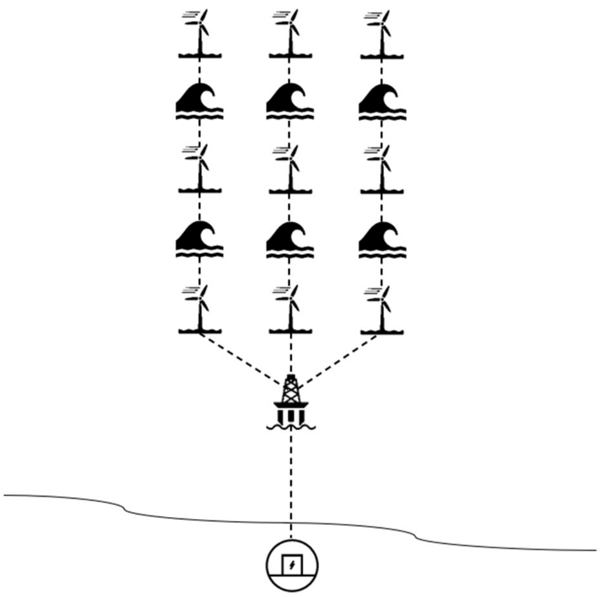
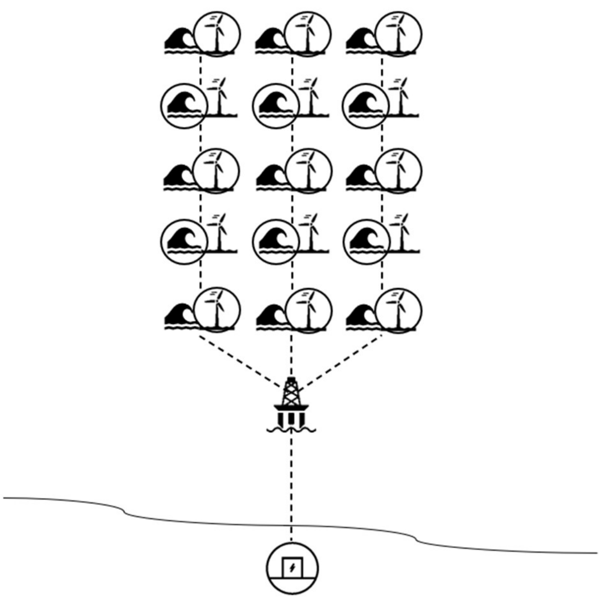
Table 3-8: Overview of sharing configurations considered

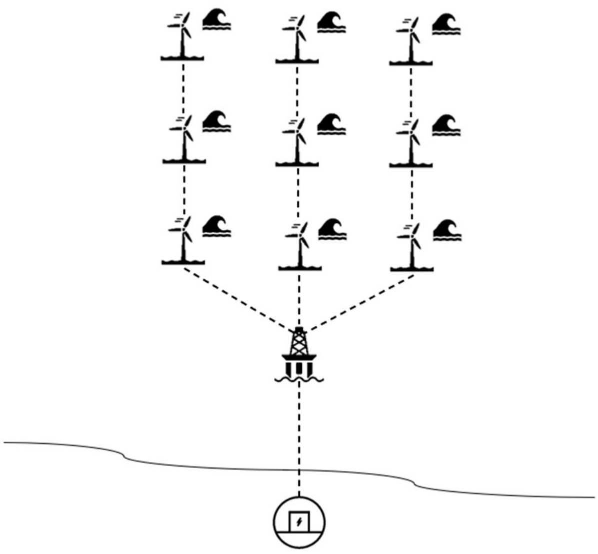
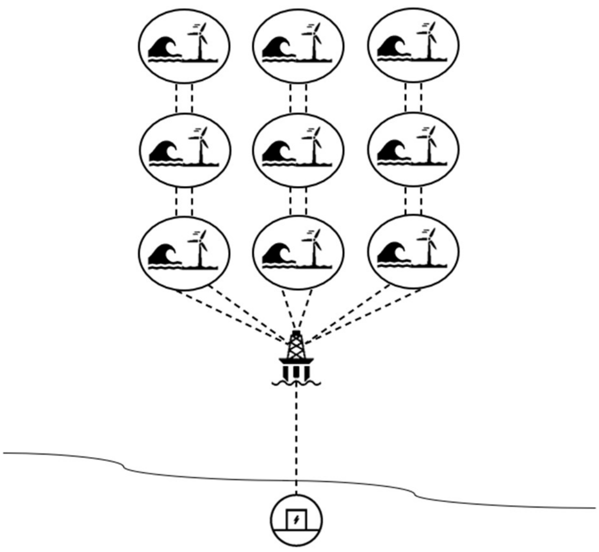
Schematic of scenario	Sharing opportunities
Baseline (Scenario 1 and 2) 	**Spatial:** Same region **Assets:** No sharing **Development:** No sharing **Supply chain:** No sharing **Installation:** No sharing **O&M:** No sharing **Ownership:** Independent projects Note that scenario 1 denotes the wind project independently and scenario 2 denotes the wave project independently.
Scenario 3 	**Spatial:** Same region **Assets:** No sharing **Development:** Surveys equipment **Supply chain:** • Economies of scale • Opportunities with same/similar components **Installation:** Vessels & (potentially) ports **O&M:** • Vessels & (potentially) ports • O&M reduction (depends on Crew Transfer Vessel (CTV) vs SOV) **Ownership:** • Independent projects • Cooperation for contracting vessel/ports/equipment

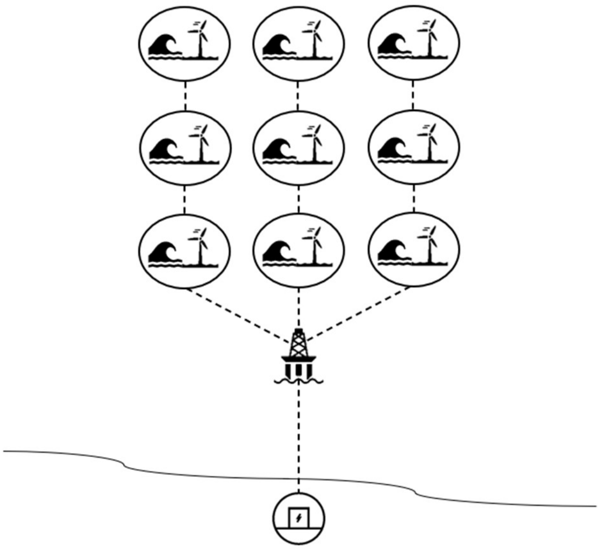
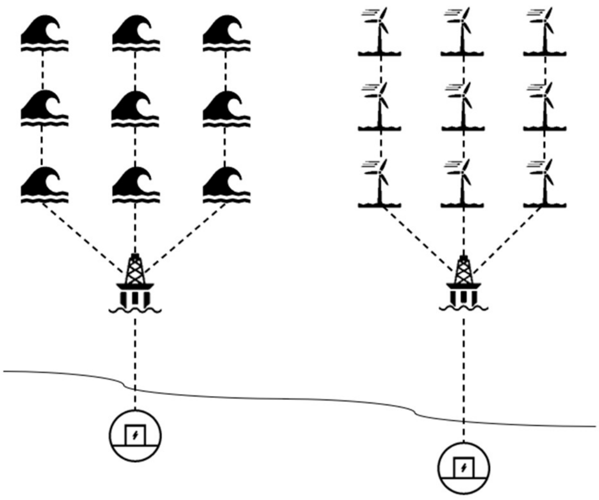
Scenario 4 	**Spatial:** Same region **Assets:** Versatile platform **Development:** No sharing **Supply Chain:** Savings due to modularity **Installation:** No sharing **O&M:** No sharing **Ownership:** Independent projects
Scenario 5 	**Spatial:** Same region **Assets:** Onshore substation **Development:** Shared consent on onshore substation **Supply Chain:** Savings for onshore substation **Installation:** Shared for onshore substation **O&M:** Shared for onshore substation **Ownership:** • Separate developers • Wave developer pays to connect to substation
Scenario 6 	**Spatial:** Same Region **Assets:** • Onshore Substation • Cable route and landfall **Development:** • Onshore consent application • Onshore data collection **Supply Chain:** • Savings for onshore substation • EPCI for landfall **Installation:** Shared for onshore substation and landfall (separate cables) **O&M:** Shared for onshore substation, onshore cables, and landfall **Ownership:** • Separate developers • Wave developer pays to connect to substation

Scenario 7 	**Spatial:** Adjacent **Assets:** Transmission infrastructure (no IACs) **Development:** Consent for transmission (Wave different seabed agreement) **Supply Chain:** Shared transmission system **Installation:** Shared transmission system **O&M:** Shared transmission system **Ownership:** • Separate developers • Wave developer pays to use transmission assets
Scenario 8 	**Spatial:** Adjacent **Assets:** • Versatile Platform • Transmission (no IACs) **Development:** Consent for transmission **Supply Chain:** • Shared transmission system • Savings due to modularity **Installation:** Shared transmission system **O&M:** Shared transmission system **Ownership:** • Separate developers • Wave developer pays to use transmission assets
Scenario 9 	**Spatial:** Same site **Assets:** Transmission infrastructure (no IACs) **Development:** Shared site lease and data collection **Supply Chain:** • Shared transmission system • Savings from supply chain maturity • Sub-component alignment **Installation:** • Shared transmission system • Vessels & (potentially) ports **O&M:** • Shared transmission system • Vessels & (potentially) ports • O&M reduction (depends on CTV vs SOV) **Ownership:** One project

Scenario 10 	**Spatial:** Same site **Assets:** • Versatile platform • Transmission (no IACs) **Development:** Shared site lease and data collection **Supply Chain:** • Shared transmission system • Savings due to modularity **Installation:** • Shared transmission system • Vessels & (potentially) ports **O&M:** • Shared transmission system • Vessels & (potentially) ports • O&M reduction (depends on CTV vs SOV) **Ownership:** • Separate developers/one project • WEC pays wind developer for seabed and transmission
Scenario 11 	**Spatial:** Same site **Assets:** • All transmission • IACs **Development:** • Shared site lease and data collection • Shared design, procurement, etc. **Supply Chain:** • Shared except WECs • Economies of scale • Opportunities with same/similar components **Installation:** Fully shared **O&M:** Fully shared **Ownership:** One project most likely, WEC developer as partner

Scenario 12 	**Spatial:** Same site **Assets:** • All transmission • IACs • Anchors **Development:** • Shared site lease and data collection • Shared design, procurement, etc. **Supply Chain:** • Shared except WECs • Economies of scale • Opportunities with same/similar components **Installation:** Fully shared **O&M:** Fully shared **Ownership:** One project most likely, WEC developer as partner
Scenario 13 	**Spatial:** Same site **Assets:** • All transmission • IACSs • Anchors • Versatile platform **Development:** • Shared site lease and data collection • Shared design, procurement, etc. **Supply Chain:** Fully shared **Installation:** Fully shared **O&M:** Fully shared **Ownership:** One project most likely, WEC developer as partner

Scenario 14 	**Spatial:** Same site **Assets:** • WEC electricals sited on WTG platform • Transmission system • IACs **Development:** Fully shared **Supply Chain:** • Shared except WECs • Economies of scale • Opportunities with same/similar components **Installation:** Fully shared **O&M:** Fully shared **Ownership:** • One project most likely, WEC developer as partner • Wind developer provides cables connection point
Scenario 15 	**Spatial:** Same Site **Assets:** • Integrated/Hybrid Platform • All transmission (no IACs) • Anchors **Development:** Fully Shared **Supply Chain:** Fully Shared **Installation:** Fully Shared **O&M:** Fully Shared **Ownership:** One project

Scenario 16	**Spatial:** Same Site **Assets:** • Integrated/Hybrid Platform • All transmission • Anchors • IACs **Development:** Fully Shared **Supply Chain:** Fully Shared **Installation:** Fully Shared **O&M:** Fully Shared **Ownership:** One project
	
Scenario 17	**Spatial:** Same region **Assets:** No sharing **Development:** No sharing **Supply chain:** No sharing **Installation:** No sharing **O&M:** No sharing **Ownership:** Independent projects Note that this scenario is equivalent to scenarios 1 and 2 combined into one scenario.
	

See Appendix A for a visual chart summarising the sharing scenarios in a single page, as well as a single page containing all the scenario diagrams.

3.2.3 Detailed Scenario Definition

This section describes in more detail the assets and activities that are shared in each of the scenarios, as well as the reasoning behind selecting each scenario. Scenarios 1, 2, and 17 are not mentioned here as they constitute the baseline scenarios, with no sharing.

3.2.3.1 Scenario 3 – Indirect Synergies, No Asset Sharing

In this scenario, the projects are in the same region but do not share any physical assets. Survey equipment is shared but consenting is separate as they are at different sites and use different technologies.

The wave project will benefit from the maturity of the floating supply chain and economies of scale since there are opportunities to use the same or similar components for the WECs and hubs as in the wind project. There are opportunities for vessel sharing between the projects in ways that do not negatively affect the wind project, for example use of vessels when they would otherwise be waiting in port or at the end of another operation where time allows, to increase utilisation. Regarding O&M, there are opportunities for sharing vessels, ports, and O&M base, only where this does not negatively impact wind farm strategy. Feasibility and cost reduction potential of this will likely vary with O&M strategy - CTV or SOV. These will both be tested in the model via sensitivity analysis.

The projects are owned independently but there is an agreement in place to cooperate with joint contracting for vessels/ports/equipment – wind would be likely to need priority but with wave improving utilisation.

The purpose of this scenario is to provide a case that explores the opportunities with sharing services as opposed to direct asset sharing. It is designed to have no negative impact on the wind developer as the wind farm maintains priority on development, installation and O&M activities and the supply chain is treated independently between the projects. Closer levels of sharing would be more likely for scenarios with two sites in closer proximity or sharing the seabed. Multiple sharing options are incorporated into one scenario because the anticipated savings from individual aspects are expected to be small. Also, the sharing options identified are anticipated to have similar levels of feasibility and could be placed under one agreement between the developers.

3.2.3.2 Scenario 4 – Versatile Platforms

In this scenario, the projects are in the same region and use common platform designs (also called versatile platforms) but without the WTG and WECs sharing the same platform. Two configurations are possible for the common platform design when utilised with WEC devices - one would be using the common platform as a shared electrical hub for multiple individual WEC units attached via array strings, the second would be using common platforms with integrated WEC devices into the structure and electricals mounted on the platform. As a starting point, this study considers the latter arrangement. In this scenario, the WEC and WTG units are separate and there is no sharing assumed in the development of the projects. It is assumed that there is a common platform design and supply available for purchase on the market (the feasibility of this assumptions is assessed later in this report). The platform will not necessarily be assumed to be the exact same design - they could be modular to allow slightly different sizes whilst still enabling savings in the supply chain. The use of common platforms would benefit both the wave and wind projects.

It is assumed that there is no sharing during the installation and O&M campaigns for this scenario, and that the projects are owned independently.

The purpose of this scenario is to determine the benefits directly associated with the common (versatile) platform design idea. As a result, no additional sharing activities are included. Additional sharing opportunities for projects in the same region are captured in other scenarios. Also, the lack of additional sharing maintains full independence between the two projects which may be beneficial from a feasibility perspective.

The specific configuration of the platforms with WECs in terms of platform layout but also the number of WECs assumed integrated within a single platform are detailed in Section 3.2.4.1.

3.2.3.3 Scenario 5 – Shared Onshore Substation

In this scenario the projects are in the same region and share an onshore substation, but with separate onshore cable routes and landfall. The consent for the onshore substation can therefore be shared and is likely to be submitted by the wind developer. The wave developer would have to submit the remainder of the onshore consent.

Supply chain, installation, and O&M of the onshore substation can all be shared between the projects but not for other aspects of the projects.

The projects are owned independently, and it is proposed that the grid connection agreement and onshore substation consent are in the wind developer's name, with the wave developer paying to connect at their substation. The wave developer will need to create a partnership with the wind developer at an early stage to get appropriate grid connection requirements built into the agreement and design of the substation.

This scenario is possibly the simplest option when it comes to asset sharing. It will highlight the potential benefits available to the grid connection timeline which transfers into cost as well as potential direct cost reduction benefits. Additional sharing options are not included as these are quantified separately in scenario 3.

3.2.3.4 Scenario 6 – Shared Onshore Substation and Landfall

In this scenario the projects are in the same region and share an onshore substation, onshore cable route, and landfall. Note that the onshore cables are not shared, just the cable route. This allows for the full onshore consent application and onshore data collection works to be shared.

All onshore supply chain, installation, and O&M works can be shared between the projects on the basis that this arrangement improves efficiency. Since the cables are not shared, they would be installed so that they can be maintained independently if required.

The projects are owned independently by separate wave and wind developers but the wave developer pays the wind developer for onshore aspects (consents, data, installation, O&M etc.). The wave developer remains responsible for the WEC export cable design and supply.

This scenario represents the next step up in terms of asset sharing. The scenario implies that elements of development, installation and potentially O&M would also be shared so a package option is presented. Note that in this scenario it could be feasible for some of these elements to be completed independently, especially maintenance, but it is included here to demonstrate the greatest potential in terms of sharing opportunities related to this asset sharing scenario.

3.2.3.5 Scenario 7 – Shared Offshore Transmission Hub

In this scenario the projects are adjacent to each other, sharing transmission infrastructure from the offshore substation all the way up to the grid connection point. Note that IACs are therefore not shared. This enables the consent for the transmission system (excluding IACs) to be shared. The wave developer will need a separate seabed option agreement and consent for the WECs and IACs.

Supply chain, installation, and O&M of the transmission system can be shared.

It is assumed that the projects are owned independently with the wind developer being responsible for build of the transmission assets and the wave developer paying to share these.

This scenario represents another step up in terms of asset sharing, possible due to the adjacency of the projects. A similar scenario with additional sharing options across development, installation and O&M is considered in scenario 9.

3.2.3.6 Scenario 8 – Shared Offshore Transmission Hub and Versatile Platforms

In this scenario the projects are adjacent to each other, sharing transmission infrastructure from the offshore substation, as in scenario 7. The projects also use a common (versatile) platform design, but with the technologies not combined (i.e. the platform design is the same but either a set of WECs or a WTG is mounted, not both). As in scenario 7, the consent for the transmission system (excluding IACs) can be shared.

Supply chain, installation, and O&M of the transmission system can all be shared. There are also supply chain benefits from utilising a single common (versatile) platform design between both projects.

The projects are assumed to be owned independently as in scenario 7.

The purpose of this scenario is the same as for scenario 7 but including a common platform to highlight the benefits afforded by the common platform.

3.2.3.7 Scenario 9 – Shared Offshore Transmission Hub and Vessels

In this scenario the projects share the same site. Transmission infrastructure is shared starting from the offshore substation all the way up to the grid connection point, thus not including IACs. The use of a single site allows for shared site lease and offshore data collection. It is assumed that the consent is shared but it is feasible to do it separately.

Supply chain, installation, and O&M of the transmission system can all be shared. There are opportunities for savings thanks to supply chain maturity and sub-component alignment. Vessels and ports for installation and O&M campaigns could also be shared.

It is assumed that the development would take the form of a single project, either designed as such from the outset, or through a wave developer buying into the project later. The buy-in would be post option agreement but pre-transmission system design.

This scenario is essentially the same as scenario 7, but the WTGs and WECs share the same site. This allows the benefits associated with sharing a single site, such as shared lease, data collection, consent and more, to be assessed. Note that the WECs and WTGs do not need to be mixed amongst each other – they can be adjacent, provided a single seabed option agreement is acquired (or there is sufficient space within the WTG option agreement).

3.2.3.8 Scenario 10 – Shared Offshore Transmission Hub, Versatile Platforms, and Vessels

In this scenario the projects share the same site. Transmission infrastructure is shared starting from the offshore substation all the way up to the grid connection point, thus not including IACs. The projects also use a common platform design, but with the technologies not combined (i.e. the platform design is the same but either a set of WECs or a WTG is mounted, not both). The use of a single site allows for shared site lease and data collection. It is assumed that the consent is shared but it is feasible to do it separately.

Supply chain, installation, and O&M of the transmission system can all be shared. There are also supply chain benefits from utilising a single common platform design between both projects. Vessels and ports for installation and O&M campaigns could also be shared.

There are two options for ownership. The developments could be designed as a single project from the outset. Alternatively, there could be separate WEC and wind developers. In this case, the wave developer is responsible for additional consent and cost of integration of additional array strings into the design. The wave developer pays the wind developer for use of seabed and transmission infrastructure, and receives production as metered at the end of the strings.

This scenario is essentially equivalent to scenario 9, but with the common platform option included.

3.2.3.9 Scenario 11 – Shared IACs

In this scenario the projects share the same site and all transmission infrastructure, including IACs. The site lease and data collection works can be shared. Given the level of integration, need for a shared consent is likely. Other aspects of development such as design, procurement, and project management are also likely to be shared.

The projects will share supply chains and benefit from economies of scale for all aspects except for WEC specific components. The installation and O&M works are shared.

The development will most likely constitute a single project with the wave developer acting as a partner, providing the WEC design.

This scenario is another step up in terms of asset sharing as it is the first scenario to include sharing of IACs. Additional sharing opportunities are included compared to previous scenarios based on expected ownership model and level of integration of WEC and WTGs in this project configuration.

3.2.3.10 Scenario 12 – Shared IACs and Anchors

This scenario is equivalent to scenario 11, with the additional feature that anchors are also shared. This provides savings in the supply chain and installation works.

3.2.3.11 Scenario 13 – Shared IACs, Anchors, and Versatile Platforms

This scenario is equivalent to scenario 12, with the additional feature that a common platform design is used although with the technologies not combined (i.e. the platform design is the same but either a set of WECs or a WTG is mounted, not both). The wave developer would be responsible for the WEC platform/hub configuration. This provides economies of scale benefits in the supply chain.

3.2.3.12 Scenario 14 – Radial WEC Strings

In this scenario the projects share the same site. The full transmission infrastructure including IACs is shared. The WECs utilise the space on the WTG platform to act as a hub for the electrical equipment (such as transformers) to enable connection into the main WTG IAC strings. Strings of WECs are separately moored and connected in a radial configuration to the WTG floating platforms. All aspects of project development such as site lease, data collection, consent, design, procurement, project management, and more can be shared.

The projects will share supply chains and benefit from economies of scale for all aspects except for WEC specific components. The installation, and O&M works are shared.

The development will most likely constitute a single project with the wave developer acting as a partner, providing WEC design and power take-off requirements. The wind developer would need to provide cable connection points on each WTG platform.

This scenario is similar to scenario 13 but with a slightly different platform sharing configuration that results in less interference with the WTG platform design. This configuration more closely resembles the existing configuration (hub and strings approach) which may improve feasibility.

3.2.3.13 Scenario 15 – Combined Substructures, Separate IACs

In this scenario the projects share the same site and use integrated platforms. This means that a WEC and WTG are both mounted on a single platform, such that moorings, anchors, and transmission infrastructure (excluding IACs) can be shared. As in scenario 14, the full development works can be shared.

The supply chain, installation, and O&M works can all be fully shared.

In terms of ownership, the development would constitute a single project.

This is the scenario with the greatest possible asset sharing, allowing an understanding of the maximum possible benefits available through sharing. Additional sharing across development, installation, and O&M are included on the basis that this configuration demands a fully integrated project. Feasibility of IAC sharing is less certain due to different voltages output from WTGs and individual WEC units, so this scenario is included to model a solution that does not involve array cable sharing.

3.2.3.14 Scenario 16 – Full Sharing

This scenario is equivalent to scenario 15, but with IACs shared in addition.

The purpose of this scenario is to replicate scenario 15, but including the possibility of IAC sharing.

3.2.4 Detailed Scenario Sketches

This section includes sketches that give further details on the layout of the WTGs and WECs assumed in each scenario, including the spacing which has been used to calculate the IAC lengths when estimating costs in the techno-economic model. Each scenario involves 125 WECs and 33 WTGs. The maximum power capacity was assumed to be 90 MW on 66 kV strings and 40 MW on 33 kV strings. Note that the figures are not to scale. The following symbols are used:

WTG

WEC on independent platform

WECs on versatile platform

WTG and WECs on hybrid platform

IACs

3.2.4.1 Scenarios 1 to 10, and 17

These scenarios all follow the same basic principle as the baseline scenarios, with the WTGs and WECs kept on separate strings. Scenarios 1, 3, 4, 5, 6, 7, 8, 9, 10, and 17 all share the same layout of independent WTGs with spacing of 1,175 m (or 5 times the rotor diameter) as shown in Figure 3-4. A rule of thumb, at least for sites with reasonably unidirectional wind resource is a spacing of 5x10 rotor diameters, so the string configuration is aligned to the prevailing cross-wind direction, with longer spacing in-between separate strings.

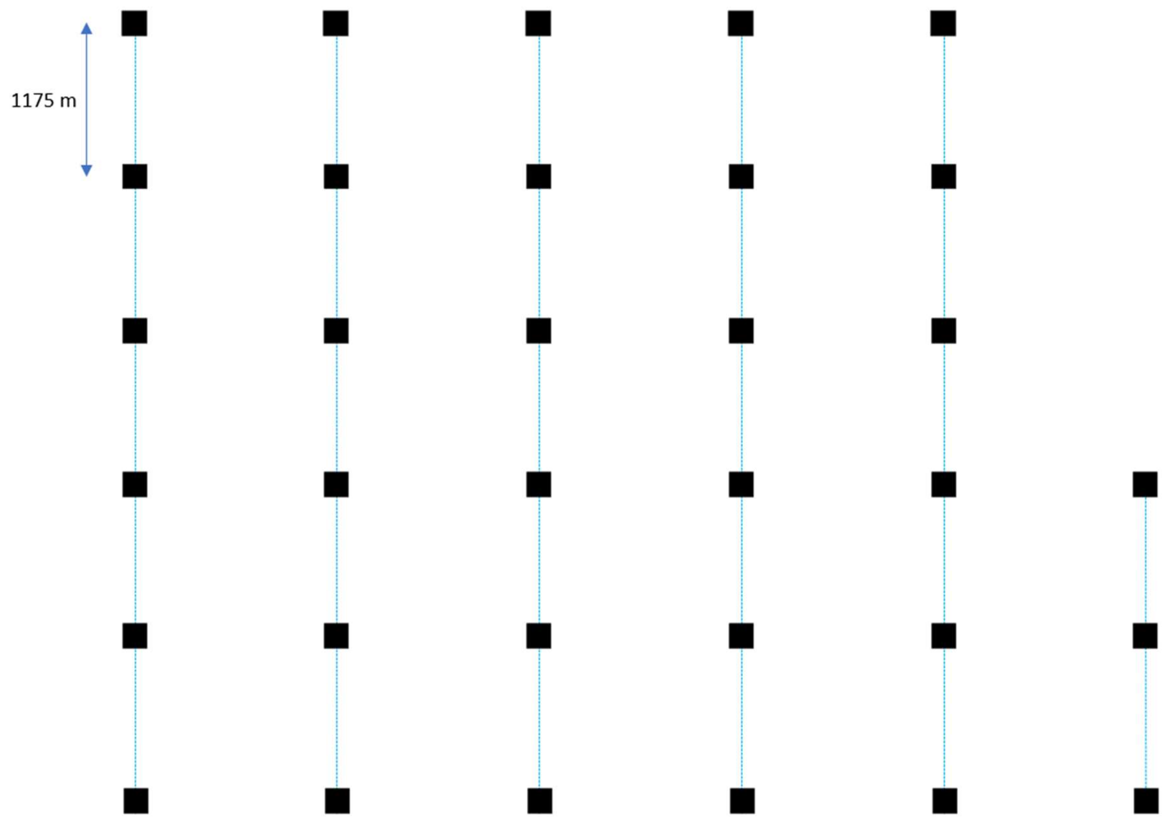


Figure 3-4: WTG layout (Scenarios 1, 3, 4, 5, 6, 7, 8, 9, 10, and 17)

Scenarios 2, 3, 5, 6, 7, 9, and 17 all share the same layout of independent WECs with a spacing of 100 m as shown in Figure 3-5. Note that the 100m spacing is selected as a conservative approach to ensure cost savings are not over reported at this early stage. With further research it may be possible to reduce the spacing, resulting in savings in IAC length and hence cost.

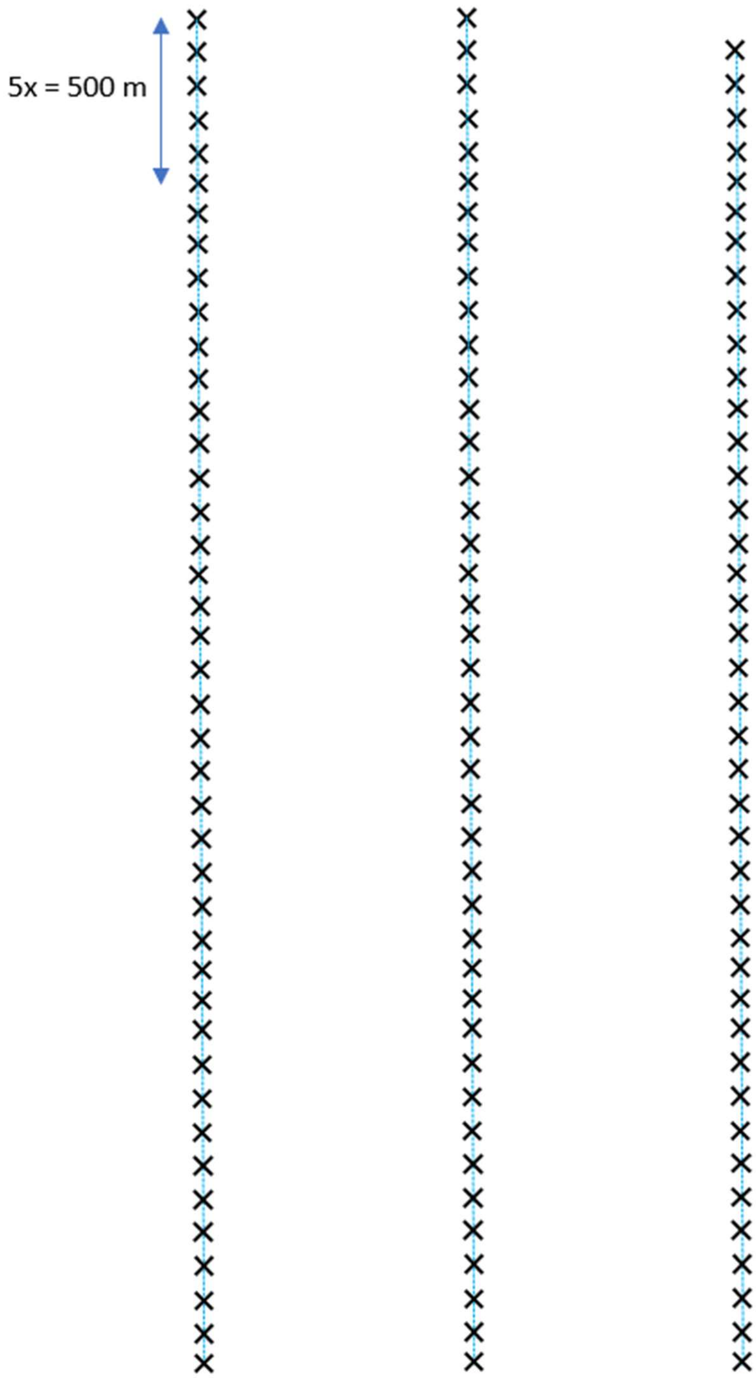


Figure 3-5: WEC layout (Scenarios 2, 3, 5, 6, 7, 9, and 17)

Scenarios 4, 8, and 10 utilise versatile platforms with 6 WECs assumed to be mounted on each platform. This is an initial, conservative assumption based on the WEC size of 0.8MW, a device width of 20m and spacing of 1D, and maintaining similar platform dimensions to that of a semi-submersible platform for a WTG (~80m width, triangular). These factors when combined allow for 2 WECs along each side of the platform. No additional WECs on the corners were considered in the base case to understand the results from an initial unoptimized case while the structural design and other implications are unknown for the versatile platform.

This requires a larger spacing between the platforms (400 m), using the 5D rule of thumb as shown in Figure 3-6. The use of versatile platforms does not affect the WTG layout. Note that one of the versatile platforms will only have 5 WECs to achieve a total of 125.

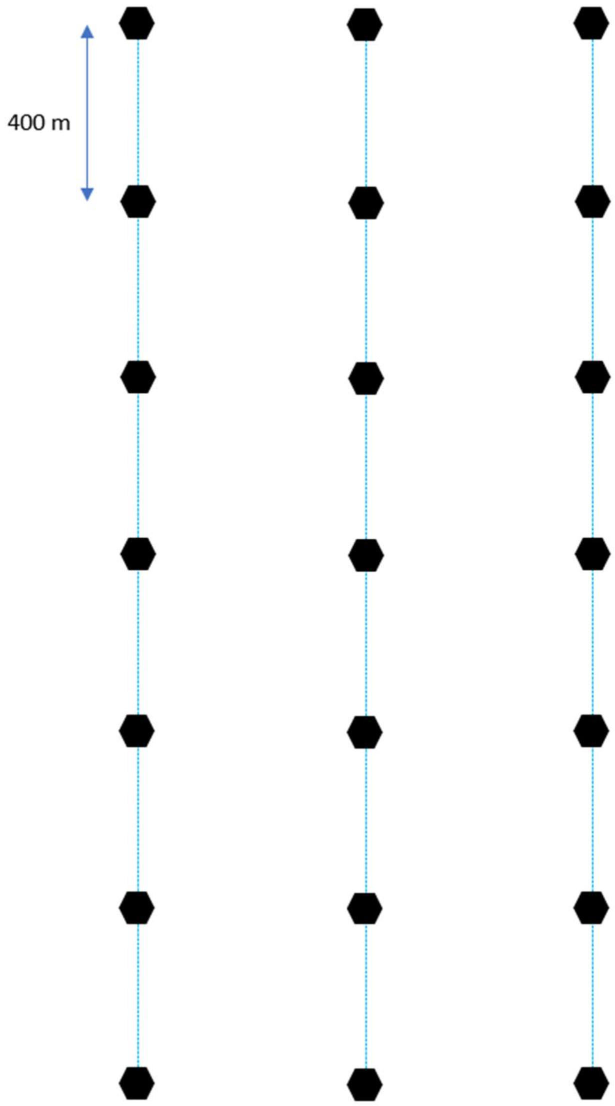


Figure 3-6: WEC layout (Scenarios 4, 8, and 10)

3.2.4.2 Scenarios 11 and 12

In these scenarios, the WTGs are interspersed by WECs and the IACs are shared. There are 5 WECs between each pair of WTGs. This allows for ample spacing between consecutive WECs as well as between WECs and neighbouring WTGs. This is shown in Figure 3-7. This also presents a reasonable case for the anchor sharing scenarios based on the assumed mooring spread of the WTGs and WECs.

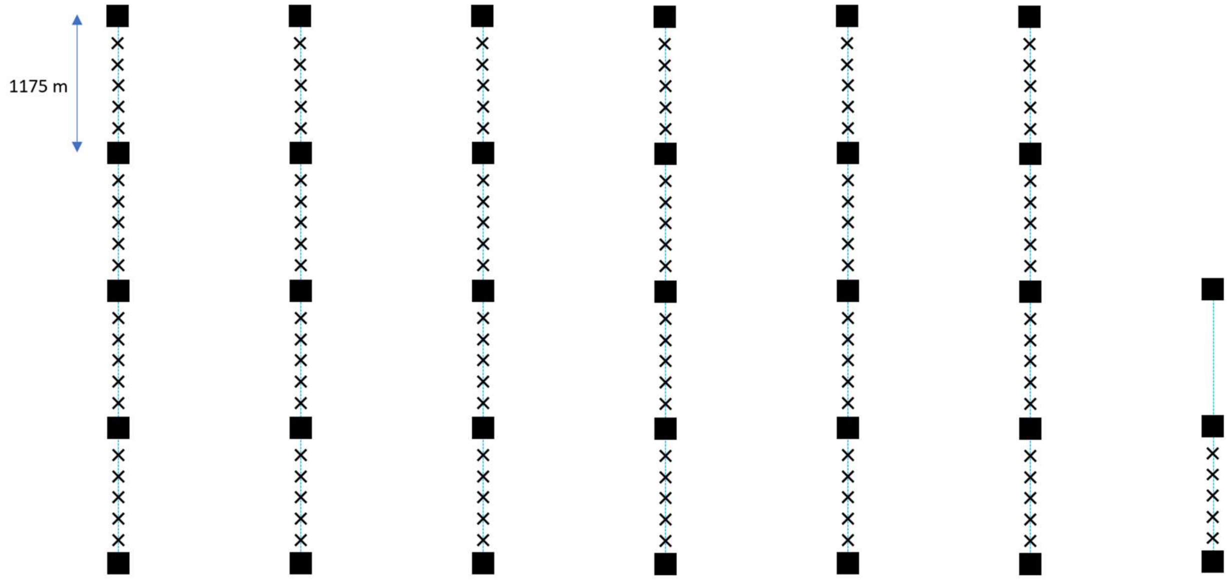


Figure 3-7: WTG and WEC layout (Scenarios 11 and 12)

3.2.4.3 Scenario 13

As in the previous scenarios, this scenario involves the WTGs being interspersed by WECs and sharing IACs. In this case, however, versatile platforms are used. The resulting layout is shown in Figure 3-8. This spacing is also assumed compatible for anchor sharing for the relevant scenarios (at least at high-level).

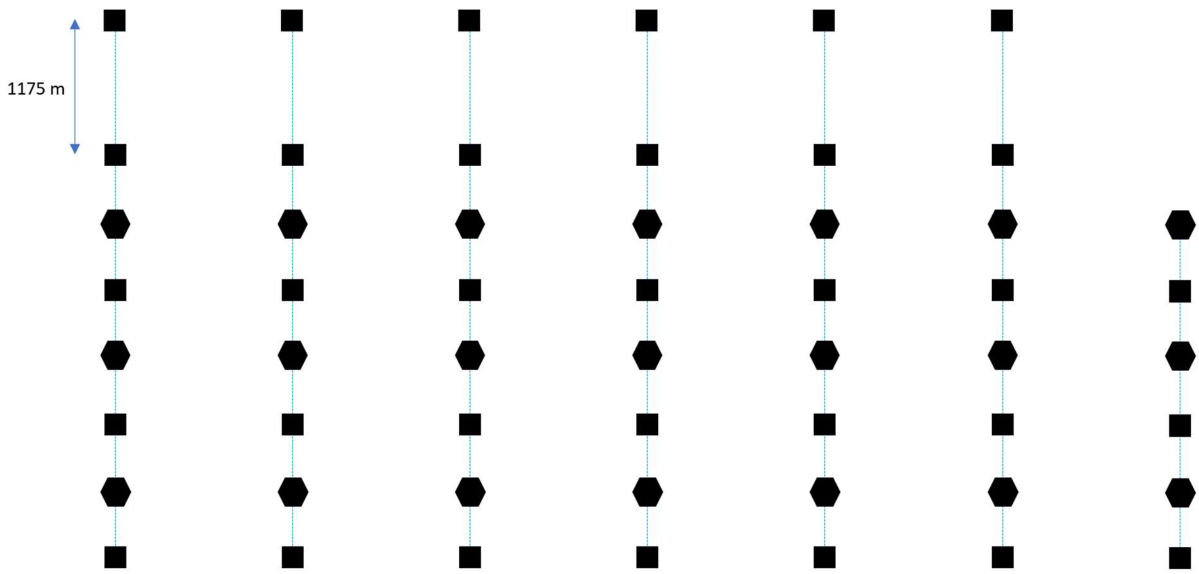


Figure 3-8: WTG and WEC layout (Scenario 13)

3.2.4.4 Scenario 14

In this scenario, strings of WECs are connected radially to each WTG. A minimum required distance of 200 m is imposed between WECs and WTGs. The spacing between subsequent WECs is 100m. The resulting layout is shown in Figure 3-9.

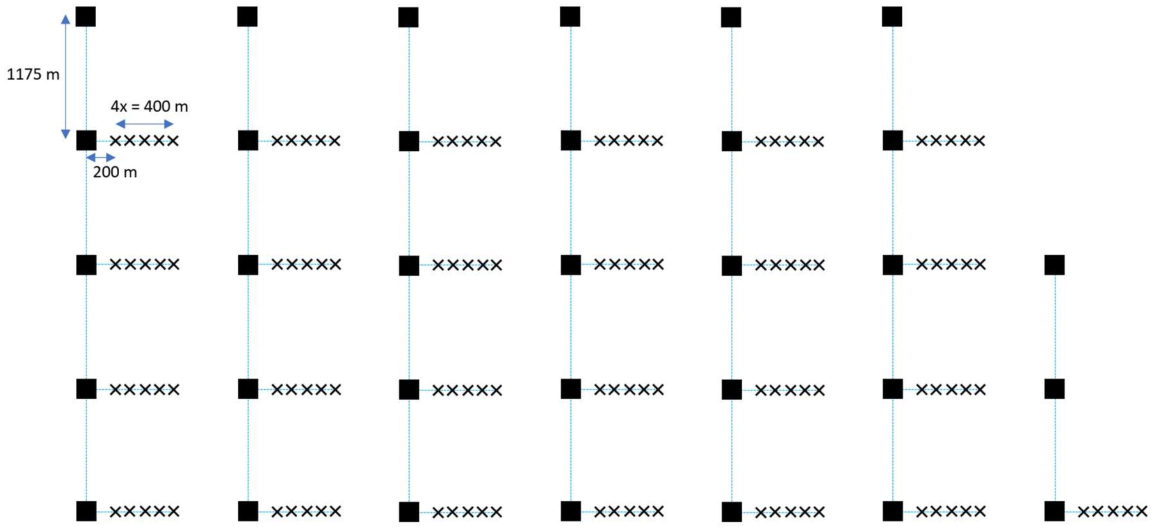


Figure 3-9: WTG and WEC layout (Scenario 14)

3.2.4.5 Scenarios 15 and 16

In these scenarios, hybrid platforms are used, in which 1 WTG and 6 WECs share the same platform. The spacing between platforms is 1,175 m. In scenario 15 the IACs are not shared, whereas in scenario 16 the IACs are shared, meaning that fewer platforms can fit on a single string, as it reaches a limit on the power capacity. This is the reason for the differing layouts shown in Figure 3-10 and Figure 3-11.

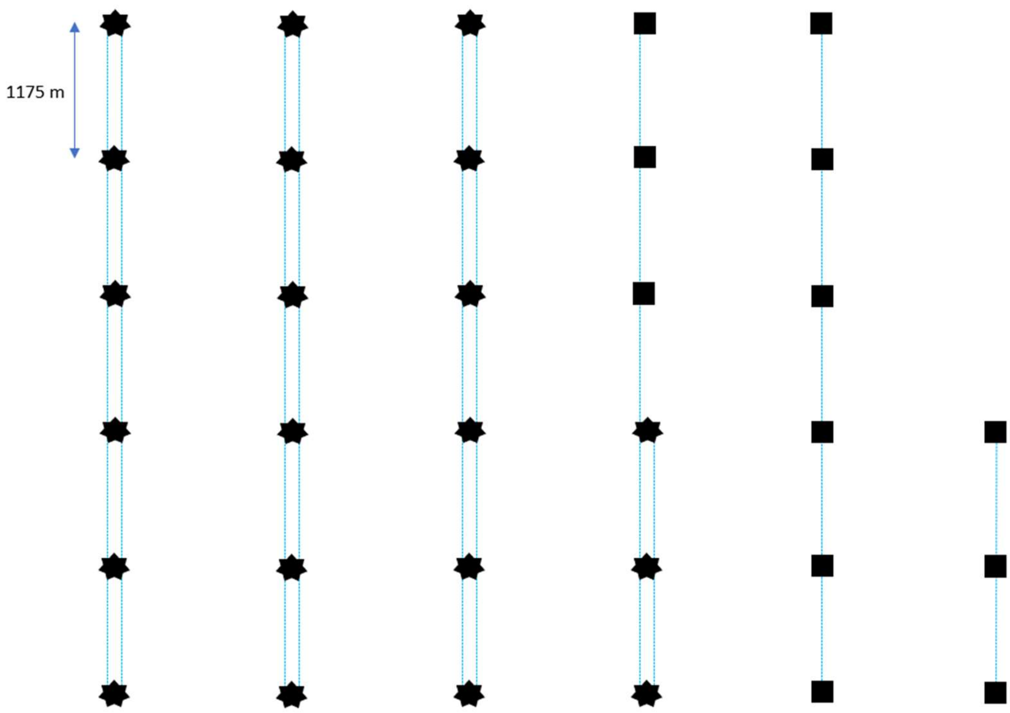


Figure 3-10: WTG and WEC layout (Scenario 15)

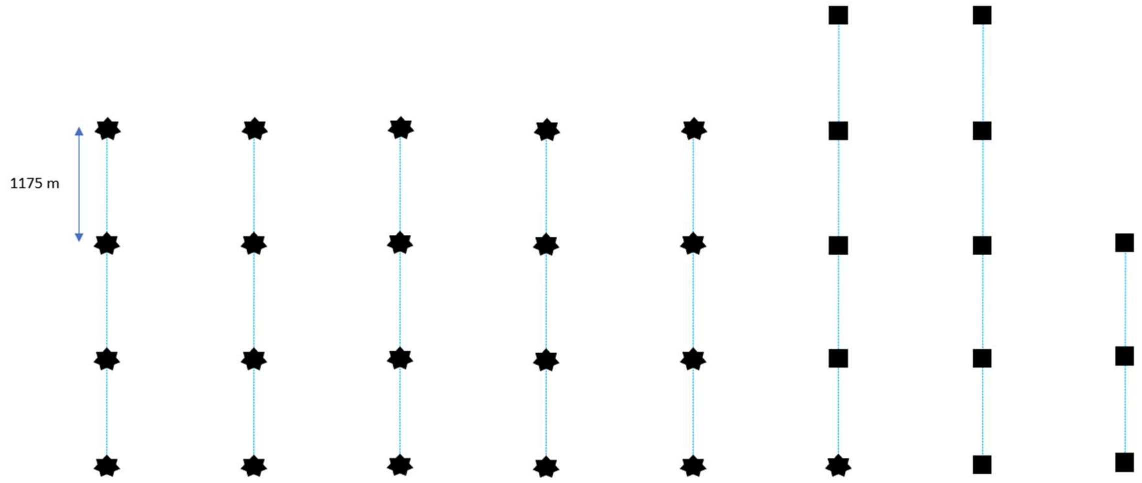


Figure 3-11: WTG and WEC layout (Scenario 16)

4 LCOE Tool

Having defined the set of baseline and sharing scenarios, the LCOE methodology for evaluating the cost related benefits of these was developed. This draws on OWC's extensive LCOE modelling experience for offshore wind projects in Scotland and specifically for ScotWind as well as for a wider global portfolio of projects including Innosea's experience with wave energy technology.

4.1 Objective

A tailored Excel spreadsheet ("the LCOE tool") was developed for this study to enable quantifying the potential benefits of mutualizing specific aspects of project activities and project assets between a base floating wind project ("the WTG project") and a base wave energy conversion project ("the WEC project").

The tool follows a mixture of top-down and bottom-up approaches based on the definition of representative generic projects. The level of detail is tailored to reflect the objectives of the project, with increased detail reflecting those aspects relevant to the selected sharing scenarios. The development of the LCOE tool was aligned with the following objectives:

1. Enable a discretisation of costs to a level enabling the identification of mutualised and non-mutualised costs.

2. Provide comparative cost and LCOE estimations for pre-selected scenarios.
3. Reflect the early-stage nature of the study and highlight core assumptions to enable the Client to update and challenge assumptions as the project progresses.
4. Provide the Client with a tool to evaluate further scenarios and amend parameters as the project maturity progresses.
5. Reflect a project comparable to a floating wind project proposed during the ScotWind leasing round.

Sensitivity studies were performed to evaluate the impact of critical parameters as well as parameters associated with the highest levels of uncertainty.

4.2 Structure

Figure 4-1 below presents the overall structure and data flow of the LCOE tool.

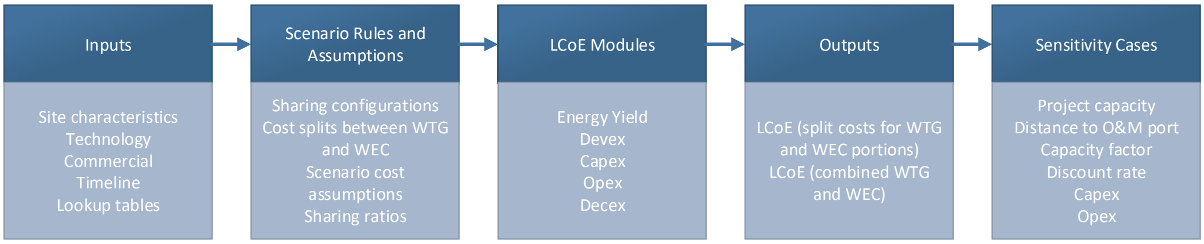


Figure 4-1: LCOE Tool Structure

Figure 4-2 outlines the key sheets in the LCOE tool used to define the inputs and scenarios, and what information can be found within each of them.

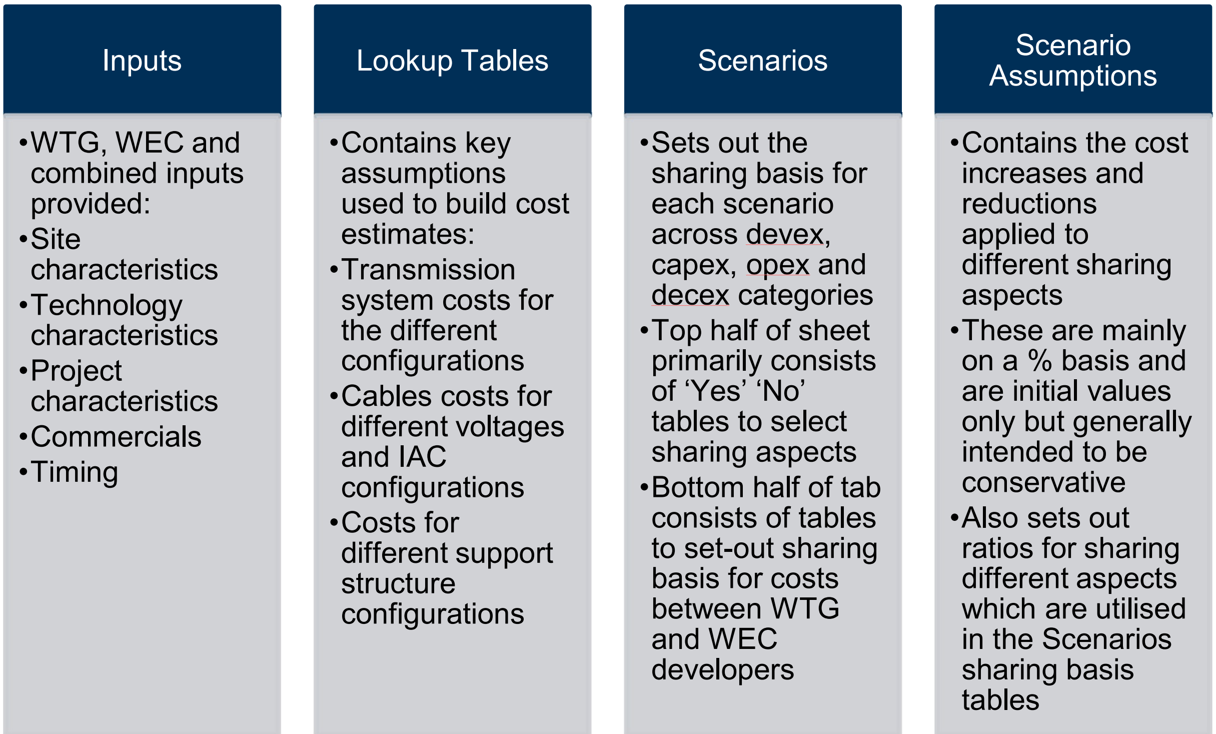


Figure 4-2: Breakdown of Inputs and Scenarios Sheets in LCOE Tool

4.3 Overall Methodology

4.3.1 General

Figure 4-3 presents the overall methodology adopted.

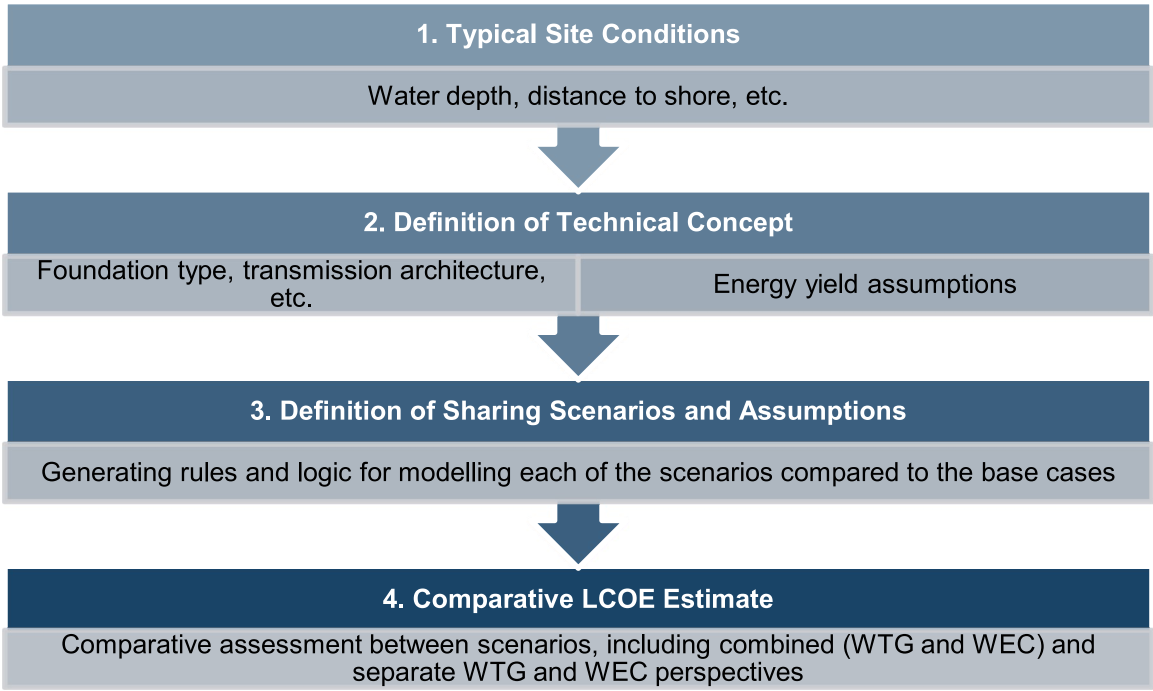


Figure 4-3: Methodology Overview

4.3.2 Technical Concept

An initial definition of relevant technical concepts for the selected scenarios was performed, serving as the basis for the cost and ultimately LCOE estimates.

The following sources of information were used to define the technical concepts:

- Publicly available information including offshore wind database, wave energy converters' websites and literature.
- Client's technical input and clarifications related to wave energy conversion.
- OWC in-house technical database on floating offshore wind projects and WEC technologies.

The accuracy of the input information is limited given the current status of the industry; however, it is expected to provide sufficient guidance at early stage and for a generic type of study. Simplifications were adopted to enable a fair comparison between all scenarios.

The following strategy was adopted to maximize the relevance of the estimated costs in the context of the comparison of all scenarios:

- Identification of cost drivers and focus areas (electrical architecture, foundation costs, etc.).
- Definition of cost benchmarks based on OWC's in-house cost database.
- Estimation of representative cost ranges for each project.

- Refinement of site-specific constraints (i.e., distance to grid connection point, bathymetry, etc.).
- Definition of relevant project assumptions (i.e., project programme, localisation requirements, etc.).
- Concept sizing of key technical packages (i.e., foundation clusters, transmission strategy, etc.).

4.3.3 Inputs and Level of Detail

The sections below briefly mention the items that comprise the tools and the considerations used to calculate the costs of the integrated wind and wave energy generation systems.

CAPEX	**Energy device:** WTG and PTO (for WEC) supply cost, accounted as a lump sum **Substructure:** quantity, type, material, overall weight, primary and secondary material quantity **Moorings:** legs per floater, configuration, mooring line length and linear weight **Anchors:** quantity per floater, type, primary and secondary material weight **Installation:** number of vessels mobilised **Inter-Array and Export Power Cables:** calculation based on length, correction factors (for IACs), number of landfall cables, transition pits, cable terminations and sealing ends, crossing of major roads **Offshore and/or Onshore Substations: S**witchgear, SCADA system, STATCOM, transformers, topside auxiliaries, foundations, equipment transportation and installation cost, onshore civil works. Other items such as PM, legal, OFTO transfer etc. are treated as lump sums, fixed percentages or with simplifications applied where these are not relevant to the sharing scenarios but are included so that the LCOE output is of the right order of magnitude.
OPEX	**O&M Agreement for WTGs (OMA)** **Major Component Exchange (MCE)** **Balance of Plant maintenance** **Onshore WTG O&M Facilities** **Insurance** to reflect risk profile of each scenario Seabed lease according to Crown Estate Scotland rules Project Management and operations primarily based on lump sum
DEVEX	**Pre-development and seabed option agreement** **Site Surveys and data collection (engineering and environmental)** **Development including EIA/consenting and engineering design and procurement** **Project Management and other administrative costs** Generally all treated as lump sum costs but with scaling applied where relevant to account for the size and characteristics of the site and project.
DECEX	DECEX treated as lump sum appropriate to project scale, for WTG and WEC separately
General Parameters	Overall capacity, payment amortization schedule and project's lifespan, energy resource, site conditions

Table 4-1: Level of Detail used for cost modelling

4.3.3.1 WEC Input Assumptions

Parameter	Value	Unit
Project capacity	100	MW
WACC	8%	-
Gross Capacity Factor	35%	-
Net Capacity Factor	29.7%	-
Number of units	125	-
Wave Resource	40	kW/m
Number of mooring lines	3	-
Mooring line length	124	m
Primary steel mass	153	Te
Secondary steel mass	14.3	Te
Concrete mass	350	Te
Availability	92%	-
Development start	3	Year
Construction start	9	Year
Operation start	12	Year
Decommissioning start	37	Year
Operating lifetime	25	Years

Table 4-2: WEC Input Assumptions

4.3.3.2 WTG Input Assumptions

Parameter	Value	Unit
Project capacity	500	MW
WACC	8%	-
Gross Capacity Factor	72%	-
Net Capacity Factor	54.9%	-
Number of units	33	-
Number of mooring lines	3	-
Mooring line length	400	m
Availability	92%	-
Development start	1	Year
Construction start	9	Year
Operation start	12	Year
Decommissioning start	37	Year
Operating lifetime	25	Years

Table 4-3: WTG Input Assumptions

4.3.3.3 Calculation of Cable Ratings

The calculation of the cable ratings – suitable voltages and cross section areas is dependent on the following variables:

- Operation voltage of the system (kV)
- Power output capacity of the system (MW)
- Frequency (Hz) of the system – 50 Hz in UK and most European countries

- Number of circuits obtained through iterative process with the offshore cable length and sizing
- Length of cable sections: onshore (1-core cable), landfall and offshore (both 3-core cables)
- Voltage class of the cables: usually 66 kV for inter-array (IAC) cables, HVAC export of 220/230kV, 275 kV, 345 kV, or HVDC export of 320 or 525 kV.

4.3.3.4 Calculation of the Onshore and Offshore Substation CAPEX

1) Calculation of cable costs:

Cable costs are calculated based on:

- Length of the cable sections: onshore, offshore and landfall
- Number of landfall cables
- Number of transition vaults
- Number of cable terminations and sealing ends
- Number of crossings of major roads via horizontal directional drilling

2) Calculation of substation costs:

The calculation of both onshore and offshore substation costs is based on the presence of the following components:

- HVDC converter: onshore, 1 item
- Switchgear: onshore and offshore – 10's of items, determined by the single line diagrams; uses the same voltage as the cable rating.
- SCADA protection system: onshore and offshore, 1 item each.
- STATCOM, reactive power compensation and harmonic filters: onshore, 1 item compatible with voltages and export power (kV and MVA) of the circuits and system.
- Transformers: onshore and offshore; 1 item per circuit/cable with MVA compatible to the export system (MWA = MW/0.9). Autotransformers and three-winding transformers are the mostly used.
- Topside auxiliaries and secondary, topside equipment integration and topside structure: offshore, 1 item that is dependent on voltage class and export power (MW), different for AC and DC systems.
- Foundations: offshore, 1 item, fixed or floating, AC or DC.
- Offshore substation equipment transportation and installation costs
- Onshore civil works

1) IAC Cost considerations

Given 72.5kV/66kV the usual IAC rating, it is often taken as the standard cost 100%, 33 kV cable class costs approximately 90%, and 145kV/132 kV 115%.

Table 4-4: Price reference used for 66kV inter array cables

	66kV cables		33kV cables
Cost Category	**EUR/km**	**GBP/km**	**GBP/km**
IAC static supply cost	€ 350,000.00	£298,302.63	£268,472.37
IAC dynamic supply cost	€ 590,000.00	£502,853.01	£452,567.71
IAC static installation cost	€ 380,000.00	£323,871.43	£323,871.43
IAC dynamic installation cost	€ 330,000.00	£281,256.77	£281,256.77

Case 1 - WTG and WEC do not share IAC (suitable for scenarios 3, 4, 5, 6, 7, 8, 9, and 10)

Calculations were done separately for WTG and WEC IACs (as WTGs assumed to use 66kV inter array cables and WECs assumed to use 33kV inter array cables), both for conservative and minimal approaches for distances between WTGs (8 x WTG diameter between WTGs and 6 x WTG diameter).

Case 2 - WTG and WEC do share IAC – consecutive WECs between 2 WTGs (suitable for scenarios 11, 12, 13, and 16)

In this scenario, WECs will be placed between the WTGs and both the minimum distance between 2 WECs or 2 WTGs must be comprised.

This case is divided into 3 subcases:

A) Both WTG and WEC using a 66 kV cable in the same array and in the surplus WEC arrays (if any)

B) Both WTG and WEC using a 66 kV cable in the same array and surplus WTG arrays using a 33kV IAC

C) WTG using a 66kV cable and WEC using a 33 kV cable

In this case transformers and connectors are needed to step up and down from the 33kV WEC IACs and 66kV WTG IACs, which incorporate additional cost. It was assumed that one transformer would be needed for each of the WEC arrays connected to a WTG (one or two).

From a cost perspective, the IAC CAPEX cost for case C will be considerably superior to cases A and B, given that cost addition of the transformers and connectors needed to step up and down from the 33kV and 66kV cables for the WECs and WTGs in the same array. Even if the cost of this option was similar to the others, further investigations on the technical constraints of many voltage changes in the same array (e.g., installation, harmonics, other electrical constraints) would have to be performed.

Case 3 – WTG and WEC share platforms, but not IACs (Scenario 15)

The calculations for this case are very similar to case 1, but the distance between WTGs and WECs is the same since they share the same support platform.

Case 4 – String of WECs connected to each WTG through transformers, shared IACs (Scenario 14)

In this case, one string of WECs is connected to each of the WTGs. The calculations are similar to case 1 regarding the distance between consecutive WTGs and WECs, with added transformers and connectors to link the 33kV and 66kV IAC cables.

Note

IAC CAPEX calculations were done solely based on the costs of equipment per sea (33kV and 66 kV cables, transformers needed to step up and down the voltage). Although the 33kV cables are in general 10% cheaper than 66kV cables and can yield considerable savings for separate WEC and WTG systems, the added cost of having reels of different ratings being installed (hiring of additional vessel, personnel, logistics, etc) might be considered.

4.3.4 Levelised Cost of Energy (LCOE)

An estimation of project Levelised Cost of Energy (LCOE) was carried out, combining the estimated costs, project assumptions and AEP.

LCOE estimates rely on the following standard equation:

$$LCOE = \frac{NPV\ of\ Total\ Costs\ Over\ Lifetime}{NPV\ of\ Electrical\ Energy\ Produced\ Over\ Lifetime}$$

As per the standard definition of LCOE (we followed the BEIS methodology), financing costs and other taxes provisions are excluded. The LCOE is estimated over the complete duration of the project, through to decommissioning.

Project programmes are designed to reflect reasonably representative expenditure profiles. It is important to note that early payments largely affect LCOE estimates and as such development duration and early payments (such as Option Agreement and OFTO transfer) are reflected in the model, to ensure fair comparison across the different scenarios. However, for the most part, expenditure is split evenly across the number of years it relates to given the high-level nature of the model and small differences in annual expenditure within the devex, capex and opex phases.

Sensitivity studies will be carried out on multiple parameters such as discount rate, WTG Capacity Factor, WEC Capacity Factor, etc. to account for the uncertainties in the technical concept. See Section 4.7.

4.4 Limitations

This techno-economic assessment work is constrained by the generic nature of the evaluated scenarios. As such, assumptions were made and described in the LCOE tool based on OWC's experience.

The tool was developed with the following limitations:

- Tool based on the Client's requirements and setup for specific scenarios
- Frozen technical concept based on initial assessment (i.e., transmission architecture fixed for a given capacity, distance to shore, etc) and supplied in lookup tables
- Influence of technologies on energy yield is excluded (e.g., damping effect of WEC coupled with FOWT)

- Comparison of various WEC technologies is excluded (i.e. a single WEC technology is modelled)
- Aspects where information is currently lacking such as the scale of potential impacts on performance and power characteristics that could be realised through WEC and floating wind sharing scenarios will not be incorporated into the LCOE model but considered qualitatively in the feasibility study and wider benefits work packages.
- The cost estimate is based on an optimistic maturity of the floating wind industry by the initiation of the execution of these generic projects. As such, costs and rates were aligned with some of the more aggressive predictions/roadmaps published by industry stakeholders.

4.5 Assumptions

4.5.1 Key Assumptions

The key assumptions used in the LCOE modelling are:

- Qualitative benefits excluded from model, to be picked up in wider benefits piece in Part 2
- Quantitative values (e.g cost of foundations, etc.) based on OWC's experience and database
- Semi-Quantitative values (e.g. effect of economies of scale on steel usage, etc.) based on OWC's experience
- Required assumptions such as: "assets halved if hybrid platform is used", etc.
- Costs benchmarked and phased based on typical project programme, considering ScotWind context and anticipated level of maturity of WTG and WEC technologies in that timeframe
- Site conditions loosely based on ScotWind NW sites to give representative parameters but maintain applicability to other geographies
- Transmission system costs calculated using OWC's in-house transmission costing tool. These costs are specific to each of the configurations
- Maintenance uses a simplified approach whilst still enabling impact of distance to shore to be assessed (at high-level)
- Platform, mooring and anchors are scaled for the different configurations (versatile WEC, WTG shared platform) but with significant uncertainty in terms of the scaling parameters used
- IAC lengths were calculated using a simplified approach based on typical device spacing and the selected water depth with additional length applied to account for routing, dynamic cables etc. These are supplied in a look-up table.
- Energy yield is based on capacity factor and does not change across scenarios

4.5.2 Scenario modelling methodology and assumptions

As discussed in Figure 4-2, the logic in the model addressing the various sharing aspects contains a number of assumptions that are important to highlight. The model works through a series of estimations of the % cost increase or reduction for different aspects based on past project experience. This could relate to the increase in mooring costs when adding WECs to the WTG platform, or increase/decrease in other asset related sharing aspects. Some of the assumptions relate to non-asset sharing for example assumed reduction in costs for sharing surveys across two sites rather than completing these separately. The assumptions should be treated as initial indicative values, as they are not based on directly comparable project experience, and there is no specific design work that has been undertaken to validate the estimates. Therefore, further work should be undertaken to assess and refine these values after conclusion of this study, focusing on the most interesting aspects for cost reduction. The values in the model are highlighted as variable inputs and can be easily modified by the user in the model to sense check the results or refine these based on additional data or analysis.

Another important point to note in terms of sharing methodology is that both installation and maintenance have two configurations for sharing depending on the selected scenario. One is where WECs make partial use of vessels/equipment without disturbing WTGs, and the other corresponds to a fully shared, integrated strategy. The percentage of time specified for partial use of vessels is also assumption based and can be varied in the model by the user.

A key part of the model is assigning the split of costs for shared aspects between the wind and wave developers. This cost splits are mostly based on a MW basis but with some exceptions relating to area basis or a combination of MW and no of units, depending on the aspect in question. This is a simplistic method for apportioning costs between the two parties. In reality, commercial negotiations would likely result in a more favourable position for the WTG developer, having the larger, more mature project.

4.6 Results

The key results from the model are presented and discussed in this section. The metrics of LCOE, Devex, Capex, Opex and Decex are provided in turn. For each metric the combined LCOE values for the WTG and WEC components of each sharing scenario are presented, which provides a view of the overall benefit of sharing that can be brought to the market. Then the costs split out for the WTG and WEC portions within each scenario are presented to show the direct benefit to each party (floating wind and wave developers). Note that in the combined cases, it is scenario 17 that provides the base case for comparison (individual WTG and WEC projects combined into one LCOE metric). For the split graphs, scenario 1 provides the WTG base case for comparison whilst scenario 2 provides the WEC base case for comparison. In the split graphs, the split from case 17 is also provided as a check (i.e. 17 should equal 1 or 2 in the WTG and WEC graphs respectively).

4.6.1 LCOE

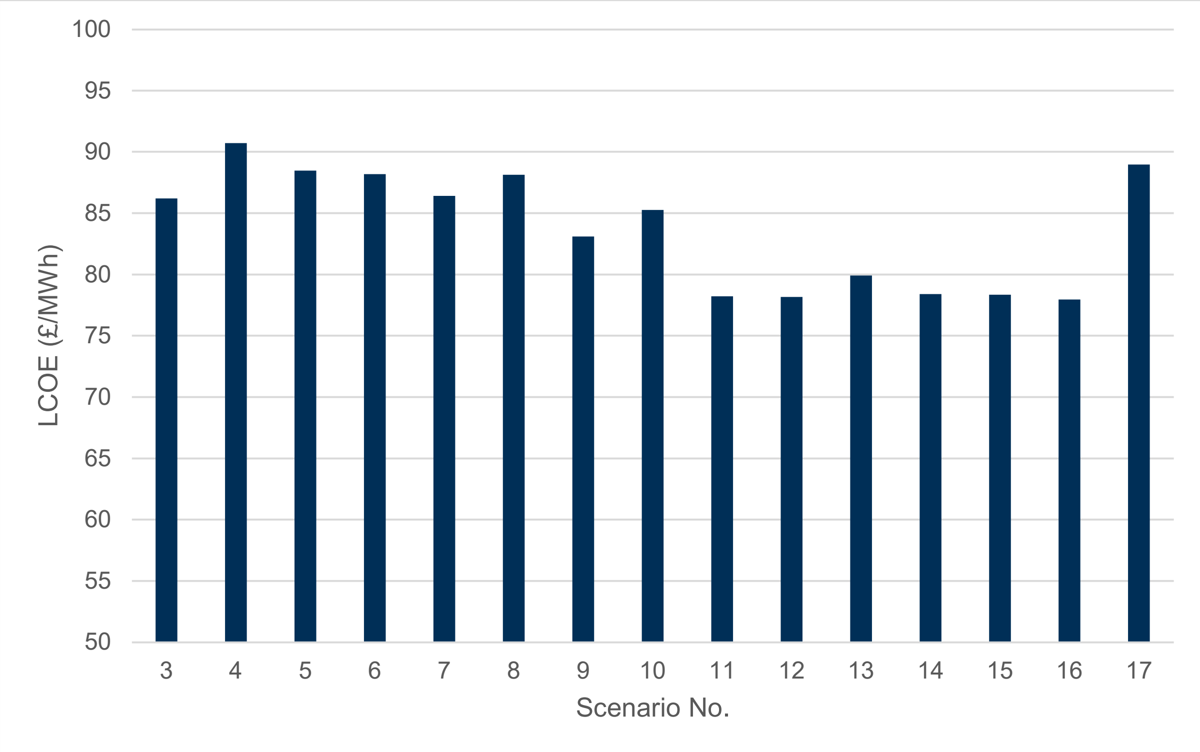


Figure 4-4: Combined LCOE

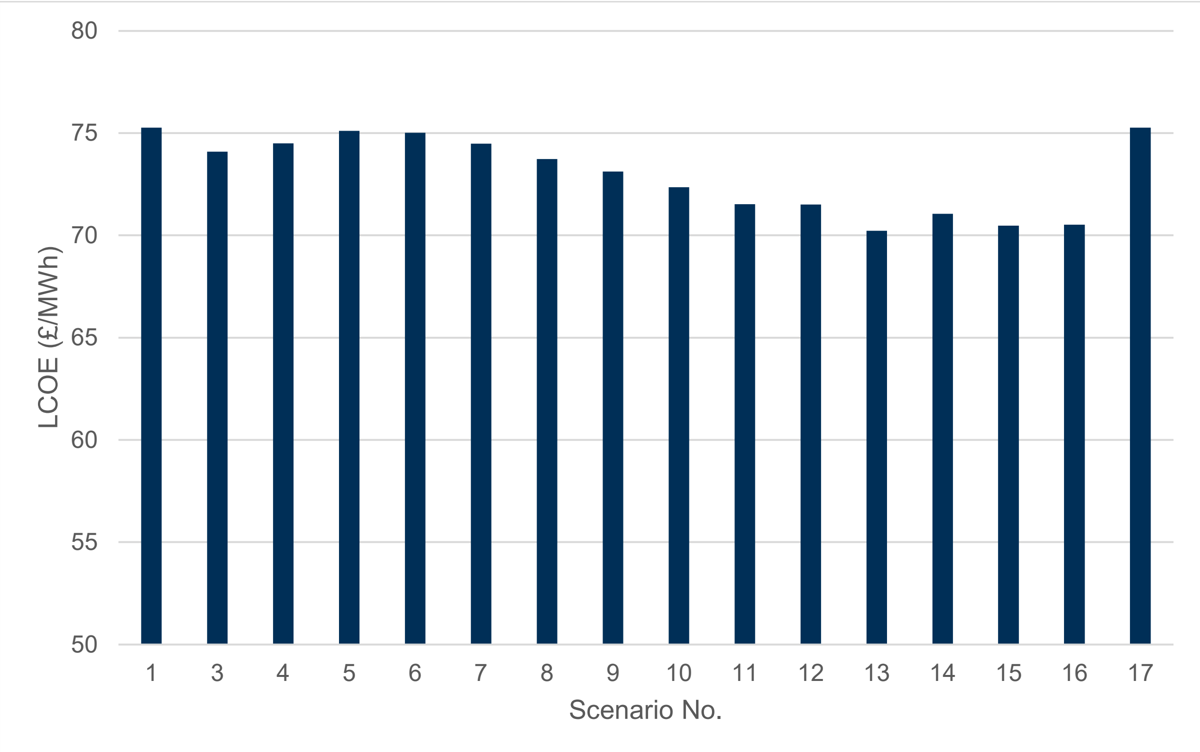


Figure 4-5: Split LCOE – WTG

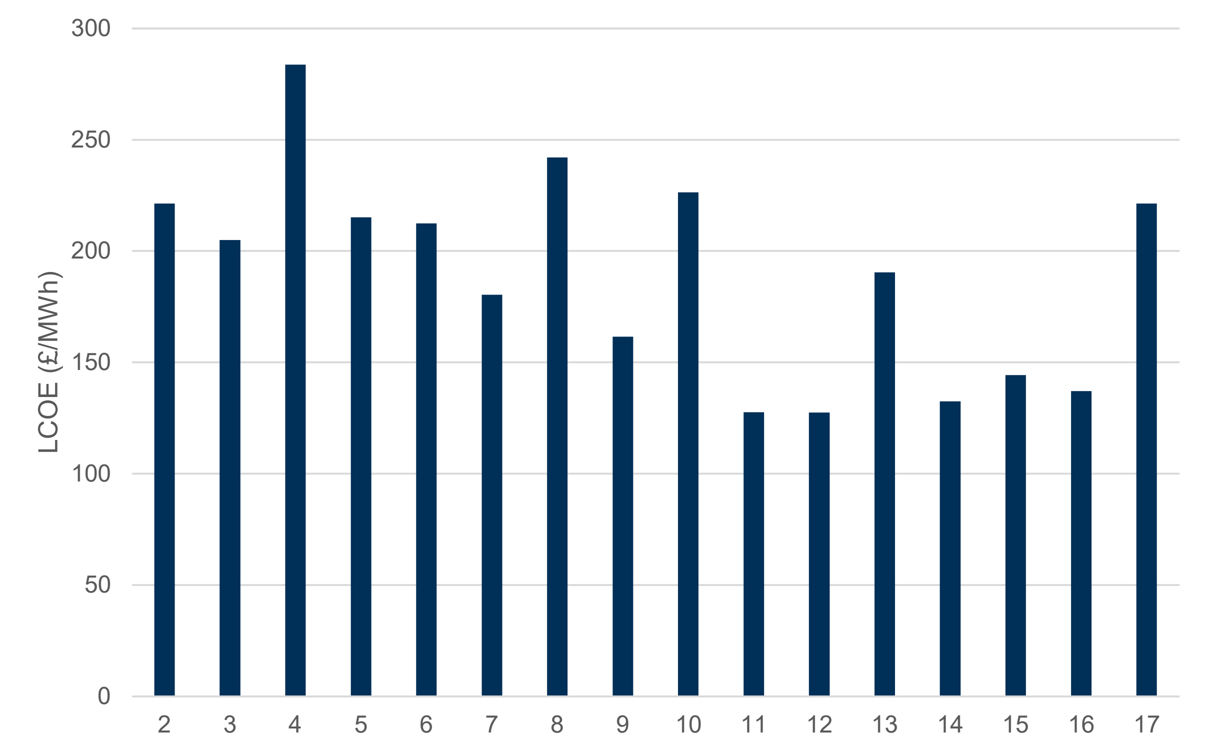


Figure 4-6: Split LCOE – WEC

Firstly, considering the combined LCOE metric, all scenarios result in an overall reduction in cost compared to the base case except for Scenario 4 (stand-alone versatile platform case). This is a key result as it clearly demonstrates there is an overall benefit to sharing projects.

Scenarios 4, 8, 10 and 13 appear to perform slightly worse than other scenarios – these are all of the scenarios involving the versatile platform. Further investigation of platform design/size/weight and optimization would be worthwhile to validate this result. In particular, the number of WECs assumed on one platform may be able to be refined which would impact the overall number of versatile units required and hence overall costs.

The maximum saving in the combined LCOE from the base case (scenario 17) is 12% and relates to scenario 16 (fully shared). This is a significant reduction in LCOE terms and demonstrates real potential for sharing to be a solution for bringing down costs in the renewables industry. However, overall, scenarios 11, 12, 14, 15, and 16 have the greatest benefits with very little difference between them. All of these scenarios have shared transmission and non-asset based sharing. The results indicate that there is only a very small additional benefit through sharing platforms or IACs. This means that there is quite a wide range of sharing configurations that can be utilised to realise the biggest benefits, providing a level of flexibility for developers and risk mitigation.

Even in the case with no asset sharing (case 3), there is still a 3% reduction in LCOE compared to the base case, demonstrating that when combined, non-asset sharing is a valuable and potentially lower risk way to achieve cost reduction as the projects in this scenario do not rely in each other.

Considering the split LCOEs, the costs are reduced compared to the base case in all scenarios from WTG perspective and there is a relatively even trend of increasing benefit with increased sharing. Scenario 13 (versatile platforms with shared IACs) reduces the WTG LCOE the furthest, by nearly 7% which is a tangible benefit to floating wind projects, especially when considering the challenges anticipated to be faced to reach CFD strike price targets and compete with other floating wind projects in easier to develop areas (i.e. less harsh metocean conditions). This is a key result as it means that not only is the sharing enabling cost reduction of the WECs but also the wind developer can see some direct cost benefit to them. This should be a strong incentive for engagement of floating wind developers in sharing projects. Scenarios 11 to 16 all have relatively similar levels of benefit, as shown in the combined LCOE figure. The additional benefit for scenario 13 which relates to versatile platforms is probably due to wave developer taking on a greater proportion of the costs. The exact split of costs between WTG and WEC needs further consideration and is likely to be based on complex commercial discussions in reality, to balance the risks and rewards between the two parties. This is likely to result in more of the cost savings sitting with the WTG rather than WEC developer across all strategies compared to what is currently modelled as the floating wind operator is likely to be the primary developer and can charge a level of premium to the wave developer for use of the shared assets and activities. Therefore, the benefits shown specifically for the WTG owner can be considered as conservative in the model indicative results.

From the WEC perspective, significant cost reductions are scene for many scenarios, with the greatest reduction occurring for case 12, at nearly 37%. This could make the difference in terms of commercial viability with respect to achieving CFD targets for the wave industry. Both 11 and 12 have very similar levels of benefit, the only difference between these being the sharing of anchors which has not had a significant impact. 14, 15 and 16 also show very good levels of cost reduction, as reflected in the combined LCOE graph.

Scenarios 4, 8, 10 and 13 (all versatile platform cases) perform relatively poorly compared to the other scenarios. In fact in scenario 4 there is an increase in LCOE relative to the base case. This trend is reflected in the combined LCOE metric and is a result of the increased cost of the versatile platform itself compared to installing individual WEC units directly. So that at least in this model and the associated assumptions applied, the benefits of having fewer platforms and easier maintenance etc. are not outweighed by the increased structure cost. The impact of the base assumptions used here is explored further in Section 4.7.8 where the sensitivity to platform weight, number of units and size of units integrated into the WEC are investigated.

To investigate further the trends seen in the LCOE graphs, the following sections consider each component of LCOE in turn.

4.6.2 Devex

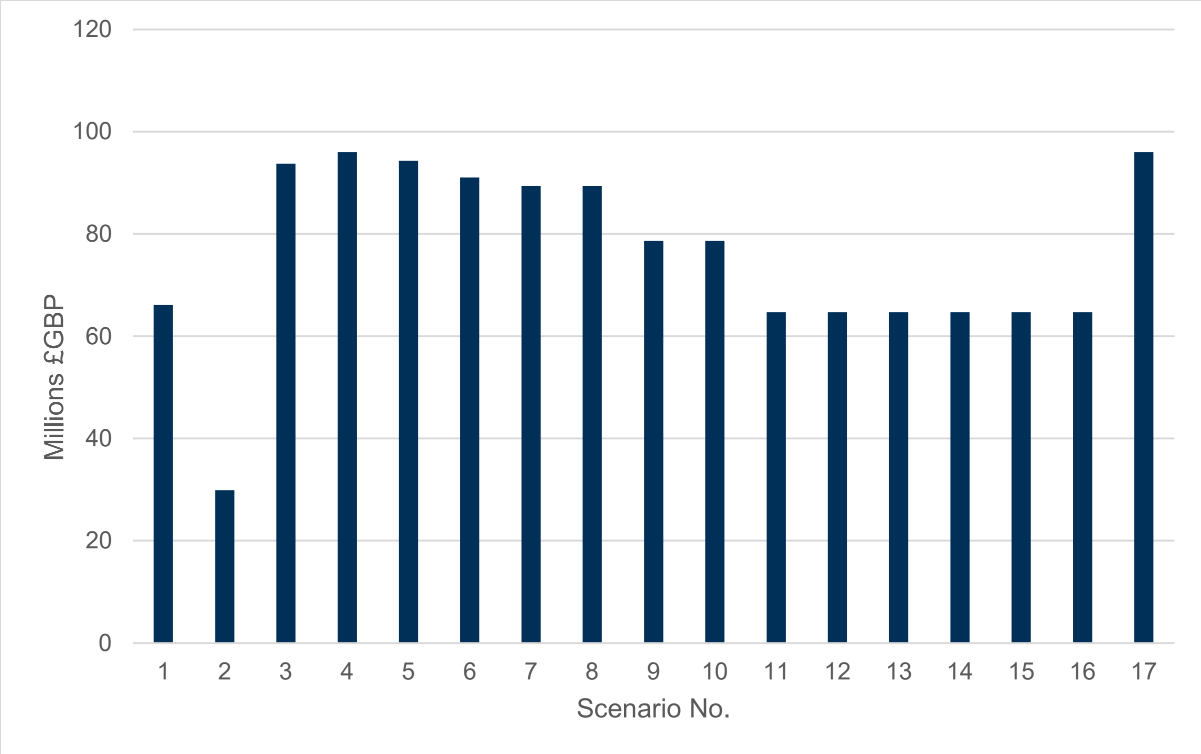


Figure 4-7: Combined Devex

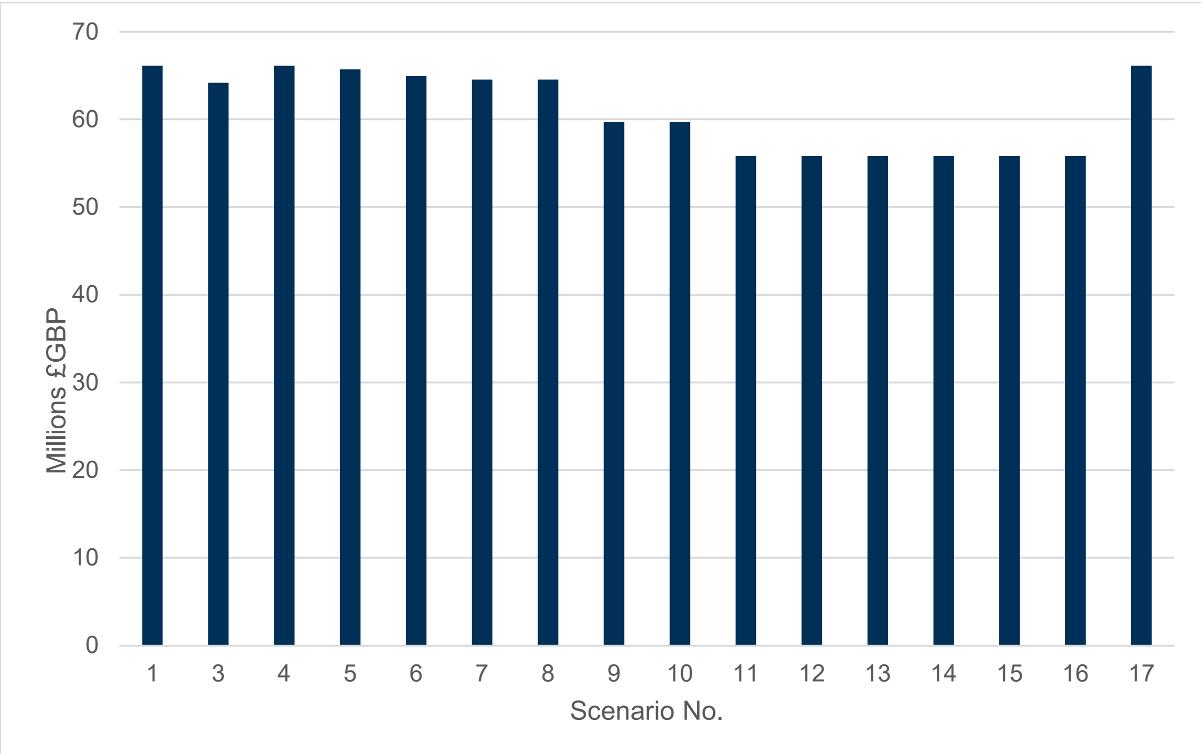


Figure 4-8: Split Devex - WTG

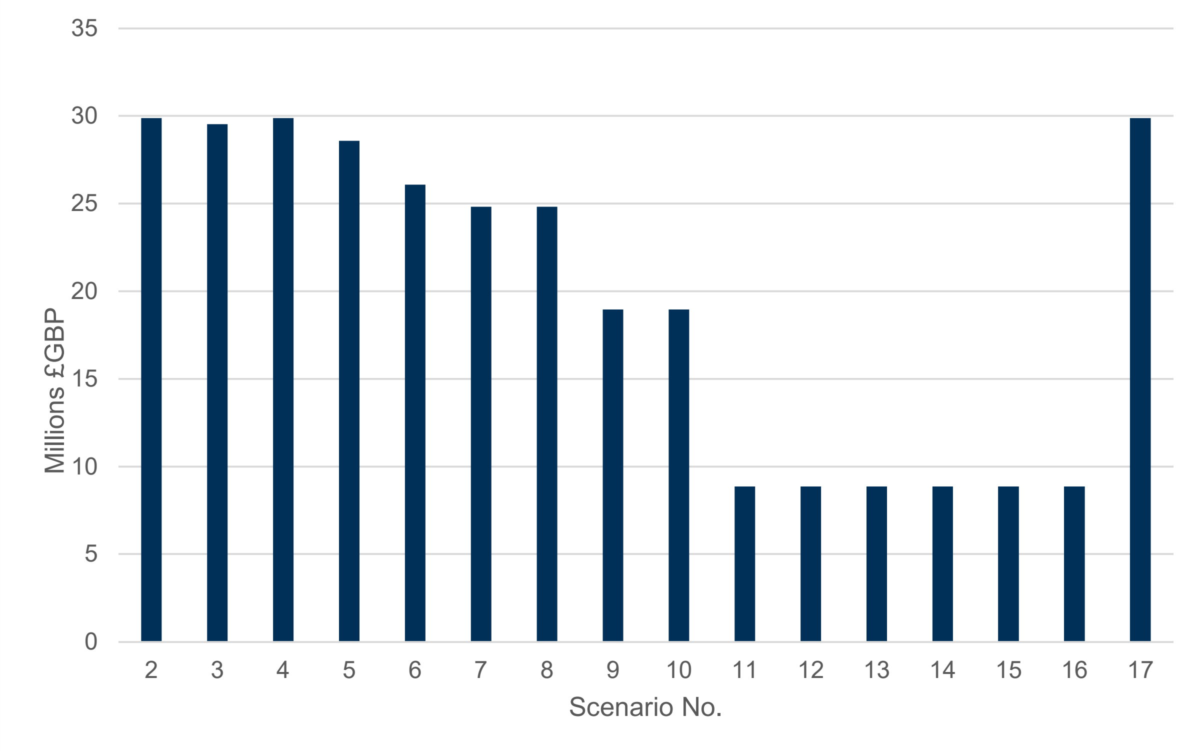


Figure 4-9: Split Devex – WEC

The combined Devex shows a significant reduction at scenario 9, where the projects start sharing the same site and hence have shared consenting, surveys, and seabed lease. There is another significant reduction at scenario 11, once the projects are modelled as a single project and so the design and project support also become shared.

Considering the split Devex charts, all scenarios show a cost reduction compared to the base case from both the WTG and WEC perspectives, excluding scenario 4 which has no Devex saving because the development of the projects is modelled as completely independent. There is a steady trend of Devex reduction from scenarios 4 to 7 which reflects the gradual sharing of more development related costs (e.g. consent and surveys) for the transmission system from no sharing in scenario 4 to full sharing in scenario 7.

The benefits are relatively larger for the WEC as opposed to the WTG developer, and this offers opportunity for negotiation between the two parties in how to split the costs, as currently the split is based primarily on an individual project size basis which favours more the WEC developer.

4.6.3 Capex

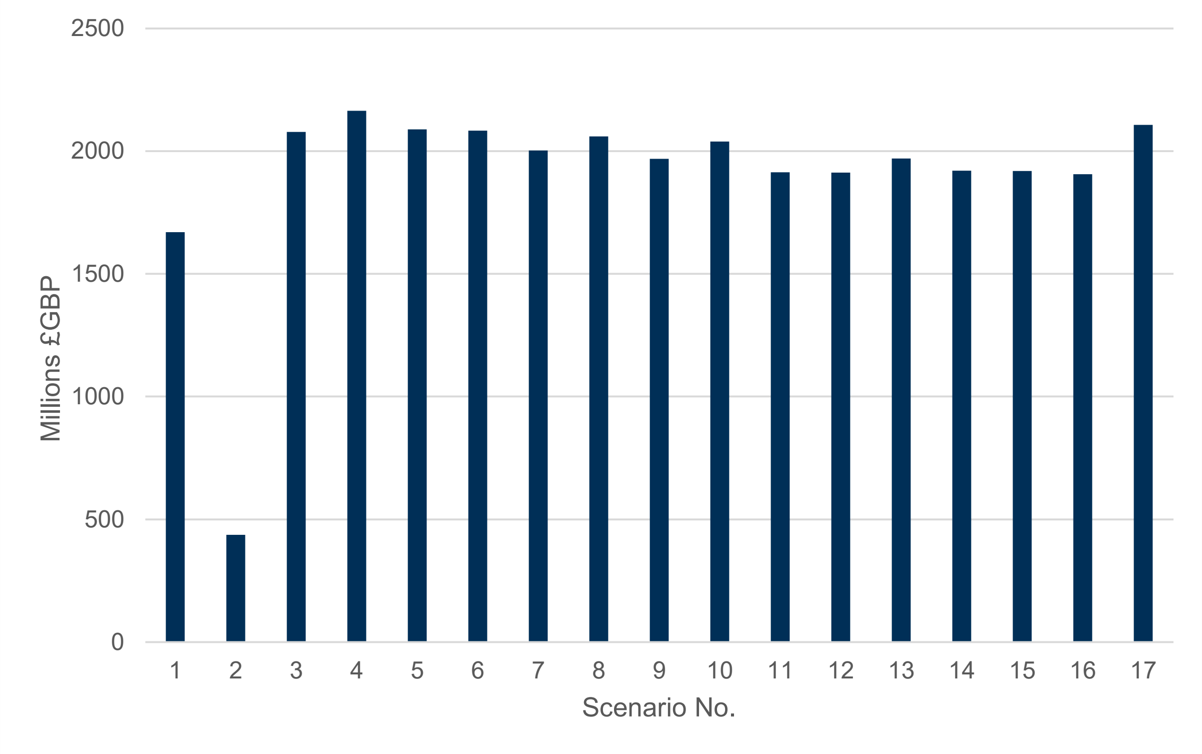


Figure 4-10: Combined Capex

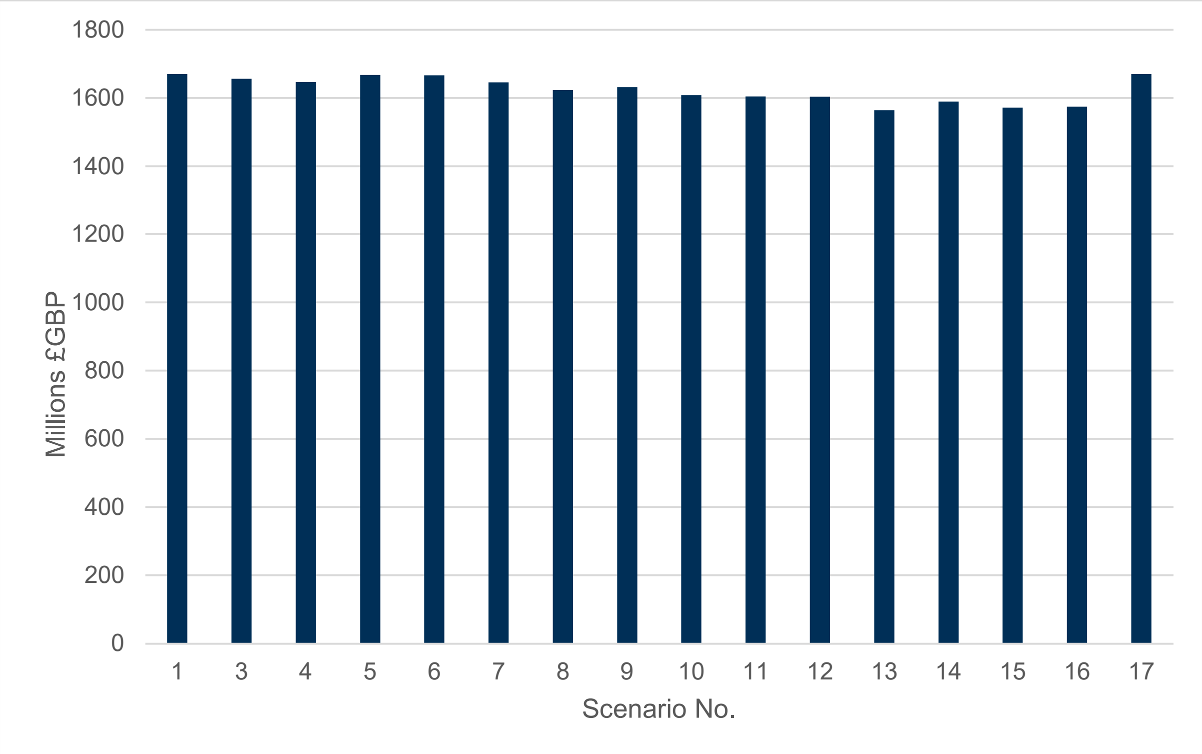


Figure 4-11: Split Capex – WTG

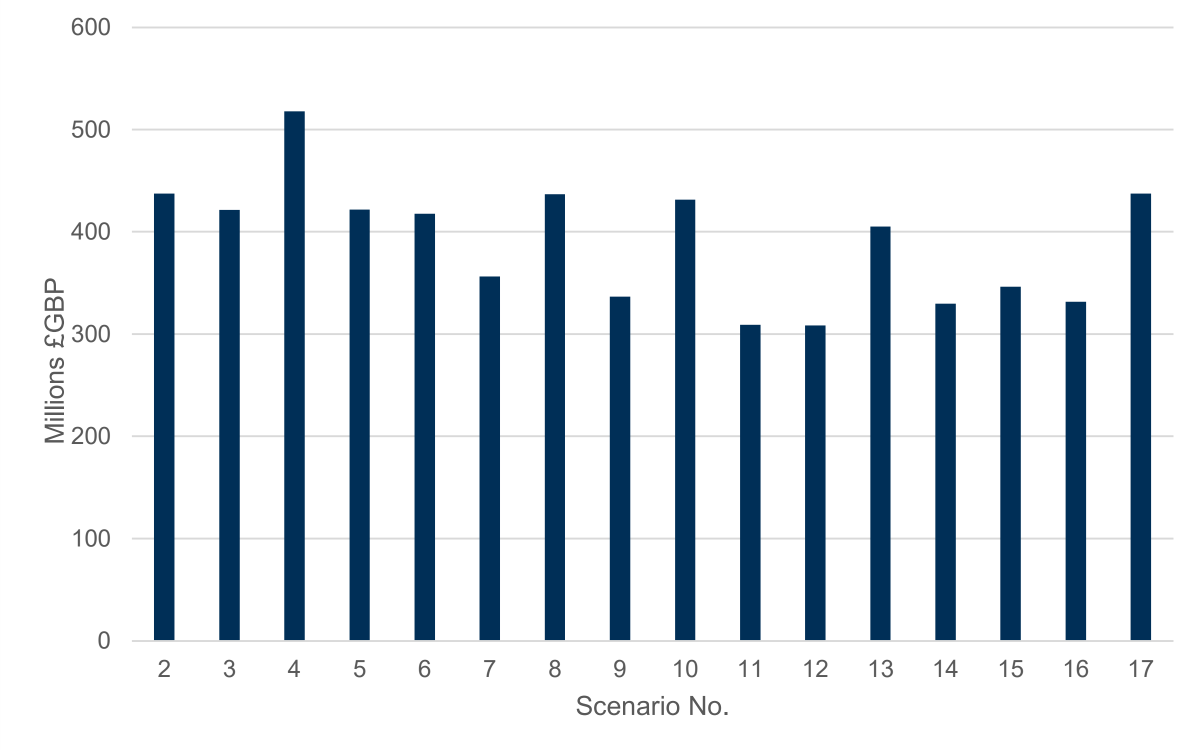


Figure 4-12: Split Capex – WEC

Given that the Capex is the dominant expenditure and that the energy yield is assumed constant between the scenarios, the Capex charts mirror the LCOE chart. As was seen in the LCOE charts, the versatile platform scenarios (4, 8, 10, and 13) result in less (or negative for scenario 4) cost reduction compared to the other scenarios. Scenario 16 has (marginally) the lowest Capex which again mirrors the result of the LCOE metric, but scenarios 11, 12, 14 and 15 are similarly low. These are the cases with the most sharing implemented across all categories.

From the WTG perspective, all scenarios result in a Capex reduction when compared to the base case. This is a very positive outcome given how crucial it is to get floating wind developers on board. The benefit of sharing the full transmission system is shown in scenario 7 from both perspectives. Again, the use of versatile platforms reduces the benefits seen from the WEC perspective.

4.6.4 Opex

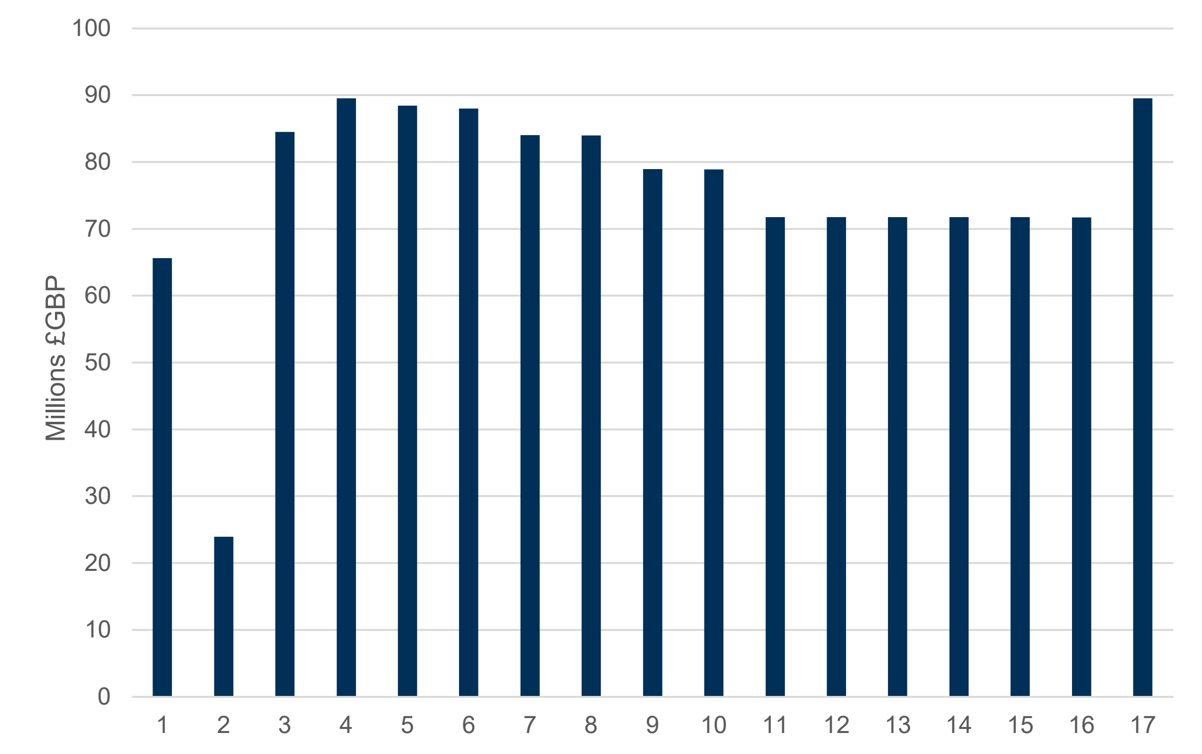


Figure 4-13: Combined Opex

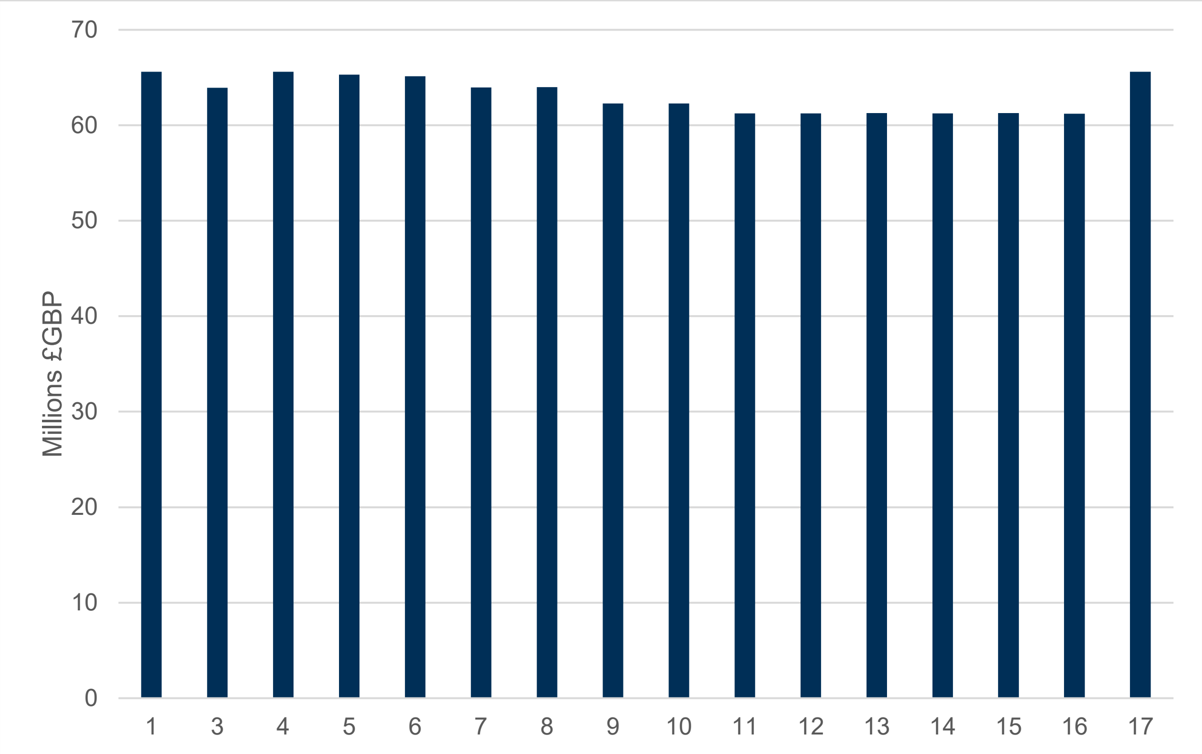


Figure 4-14: Split Opex – WTG

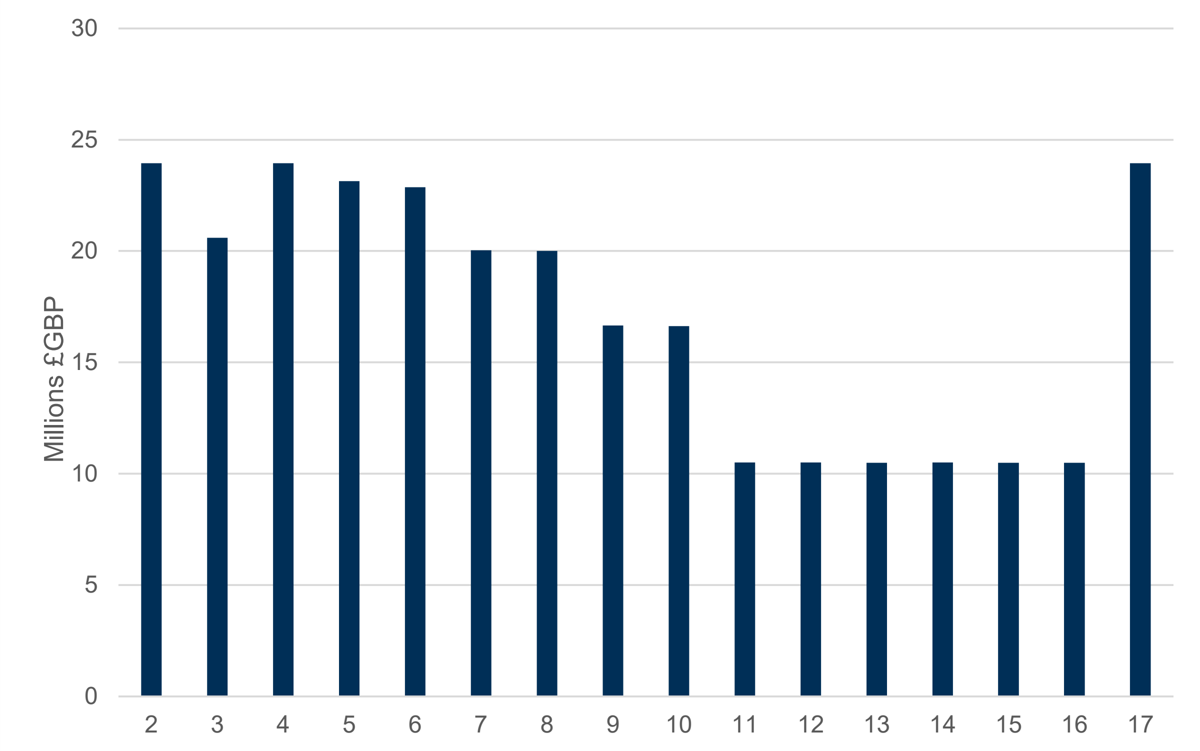


Figure 4-15: Split Opex – WEC

Across all scenarios, the Opex is equal to (Scenario 4) or lower than the base case in the combined figure. There is a significant drop from scenario 8 to 9 as the maintenance of the devices and the balance of plant becomes partially shared. There is another drop from scenario 10 to 11 as O&M becomes fully shared.

Considering the split Opex, scenario 3 indicates the significant savings that could be achieved for independent projects with some level of collaboration on vessel/equipment usage. Again, it is positive that costs are reduced compared to base case for all scenarios from WTG perspective, and there are significant cost reductions for the WEC developer across a wide range of scenarios.

4.6.5 Decex

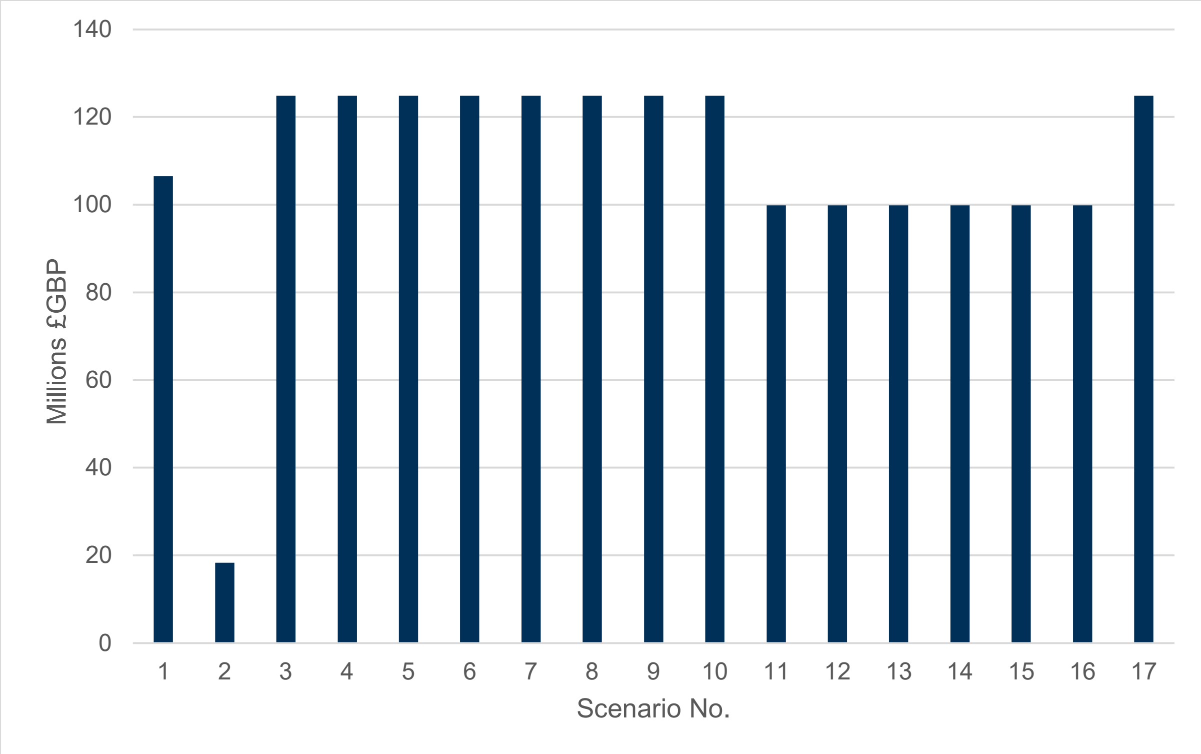


Figure 4-16: Combined Decex

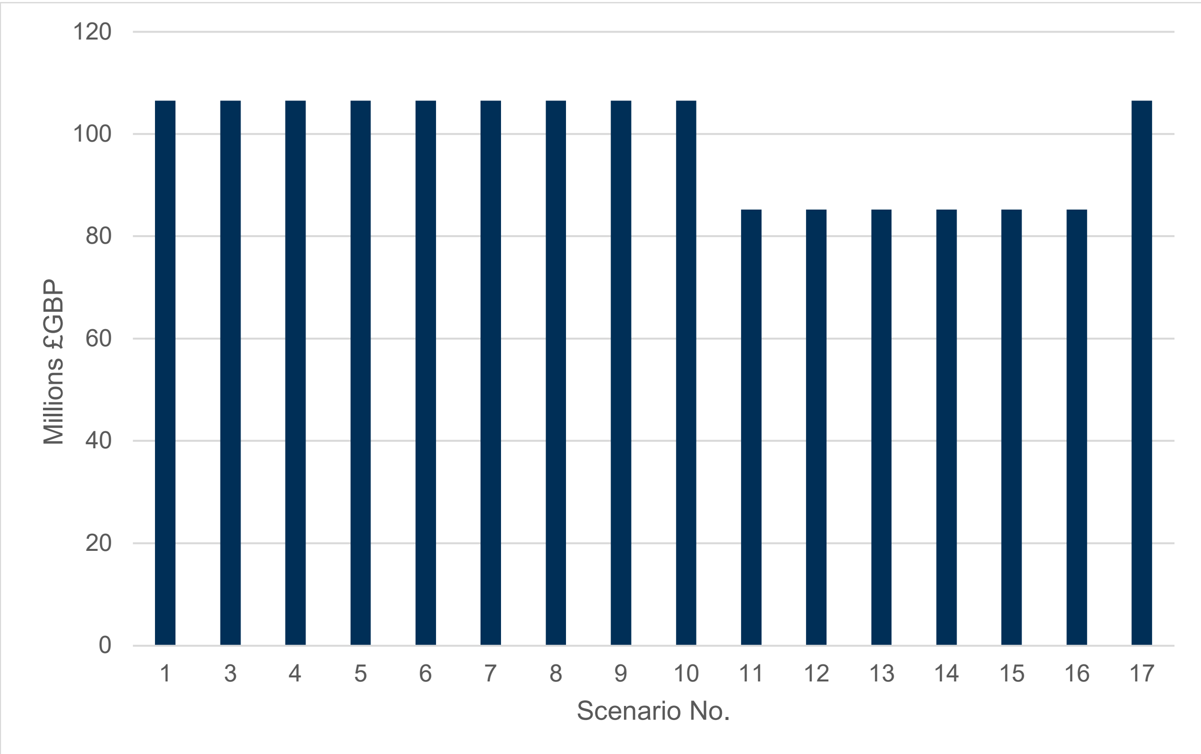


Figure 4-17: Split Decex – WTG

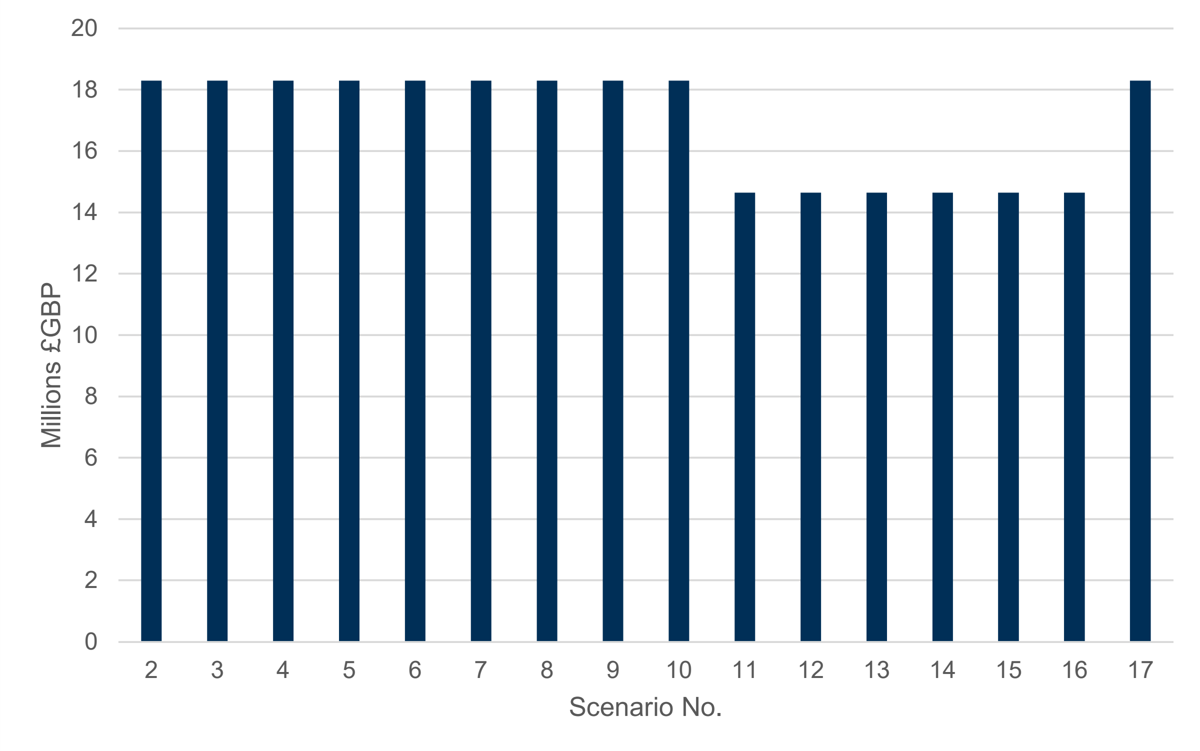


Figure 4-18: Split Decex – WEC

The Decex charts show the simple approach to Decex in the model, given the lack of impact on LCOE of Decex in general, as well as the unknowns surrounding costs for this. A single level of reduction comes in from scenario 11 onwards, where Decex starts being shared between the projects.

4.7 Calibration & Sensitivity Studies

To sense check the results, a set of sensitivity cases were run in the model to test for any impact on the trends between scenarios and the overall cost reductions achieved.

4.7.1 References to benchmarks

The following results were obtained for the base case scenarios:

- Base case (WTG): 75 GBP/MWh for a 500 MW floating wind project.
- Base case (WEC): 220 GBP/MWh for a 100 MW wave energy project.

Although the assessment is comparative in nature, the WTG and WEC base cases remain aligned with industry expectations with ScotWind rounds targeting floating wind LCOE in the range of 70 GBP/MWh and WEC technology estimated to offer LCOE in the range of 180-200 GBP/MWh. Note that within the model, a benchmarking factor is specified for each of the WTG and WEC projects in the inputs tab to enable alignment of the base cases to be altered. This provides a simpler approach to scaling the results than incorporating learning rates and other cost reduction strategy elements into the model, which was not the purpose of the assessment.

4.7.2 Sensitivity to Opex

Further studies are required to refine the Operation & Maintenance (O&M) costs for WEC projects. The estimations in the model are currently based in part on market benchmarks so the uncertainty in the model assumptions is relatively higher for this aspect. The sensitivity study reveals that a 20% reduction of the estimated Opex leads to a reduction in overall LCOE of ~8% for Scenario 2, showing that this is a relatively impactful parameter on the results. Whilst the absolute values are affected, this does not impact the trends seen in LCOE.

Similarly a 20% decrease in WTG Opex results in a 7% reduction in LCOE but without changing the trends in the graphs.

A reduction in the maintenance costs specifically rather than in Opex overall was also tested. This resulted in only a 3% reduction in LCOE for the WEC, and a 2% reduction for the WTG case, without any changes to the graph trends. This parameter has less influence on the results because a large proportion of the overall Opex relates to the seabed lease and TNUos fees.

4.7.3 Sensitivity to Capex

A 10% reduction in WTG capex results in a 7% reduction in LCOE, demonstrating the significant influence Capex has on LCOE. There was no impact on the LCOE trends.

A 20% reduction to procurement and installation costs specifically was also applied. In this, the reduction was applied first to procurement for both WTG and WEC simultaneously, and then to Installation parameters. The procurement case resulted in a 9% decrease in WTG base cost and 10% reduction to the WEC base case which is significant due to the large proportion of Capex that procurement accounts for. However, this makes no difference to the trends nor the % cost reduction that is achieved in the combined case (still around 12-13% for scenario 16).

Similar results are found when the installation costs are reduced by 20% for both WTG and WEC simultaneously but with a reduced impact of around 5% for WTG base case and 4% for the WEC base case, as installation costs are a slightly smaller proportion of capex than procurement costs in the model.

4.7.4 Sensitivity to distance to shore

The impact of distance to shore was assessed to ensure broader appeal to projects beyond the specific assumptions made for this study and its loose alignment with ScotWind site characteristics. This sensitivity relates to the distance to O&M port assumption only, so that the maintenance strategy switches from SOV to CTV. This switch results in a reduction in base case WTG of nearly 3% and to the WEC case of 6%. It is interesting that the WEC case is more impacted by this parameter than the WTG case. This is due to the greater number of units in the WEC case. Also, in terms of trends whilst there is no difference in the WTG case, for the WEC the cost reduction is more pronounced in the earlier scenarios and less so in the scenarios with greater sharing where the lower influence of this parameter on the WTG case is reflected due to the greater proportion of shared costs. The trends in the combined LCOE are not affected.

4.7.5 Sensitivity to capacity factor

Studies have demonstrated the potential for WECs to positively affect the capacity factor of floating offshore wind by indirectly reducing the motions of WTG floaters. Although a detailed analysis of this is outside the scope of this study, a sensitivity study was performed which reflects the output of such a benefit. Increasing the net capacity factor from 55 to 60% results in an 8% reduction in WTG LCOE. Although benefits brought by WECs would likely be lower (order of a % or so), this result demonstrates the significant sensitivity of LCOE to capacity factor and even a small improvement would be beneficial. Note that this result does not impact the overall LCOE trends.

A slight improvement in capacity factor is expected to greatly affect the LCOE, therefore highlighting the benefit of investigating this point further. Further simulations can be performed using the LCOE Tool sensitivity tab.

A change to WEC capacity factor was also tested, as the WEC capacity factor is set quite low in the model and is a key area for improvement in the industry. An increase of 5% results in an LCOE reduction of 15%, again demonstrating the significant influence of this parameter of project costs. Similarly, this does not affect the overall LCOE trends.

4.7.6 Sensitivity to discount rate

Discount rate is associated with high uncertainty so it is important to understand the impact of this on the results. A reduction of only 1% for both WTG and WEC cases simultaneously results in a reduction of WTG LCOE of 6% and 5% for the WEC case. This highlights the very significant influence discount rate has on the results and shows the importance of proving risk reduction to achieve the best possible financing arrangements. However, this does not impact the overall LCOE trends between scenarios.

Increasing the WEC discount rates from 8 to 10% while the WTG discount rate remains unchanged results in a 12% increase in LCOE, but again there is no change to the combined LCOE trends.

4.7.7 Sensitivity to project size

The WTG and WEC project sizes were also tested in the sensitivity analysis to understand any impact in different ratios.

A 1000 MW WTG project combined with the same 100 MW scale wave project was modelled. This resulted in a reduction in WTG LCOE of 12% demonstrating the potential scale of benefits that can be achieved through scaling up projects. Note that there are a number of assumptions made when scaling up the projects including economies of scale benefits based on number of units, and the increase in project costs across many categories. However, the transmission system and IAC cable lengths were recalculated based on this specific scenario. Interestingly this change in ratio of WTG to WEC projects does have an impact on the result trends. From the WTG perspective, whilst scenario 13 still brings the greatest benefit, scenario 14 is now slightly better than 15 and 16. Similarly scenario 4 is relatively more favourable than in the original results. These are the versatile platform cases with the increased costs having a relatively lower impact because of the relatively larger scale of WTG to WEC project. In the combined LCOE results, this results in a smoothing effect across the scenarios, with 11 through 16 achieving very similar levels of cost reduction. Scenario 14 is now the marginally best option, however, the cost reduction is now only 8% as opposed to the 12-13% reduction seen originally. This make sense as the relatively smaller WEC project has less influence on the project overall and hence the level of cost reduction that can be achieved.

A second case was tested to make the project ratios more even by setting the WEC project size to 500 MW whilst maintaining the original 500 MW WTG project size. In this case the WEC LCOE reduces by over 20% demonstrating the importance of scaling up projects as a means to realising cost reductions. The change to the trends is interesting for this case. Whilst no change to the WTG project was made, in terms of sharing the cost benefits, the trend does change even from the WTG perspective for the scenarios with a greater level of sharing incorporated. A relatively smaller proportion of the costs are now attributed to the WTG developer resulting in improved cost reductions for scenarios 9 through 16. In the combined case, there is a substantial increase in the maximum cost reduction achieved, at ~33% for scenario 16. This illustrates the strong influence of the ratio of WTG to WEC project size on the overall level of cost reduction, and this should be investigated further to determine the optimal ratio. In general, the trends are similar for the combined LCOE graph compared to the original results, although the differences between scenarios are more pronounced.

A final case that was tested was to investigate the cost saving for a WTG project of 600 MW size. This was included to demonstrate the difference between cost savings for a 600 MW WTG alone project as opposed to the 600 MW projects consisting of 500MW of WTGs and 100MW of WECs to answer the question 'is it better to just build a bigger WTG project rather than share with WECs?'. The 600MW WTG project sees a 3% reduction in LCOE compared to the base case, as shown in Figure 4-19. When comparing the 600MW WTG project to the 600MW sharing scenarios, the sharing scenarios result in an improved level of cost reduction from scenario 10 onwards. This is an important result as it clearly shows there is additional benefit from bringing an element of wave energy sharing into a floating wind project rather than purely relying on upscaling of the floating wind project to realise cost reduction. Also note that the cost reduction attributed specifically to the WTG developer in the sharing scenarios is only likely to increase as the model does not represent the commercial aspects with respect to determining the cost split between WTG and WEC developers.

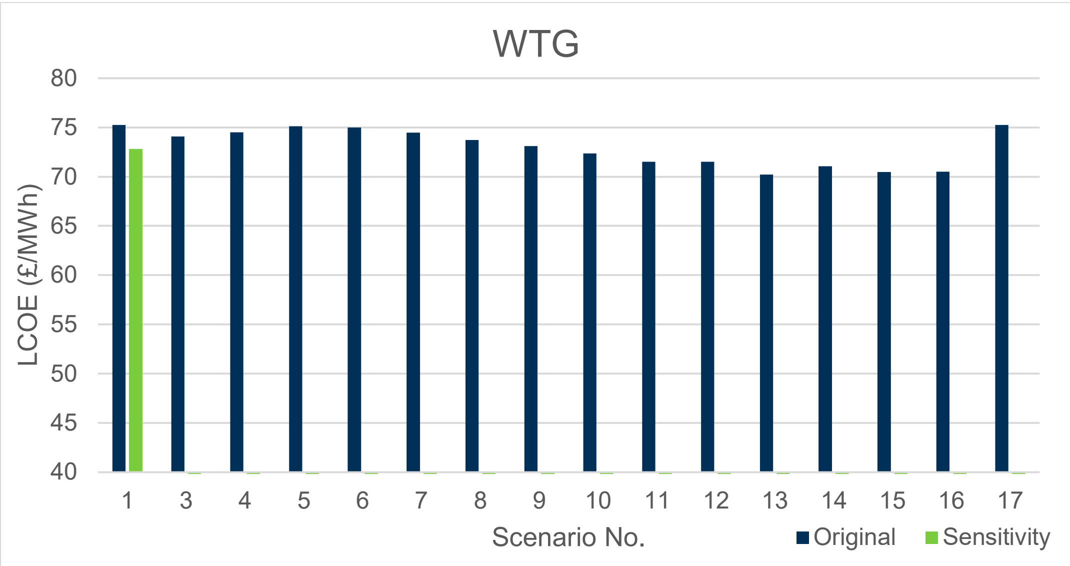


Figure 4-19 Comparison of 600 MW WTG project with original results from WTG perspective (i.e. for 500 MW wind project plus 100 MW wave project)

4.7.8 Sensitivity to versatile platform assumptions

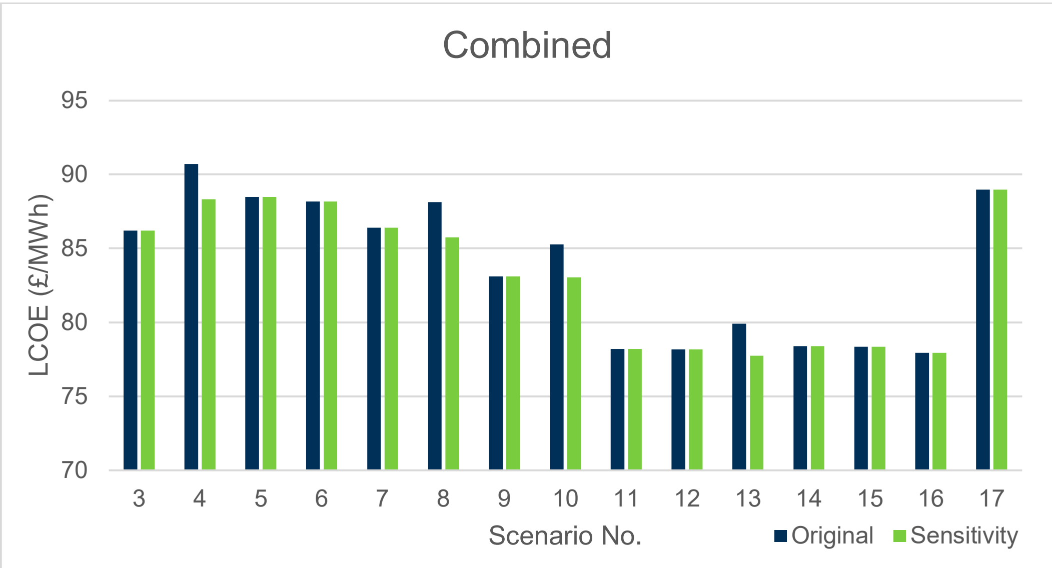
The results indicated that the versatile platform scenarios could be less beneficial than other configurations, so it is important to investigate this further to understand how this result has been impacted by the underlying assumptions relating to the versatile platform, especially given these are conservative at this early stage given the level of uncertainty and lack of design information for such a platform. Key assumptions to investigate are:

- The weight of the platform structure
- The number of WEC units per platform

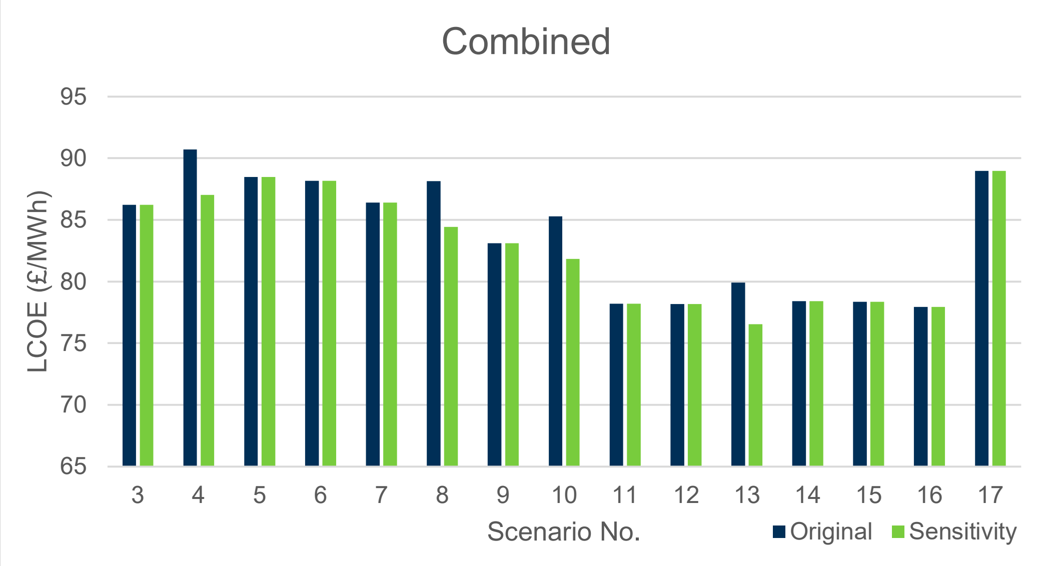
- The relationship between number of units, scale/capacity of the units and hence the number of platforms, because although more units can fit on a platform if they are smaller in size, they will also likely be lower capacity, and hence more platforms will be needed to reach the same project capacity

Figure 4-20 shows the isolated effect of increasing the number of WEC units per platform whilst maintaining the same unit capacity, so that the overall result is a smaller number of platforms for the same project size. Figure 4-20a shows 12 units per platform and Figure 4-20b shows 24 units per platform, both compared to the original results which were run with 6 WECs per platform (basis for the choice of 6 was the dimensions of the WEC units and WTG platform).

The improvement in cost benefit can be clearly seen in the figure for the versatile platform scenarios (4, 8, 10, 13). For the 12-unit case, the versatile platform scenarios now sit level with surrounding scenarios in terms of LCoE rather than having higher LcoE compared to adjacent scenarios. When 30 units are considered, the improvement is even more pronounced with the versatile platform scenarios now looking more favourable compared to the adjacent scenarios. Therefore, the number of WECs per platform is clearly a key driver to the cost reduction potential. This makes sense in the sensitivity context presented here, seeing as this leads to fewer platforms overall and hence less units to install and maintain. However, there is a question over how practical it would be to incorporate higher numbers of units of the same capacity on the same size of versatile platform.



a)



b)

Figure 4-20 Comparison of sensitivity scenarios with original results, a) 12 WEC units per versatile platform, b) 30 WEC units per platform (original results have 6 WEC units per platform. IAC length adjusted to reflect number of versatile platforms in sensitivity cases, but no other parameters changed in these sensitivity cases.

Figure 4-21 shows the relationship between number of units per platform (same capacity of individual units) versus LCoE for the four versatile platform scenarios. This shows a relatively greater benefit of increasing number of units for lower number of units compared to higher number of units (i.e. the difference between 6 and 12 units is greater than for 24 and 30 units).

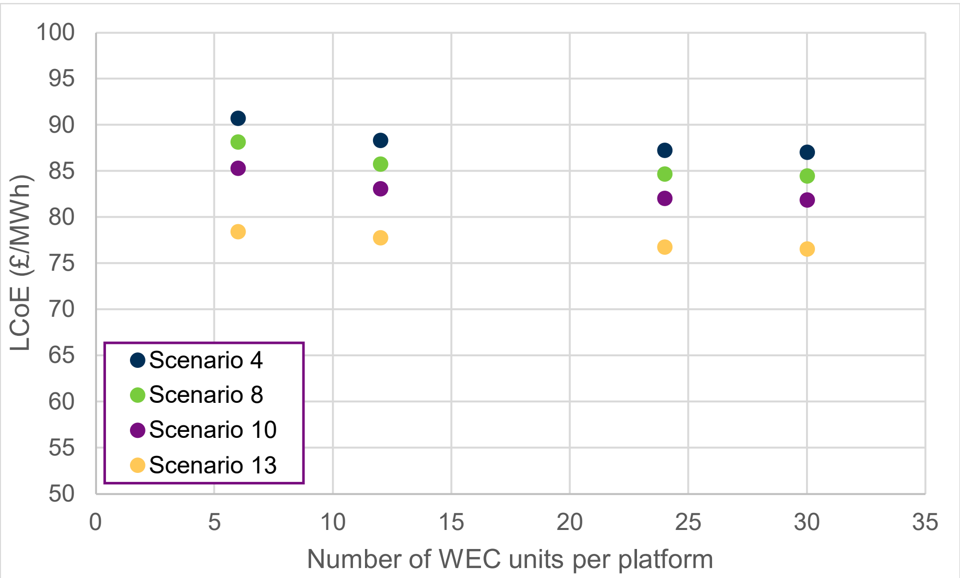


Figure 4-21 Reduction in LCoE with increased number of WEC units per platform, while holding WEC unit capacity and versatile structure weight constant.

To understand the implications in terms of practicality of incorporating a greater number of WEC units onto the same platform, a second set of sensitivity cases was included where the capacity of WEC units was scaled down in proportion with the increase in number of units, so that overall the same number of versatile platforms are required to achieve the same project capacity. However, to better match the likely reality, the power capture was improved as the unit size reduced to reflect that slightly smaller units than used in the original study may in fact be more optimal with respect to the wave dimensions. Net capture width ratio was increased from 35% to 37% for 12 units and 39% for 24 and 30 units.

The results are shown In Figure 4-22. A key element shown is the improvement in energy capture assumed which has resulted in a reduction compared to the original results across all cases. However, it can also be seen that the trend relating to the versatile platform cases has been altered in addition to this. While the versatile platform scenarios were higher than the adjacent scenarios originally, with 24 or 30 units modelled in this way, these cases are now showing a slight improvement compared to adjacent scenarios. Interestingly this was not seen when running 12 units in the sensitivity analysis where the original trend was still reflected.

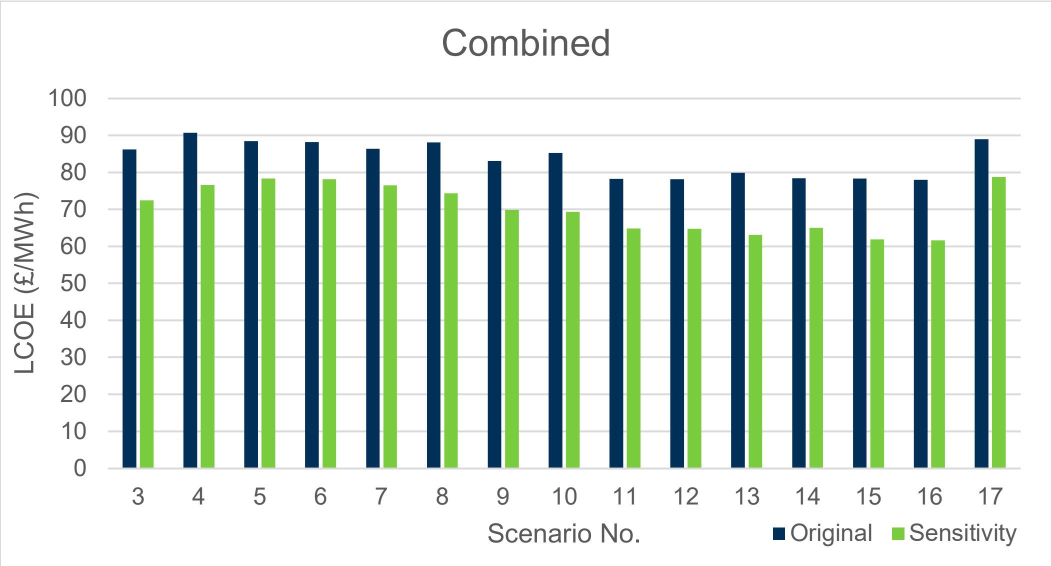


Figure 4-22 Sensitivity case with increased number of units but capacity of units and number kept in proportion to original assumptions. And hence also same number of versatile platforms. Improved yield estimate included to account for smaller devices potentially being more compatible with wave conditions. (Sensitivity case shown is for 24 WECs per platform)

The final aspect considered in this part of the sensitivity analysis was the versatile platform weight. Even with a 25% reduction on versatile platform weight applied, this resulted in only up to about 1% reduction in any of the 4, 8, 10 and 13 versatile platform scenarios. So, the results are actually relatively insensitive to this parameter. This provides greater flexibility in terms of the platform design, where some level of trade off in the platform weight, if this enables a greater number of units to be incorporated, may well result in an overall benefit.

4.7.9 Additional significant factors

Although the LCOE of WEC projects are noticeably higher than the floating wind project, the limited scalability of WEC projects provides opportunities.

The assessment revealed the following parameters are expected to largely influence the economics of the projects:

1. Sharing of transmission facilities (onshore substation and offshore transmission hub)
2. Lowering of discount rate. Estimated LCOE were grouped into 3 categories (shared offshore transmission hub, shared onshore substation and no electrical infrastructure shared).

The assessment revealed that the mutualisation of transmission facilities is expected to greatly benefit the economics of WEC projects. As such, scenarios relying on sharing of onshore and/or offshore transmission infrastructures offer lower LCOE than scenarios assuming split infrastructure.

The offshore wind industry's progressive reduction in LCOE was partially due to a reduction in procurement costs via economies of scale, industry learning as deployment numbers increased as well as innovation and optimisation aspects, but one of the strongest drivers is due to a reduction in financing costs as the perceived project risks reduced with the maturing of the industry. As such, a reduction of the discount rate would largely benefit the wave energy project. Shared infrastructure can reduce the overall project risk while allowing the first large scale WEC projects, thus participating in de-risking the technology and lowering the discount rate.

The following parameters are expected to contribute to a lesser extent:

- **Mutualisation of vessels during installation and operations:** the marine spread involved in the installation of floating wind farms presents higher specifications and therefore increased day-rates which leads to a reduction of the benefit of mutualising campaigns. As the generic projects are assumed to be located in Scotland, the reduced vessel mobilisation cost is also not significant. The impact would likely be more pronounced in secluded markets (i.e., Australia, etc).
- **Mutualisation of anchors:** WEC anchors are noticeably smaller than anchors considered in floating wind and as such, the benefit of mutualising anchors is limited. Mutualisation of anchors may lead to lengthy discussions with mooring designers to ensure the anchors are suitable to both systems
- **Mutualisation of array cables:** the length of IAC is generally limited for projects relying on an offshore substation. This conclusion may differ for projects connected to shore without an offshore substation.
- **Mutualisation of substructure:** The substructure cost in a WEC project is generally limited. The modifications required on a WTG floater to accommodate WEC system are, although hardly quantifiable, expected to be greater than standalone WEC substructures. The limited technological readiness of scenarios involving combined substructures is not reflected in this assessment.

Although the impact of each configuration on the annual energy production is expected to be relevant, further studies are required to quantify this impact.

4.8 Selection of Focus Scenarios

Based on the results of the LCOE modelling a shortlist of scenarios was selected to focus on for the wider benefits and feasibility assessments. Whilst all scenarios are considered where possible, given the number of scenarios for some aspects, particularly the Economic Impact Assessment and Feasibility, it was appropriate to narrow down the number of cases. The aim in the shortlist was to include those scenarios with the greatest cost reductions but also to include a range of sharing scenarios to better assess the differences between scenarios in terms of wider benefits and feasibility. These are selected based on understanding of the risks and implications in terms of feasibility and also taking into account the LCOE trends between scenarios to focus on the key or step change scenarios as the assets and activities become progressively more shared from left to right across the graphs.

This led to the following list of focus scenarios:

- 1 and 2 (and 17) as the base case scenarios
- 3, due to potential higher feasibility given no assets are shared
- 4 which represents the versatile platform scenario on separate WEC and WTG projects, and although does not look favourable from an LCOE perspective is interesting to explore in terms of wider benefits from the supply chain. This may in the longer term enable assumptions to be revised (such as optimising number and size of units per platform, see Section 4.7.8 for further discusstion) for this scenario resulting in improved LCOE results.
- 6, 7, as these cover the onshore and offshore transmission system sharing configurations
- 9, as a shared site but with separate strings and including the versatile platform design which may be of considerable benefit to WEC technology in the long run due to improvements in O&M and installation
- 10, as a shared site with WTG and individual WEC units on the same string with concerns over feasibility in terms of voltage compatibility
- 16 as the fully shared scenario

5 Wider Benefits

To complement the techno-economic modelling work, the potential wider benefits of each scenario are investigated here. This will begin with identification of the relevant stakeholders. An understanding of the wider benefits from the perspective of all stakeholders is important, as their buy-in is essential for successful implementation of sharing scenarios – particularly in the case of floating offshore wind stakeholders. This will be followed by assessments of the impact of wave-wind co-location on transmission, performance, project development, the local supply chain, and more. The aim is to identify any benefits of collocation that are not captured in the LCOE analysis. The wider benefits assessment followed the overarching approach provided in Figure 5-1 with the results feeding into the scenario ranking assessment which is presented in Section 8.

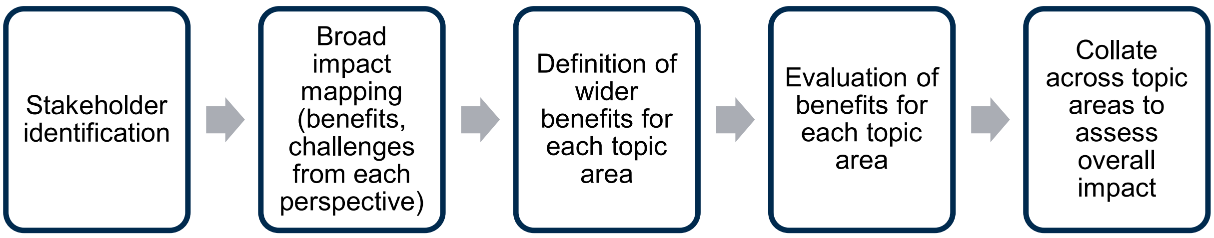


Figure 5-1 Overview of wider benefits assessment approach

The four key focus areas in terms of wider benefits investigation are detailed in Figure 5-2. This assessment aims to provide a qualitative discussion covering each of these topics.

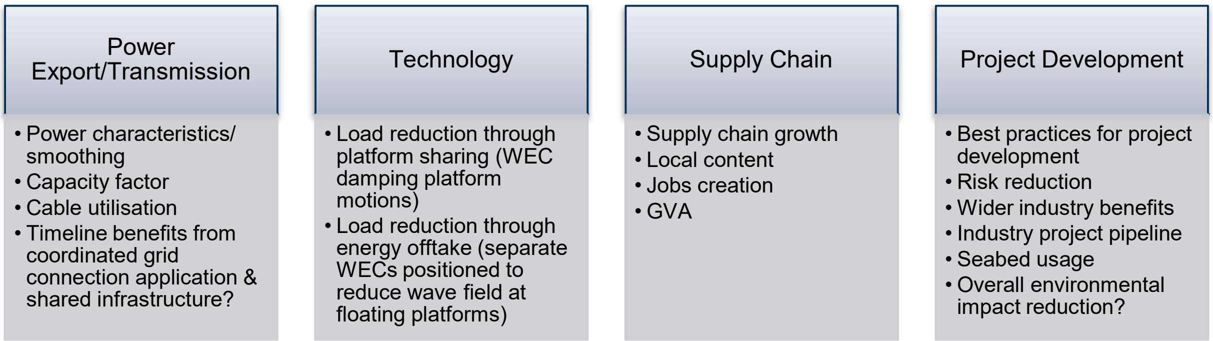


Figure 5-2 Specific topic areas considered in the wider benefits assessment

5.1 Stakeholder Identification

In order to understand the wider benefits to project stakeholders, it is first necessary to identify the relevant stakeholders and the reasons for their interest. Figure 5-3 gives a high-level overview of the various stakeholder groups that have been identified. More detail on the interests associated with each stakeholder group is provided in the following sections.

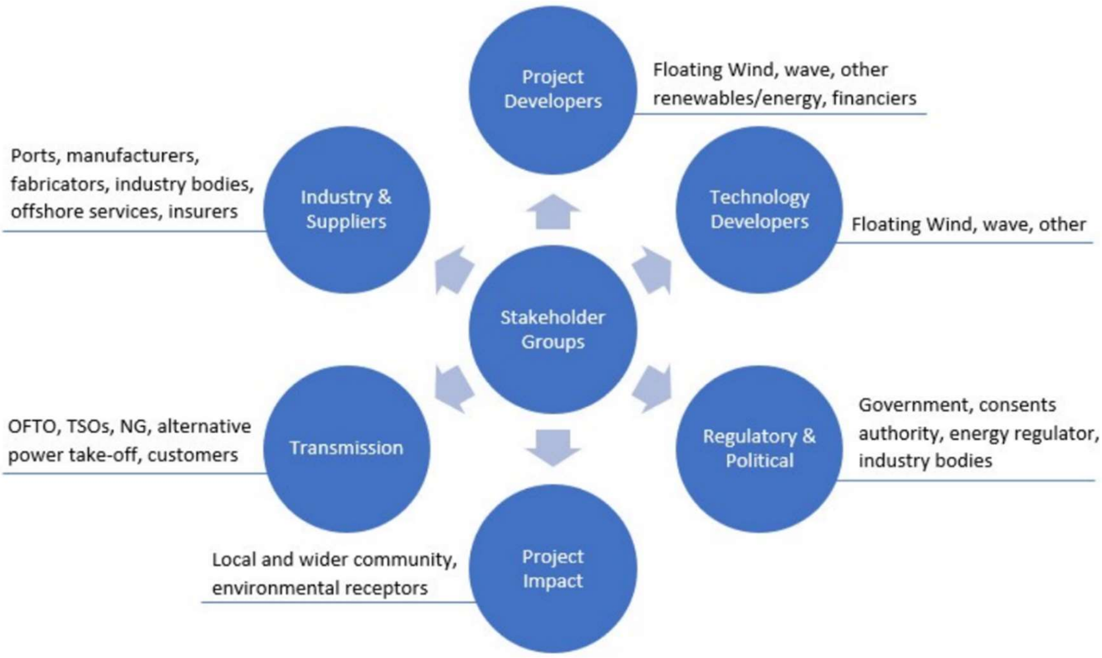


Figure 5-3: Stakeholder groups relevant for wave-wind collocation projects

Figure 5-4 shows a useful chart that can be used to categorise the importance of stakeholder groups and identify the best approach to stakeholder management for each group. The following sections will cover these trade-offs of power and interest for the different stakeholders presented.

Figure 5-4: Stakeholder power-interest map [14]

5.1.1 Project Developers

Project developers (and investors) have both a high interest and high power in wave-wind collocation projects. This is because they will be the owners and operators of the project and so they have the most to gain from successful cost reductions and increased revenue. The interest of the wave developers is driven by the possibility to use shared assets and activities to improve the competitiveness of wave technology. On the other hand, the buy-in of floating wind developers is particularly important, as projects cannot go ahead if they are not on board. As a result, floating wind developers should be involved in the decision making and engaged with regularly to ensure they understand the benefits available to them as a result of the sharing scenarios.

The potential benefits that link to the developers' interest in the project include:

- DEVEX, CAPEX and OPEX reductions, included in the LCOE section
- Load reduction on WTGs using strategic positioning of WECs
- Possibility of reduced consenting risk due to reduced footprint for platforms, cable routes, and substations where projects share assets
- Increased utilisation of electrical and BoP assets
- Increased utilisation of vessels and equipment for surveys, installation, and maintenance activities

Developers of other energy assets, aside from the direct wave-wind project developers, will also have interest in the project. Their own projects could be impacted for example through reduced competition for seabed leasing or grid connection, improvements to grid networks, opportunities for shared energy storage, and more. However, their power and interest will generally be low so they do not need to be engaged with as closely.

5.1.2 Technology Developers

Technology developers will have a high interest in wave-wind collocation projects as the chosen technologies will have a large impact on their operations. On the other hand, they have relatively low power over the project. As a result, they should be kept informed on the development of the project and the chosen technologies to ensure feasibility of fabrication, but they do not necessarily need to have direct involvement in decision making. However, strong engagement with technology developers from the outset could lead to a better understanding of the benefits and challenges of combined wind-wave projects, and the faster development of robust solutions to these.

The potential wider benefits that link to the developers' interest in the project include:

- Opportunity to develop in emerging markets of floating wind and wave
- Opportunity to develop new IP through new technologies (e.g. versatile/hybrid platforms)

5.1.3 Regulatory and Political Authorities

Regulatory and political authorities include groups such as government bodies, consenting authorities, energy regulators, and industry bodies. These groups will have a high interest and high power in wave-wind collocation projects as they will be responsible for major stages of the project development and have the power to give projects the required approvals. Government bodies are responsible for the allocation of subsidies for projects and so it is key that they understand the wider benefits of the project available to them as a result of the sharing scenarios, on a national and potentially international scale. Consenting bodies must be made aware of the environmental benefits of the project to ensure that consenting is not a bottleneck for the project.

The potential wider benefits that link to the interests of regulatory and political authorities include:

- Reduced seabed usage and environmental impact by asset sharing
- Development of UK supply chains
- Increased local job creation
- Development of new markets in UK
- Improved progress towards UK renewable energy targets

5.1.4 Land Owners

Land Owners, as Crown Estate Scotland, as the party responsible for seabed rights, are a key stakeholder with both high levels of influence and interest and it is important to engage with them to ensure there is a pathway to obtaining seabed option agreements/leases for projects with multiple generation technologies. Current leasing programmes have been separated by technology type (wave and tidal compared to offshore wind). Potential benefits to land owners are:

- Reduced space requirements both offshore and onshore through sharing of assets (cable corridors, substations etc.)
- Potential for improved revenues where seabed lease is based on energy production
- Alignment with CES goals in terms of contributing to renewables growth and establishing a new market for wave energy/combined projects

5.1.5 Community and Environmental Groups

Community and environmental groups include local councils, worker's unions, environmental activist groups, and more. These groups will have a high interest in wave-wind collocation projects but will have relatively low power over the project. As a result, they should be kept informed on the development of the project through regular communication, but they do not necessarily need to have direct involvement in decision making.

The potential wider benefits that link to the interests of community and environmental groups include:

- Increased local job creation
- Development of UK supply chains
- Reduced seabed usage and environmental impact by asset and logistics sharing
- Potential for community ownership

5.1.6 Transmission Operators

Organisations involved in transmission such as OFTOs, TSOs, and National Grid will have a high interest and high power in wave-wind collocation projects. They will be interested because the connection of the project to the grid will require their direct involvement and, in the case of OFTOs they will ultimately take on ownership of the assets. As a result, they should be involved in decision making and engaged with regularly to ensure they understand the benefits available to them as a result of the sharing scenarios. Existing regulations also need to be reviewed to ensure compatibility with shared generation methods.

The potential wider benefits that link to the interests of transmission operators include:

- Opportunities for power profile smoothing due to different temporal outputs of WECs and WTGs
- Reduced pressure on grid connection pipeline due to sharing of assets
- Increased utilisation of electrical and BoP assets

5.1.7 Industry and Suppliers

The industry and suppliers group includes ports, manufacturers, offshore services, insurers, and more. These groups will generally have a high interest in wave-wind collocation projects as they have the potential to have a large impact on their operations. However, they have relatively low power over the project. As a result, they should be kept informed, but they do not necessarily need to have direct involvement in decision making.

The potential wider benefits that link to the interests of industry and suppliers include:

- Opportunity to develop in emerging markets of floating wind and wave
- Increased local job creation for ports and manufacturers
- Improved modularity of design (e.g. with versatile platforms), resulting in opportunities for economies of scale
- Supply chain consolidation and growth

5.1.8 Next Steps Discussion

Having identified the relevant stakeholders, their influence, and their level of interest, the next steps are to create a stakeholder register and a stakeholder engagement plan. A stakeholder register is a document that holds the details on all of the relevant stakeholders including level of interest, level of influence, contact details of representatives, and reasons for interest. A stakeholder engagement plan identifies the strategies and actions that will be used to effectively engage each stakeholder or stakeholder group. Depending on their level of influence and interest, different stakeholders will require different levels of engagement and different methods of communication, as summarised in Figure 5-4. These documents should be regularly reviewed and revised as new stakeholders may be introduced at later project stages, or the level of interest of a stakeholder may change.

Stakeholders with high levels of influence should be engaged with early and often as it is important to involve them in the decision-making process from the very beginning. For example, one of the priorities is that floating wind developers need to be consulted regarding what the most feasible and beneficial sharing scenarios are from their perspective to ensure they are on board for collocation. Due to the relatively low maturity of wave technology (compared to commercial offshore wind), the first step before engaging the floating wind developers, would be to ensure that the specific wave technology concepts are suitable for co-location needs, taking into consideration any additional risks that the wave converters might bring to the project. Risk management would be a key parameter in these types of projects.

Stakeholders with less influence but a high level of interest include technology developers, community and environmental groups, and industry and suppliers. These stakeholders should be kept up to date with regular communication. Examples of this include RfIs (requests for information) to suppliers and developers, open forums, newsletters, website updates. These will allow stakeholders to provide their input and allow for early identification of any gaps in the supply chain. This will also reduce the risk of objections later down the line, or, in the worst case, litigation.

The most influential stakeholders are the project developers, regulatory and political authorities (including Crown Estate Scotland), and transmission operators (such as OFTOs, TSOs, National Grid). Engagement with these stakeholders should begin as early as possible by identifying representatives to speak to and setting up regular consultations. It is crucial that they understand the benefits available to them so that they can become advocates for wave-wind collocation projects. The project can only go ahead with them on board.

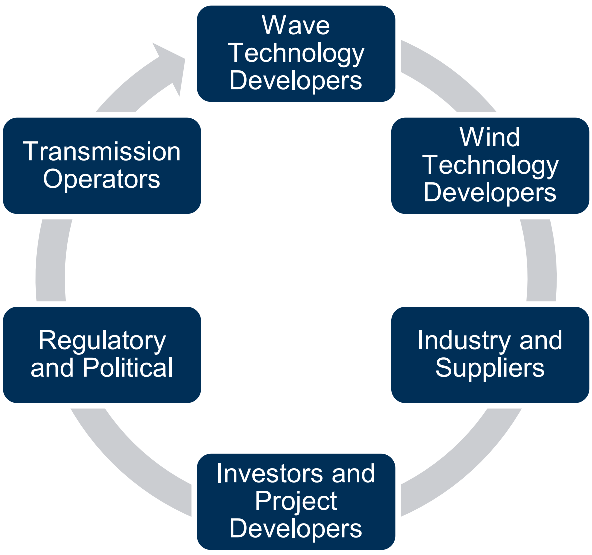


Figure 5-5: Iterative Process for next steps in stakeholder engagement

5.2 Power Export Characteristics and Transmission Impacts

5.2.1 Cable Sharing

Depending on the electrical parameter characteristics of the WECs used, there is an opportunity to use the same cables to have the WECs and WTGs collocated together on the same circuits, which would offer lower cabling costs through economies of scale and having a single set of cables. This arrangement, if deemed technically viable, requires the output voltage to be consistent. After potential optimisation, the WECs could utilise the same switchgear within the WTG to further reduce costs via piggy-backing the cables onto the WTG inter array cables switchgear compartment. Cognisance would have to be given in the O&M scenarios should one of the devices be out on outage (either pre-planned or due to an incipient fault) and should also be discussed with OEMs in terms of activities and routine maintenance periods. Using cables with the same CSA (cross-sectional area) for the WTGs and WECs also offers savings in term of the T&I as the cable lay vessel (CLV) would require less load out and the CLV carousels available are fully utilised to their optimal installation strategy.

5.2.2 Load Variance

Having the WECs and WTGs on the same circuits also improves utilisation of the IACs, as usually OWF cabling is rated for full steady state load for that section of the array downstream. However, the variance in wind & wave conditions and potentially units out on outage mean that the cable rarely sees the full ampacity headroom be utilised throughout the wind farm's lifetime. Therefore, there could be feasibility of the WECs (dependent on device nominal rating) utilising the spare headroom within the cable that would be being procured for the WTGs regardless, without the cable being adversely affected by needing to increase the cross-sectional area. This would, however, cause the cable to be more heavily loaded, increasing the temperature and current of the conductors, thus increasing electrical losses and reducing revenue. The increased losses and the previously highlighted O&M factors would have to be considered against any benefit of having them on the same array i.e. switchgear and cable savings.

5.2.3 Revenue Streams

There is potential for additional revenue streams from the WEC and/or the WTGs to provide reactive power (VAr) across the Offshore Grid Entry Point (OFFGEP) should the reactive capability of the devices allow. To assess the feasibility of this, P/Q capability curves of the WTGs and WECs would be required (if available). Electrical system studies would then be conducted to determine whether this service can be provided to the TSO and be reimbursed. Another option which has been employed in other offshore projects is to utilise WTGs for this purpose. This mitigates the need for offshore shunt reactors and therefore eradicates the CAPEX expenditure for the shunt reactors themselves (typically 1 per export circuit) and also creates CAPEX savings on primary steel due to the reduction in footprint of the offshore substation topside weight. Depending on the MVAr rating of the shunt reactors which are defined by the system studies, the CAPEX alone of the plant itself and not including associated OSS/FOU savings could be in order of ~£2.5-£3.5M each.

There are other avenues that could be evaluated in regard to the potential range of ancillary revenues and the balancing market exposure for supported Offshore Wave/Wind assets. This modelling uses different background scenarios i.e. NGESOs Future Energy Scenarios 2021 to assess against potential energy mix and against government climate targets. The level of wind curtailment is an important factor when considering wind's opportunities from ancillary services, as these are the periods where it is likely to be most competitive. It is also important to understand the revenues lost to curtailment in each of the scenarios – as the projections for ancillary revenues are (in some cases) a mitigation of these, rather than an additional revenue. The level of curtailment will vary for different cohorts of wind plant, based on their level of support and the rules for receiving that support.

Three new frequency response services are being brought forward where, depending on the service, payments (£/MW/h) could be seen due to availability for either dynamic containment, dynamic moderation or dynamic regulation. Likewise, National Grid is looking at wind to provide system stability services through its Stability Pathfinders work utilising newly developed virtual synchronous machines (grid forming). These will provide inertia due to penetration of renewable energy systems and mothballing of conventional generation utilizing synchronous machines such as coal and nuclear plants. Thus, wind farms can provide inertia to the grid and receive appropriate payments through long-term contracts. As highlighted previously, reactive power can also be an opportunity for consideration as periods of low or high active power flow occur where there could be significant potential for growth on a local geographical scale. This is dependent on development of the local network used for connection and any reactors the TSO might be planning to reinforce the network with as this would mitigate the need for support from distributed generation.

5.2.4 Electrical Benefits Summary

In summary, there are numerous benefits of having shared infrastructure as listed below. The level of synergy realised is dependent on whether the WECs and WTGs are independent or combined arrays since OFTO infrastructure accounts for approximately one third of overall project costs.

- Improved utilisation of IACs.
- Opportunities for revenue through provision of ancillary grid services.
- Easier divestment of the OFTO components as only 1 OFTO. Having two sets of infrastructure is both construction cost and resource intensive further down the line in providing justification to OFGEM and OFTO bidding parties. Typically, the OFTO divestment process is a 4-year process and is expected to increase due to the number of renewable projects in the UK pipeline.
- Fewer external stakeholders such as landowners, local community, utility crossings to deal with due to the reduced impact of having narrower export cable corridor (i.e. reduction of cable joint bays along the onshore export corridor) and also the single onshore substation therefore reducing visual impact, noise emissions and land acquisition costs.
- Reduced construction timelines associated with shared OSS/OFCA/ONCA/OnSS.
- Half of the interface requirement with NGESO/TO to progress through the grid connection offer process to establish a suitable point of connection onshore to integrate into the National Grid network either through existing substation or green-field site and determine the suitable agreement type. This is dependent on current capacity bottlenecks or proposed reinforcement works plans in the immediate area of the landfall and OnSS. The pre-determined time saving of having one connection would be at least 6 months as there are 3 months adjoining periods on NGESO and client side in providing and reviewing connection offer. But in reality, the time saving to programming would be more due to pre-application and application submission stages.

- Mitigation of issues such as: export corridor having mutual heating effects on other if there were two sets of OFTO export assets; or the cumulative effects of noise of two substations on any local sensitive noise receptors.
- For the same weather system, the wave climate peaks typically trail the wind peaks and lead to a smoothed power output. As a consequence, a combined exploitation will result in a reduction of sudden disconnections from the electric grid, an increase in availability (thus reducing the number of periods of non-activity) and a more accurate output forecast. However, wind and waves roses for significant wave heights and wind speed would be needed to further quantify energy yield and combined AEP. These comprehensive datasets form the basis for any site-specific wave-wind correlation, characterizing the existing climate conditions and providing the necessary probabilistic information required.

5.3 Technology and Performance Impacts

The wave technologies concepts are numerous and there can be different performance drivers depending on the main properties, configuration and mooring systems. For example, point absorbers (the assumed device type in this study) as well as flaps, either in heave, pitch or more dimensions need an inertial reference to react against. The inertial reference can be provided in three ways:

- Through taut moorings to the seabed (e.g. CETO, CorPower, while AWS use a positively buoyant body and taut moored foundation unit).
- By being directly linked to fixed foundations in a nearshore environment (e.g. Wavestar buoys, Oyster type device)
- By a secondary body which is engineered to be stable in most conditions (e.g. Wavebob type devices use a large, ballasted body, OPT and RM3 devices are based on heave plates, Langlee and others).

From a performance point of view, the first two solutions are technically more efficient as they provide a stable base to react against even in longer waves, however as the depth and loads on devices increases, the solution can prove to be very costly. The last group can benefit from a slack mooring of the stable body, which opens up a wider range of locations.

5.3.1 WEC and WTGs sharing platform

For hybrid concepts, WEC point absorbers and flaps can benefit from the large stable platform provided by a floating wind turbine foundation. The performance of the WECs with a secondary stable body would potentially increase due to the increased stability of the reference, and the other WECs would benefit from better economics as expensive foundations and moorings are removed, and access to more potential locations, since it is now possible to leave the nearshore and intermediate depth (30 to 70m depth) zones.

In both cases, there is a potential negative impact on the platform stability itself and structural engineering as the overall wave induced loads are likely to increase. The opportunity to place more than one WEC on the platform comes with the risk of negative interactions between the WECs. On the other hand, as wave and wind resource are not entirely correlated, there is a potential to limit the variability of the power produced by the platform. A summary of the main advantages and disadvantages is provided in Table 5-1.

Advantages	Disadvantages
- Increased stability of the platform over larger periods allows for an increase in absolute performance of WECs. - Reduction of structural cost of secondary body and/or moorings - Access to new potential location for nearshore or depth limited concepts - Potentially smoother power output from the combined wave-wind operations as wind and wave resources are not always temporally correlated.	- Risk of negative interaction between WECs if spaced closed together - Risk of negative impact on the FOWT platform stability as overall wave induced loads are increased if solution not thought through. - Risk of negative impact on structural requirement of FOWT platform. - Negative impact on development complexity of FOWT platform

Table 5-1: Advantages and disadvantages of using a FOWT platform as a stable inertial reference for a WEC to react against

For hybrid platforms, i.e. platforms combining wind and wave energy production units, it is potentially possible to use the WEC units to actually stabilise the platform, and therefore reduce the acceleration and motion of the nacelle of the WTG. This could allow an increase of the WTG production, and reduce the tower loads and therefore the cost of the WTG.

Several studies have been conducted on the topic [9], [10], [11], [12], [13]. These studies have considered different arrangements of floaters and WEC types. Several of these studies [9], [11], [12] consider Oscillating Water Column WECs added to the floaters (a barge type floater, spar type floater and a semisubmersible type floater respectively). One study [10] considers a hypothetical WEC added to the FOWT with a mathematical representation of the system as an additional degree of freedom of the system (this could possibly be a point absorber in heave linked to the platform). In most cases, these studies show that a significant reduction in the FOWT motions (principally the pitch and roll) can be achieved. However, this requires an optimisation of the WECs characteristics taking into account this objective, and not solely the maximisation of the WEC power production or its economic performance. In particular, this study [10] mentions that to achieve maximum motion reduction, the WEC response should be shifted to a lower frequency than the FOWT natural frequency. This shift should not be too large, however, as interaction between the bodies is required.

The remaining study [11] presents what might be the most complete attempt to design a wind-wave combined system which works well for both energy production systems. It uses a hinged mechanical layout which intends to decouple the heave motion of the WECs from the FOWT, but keep it coupled with the pitch and roll motion of the spar floater. In doing so, a 9% increase in power production is obtained for the combined system compared to the FOWT alone, as well as a significant reduction of the stress at tower base (23%). This is comparable to the reduction in pitch motion demonstrated experimentally when the active control of the oscillating water columns is implemented [12].

One WTG manufacturer is currently devising a system which could increase AEP and mitigate maintenance after standstill, whilst also realising the benefits of aerodynamic damping for floating WTGs to reduce fatigue loads (FLS). However, ultimate loads (ULS) are often the design driving loads for which floating structures are dimensioned. So whether increased periods of time with aerodynamic damping will provide a quantifiable benefit or not is something that must be assessed on a case-by-case basis. The TRL of this technical solution should be monitored going forward.

Overall, it appears unlikely that a WEC developed independently to perform as a standalone device could be directly added to a platform in a plug and play fashion. As a minimum, a reconsideration of the WEC control to take into account the FOWT characteristics will be required to achieve active damping of the FOWT motions and yield a benefit in terms of WTG tower stress and production.

5.3.2 WEC and WTGs sharing site (not on same platform)

Several studies have considered what could be the beneficial impact of locating WECs in the surrounding area of a wind farm. The impact would potentially be seen in the design conditions considered for the FOWT design, potentially leading to lower costs, but it is mainly anticipated that the wind farm accessibility for O&M will be improved. The weather window would be increased for operations by increasing the number and length of occasions in which the significant wave height is below the required thresholds.

The authors of two such studies [5], [6] investigated the potential of different co-located layouts using a wave propagation model based on SWAN (Simulating Waves Nearshore) to model the impact of the WECs on the wave field at the potential wind farm location. The WEC considered is WaveCat, a rather large overtopping device which would act as a terminator. This WEC selection for the case study would emphasize the potential impact of WECs on the wave field, and it cannot be expected that all types of WECs will induce the same effect. The main benefit lies in the increased accessibility of the turbine. Potential improvements of ~15% are reported, but this is only valid for the case study considered. Nonetheless, the possibility to quantify the potential benefits through the use of a wave propagation model is demonstrated, and a feasibility study with different configurations and layout could be commissioned to explore the benefits for future FOWT farm deployment.

5.4 Local Content and Supply Chain

OWC performed a qualitative assessment of the current capability and capacity of the Scottish supply chain to deliver floating offshore wind projects in ScotWind while accounting for the supply chain requirements afforded by WEC projects.

5.4.1 Supply Chain Assessment Methodology

To access the capability of the Scottish supply chain, OWC followed a combined qualitative and quantitative approach. Previously conducted studies of the Scottish supply chain were reviewed to identify areas of strength. To assess the capability of each area of the Scottish supply chain, OWC compiled a non-exhaustive list of companies that either have supported or have expressed their interest in helping offshore wind activities, including floating wind.

Each company and provided service/component has been assessed based on the company's track record and the transferability of each service. The track record criterion (see Table 5-2) is used to differentiate companies that have already supported the offshore wind sector, fixed-bottom and floating, from companies transitioning into the industry. Existing offshore wind suppliers have been differentiated based on their experience into those that have supported just a few projects – small-scale experience – and those that have supported multiple projects – large-scale experience.

Criteria	Score	Description
Track	0	No experience

Criteria	Score	Description
record	1	Experience supplying other renewable sectors
	2	Experience supplying onshore wind farms
	3	Experience supplying other maritime sectors
	3	Experience supplying other parallel offshore sectors such as oil and gas
	4	Experience supplying offshore wind farms, but the supplier has yet to support multiple offshore wind farms
	5	Experience supplying multiple offshore wind farms (large-scale experience)
	5	Experience supplying floating wind farms

Table 5-2: Company track record ranking system

Each component/service has been assessed based on its transferability from other sectors to the floating wind sector. The transferability criterion represents the ease of transferring a service or activity from one industry sector to another, using a N/A, Low, High and Medium ranking as depicted in Table 5-3.

Criteria	Score	Description
Service/ Component transferability	1	Not Applicable – The service/component cannot be transferred to the floating wind sector.
	2	Low – The service/component will require significant resources to be transferred to serve the floating wind sector.
	3	Medium – The service/component can be transferred to serve the floating wind sector but some modification or experience is required.
	4	High – The service/component is easily transferable from other industry sectors to serve floating wind projects.

Table 5-3: Service/component transferability ranking system

The results of each package and service / component are indicated below. Each package and service / component are assessed based on current and potential capability: Low, Medium, or High. Components with no known current or future suppliers or capabilities are described as Not Applicable (N/A). *Note: The Not Applicable (N/A) in this case represents the case where a supplier was not identified for the respective service / component.*

5.4.2 Supply Chain Capabilities

The current capability of the Scottish supply chain to provide the services and components required for wave-wind collocation projects is summarised in Table 5-4. A detailed analysis of each sector is given in the following sections.

Sector	Capability
Professional services	The Scottish supply chain can provide almost all Professional Service activities and services at a Tier-1 level as major offshore wind service providers have established entities in the region.
WTG components	There are few components that can be provided by the local Scottish supply chain. No established Tier-1 suppliers. Plans for future development e.g. tower factory at Port of Nigg.
Balance of plant components	The existing Scottish supply chain is constrained regarding the support of manufacturing activities linked to balance of plant. Limited capabilities across all identified Tier-1 and Tier-2 categories.
WEC components	The existing Scottish supply chain is constrained regarding the support of manufacturing activities linked to WEC components. Limited capabilities across all identified Tier-1 and Tier-2 categories.
Mooring and anchoring components	The Scottish supply chain can support the mooring and anchoring systems necessary for floating offshore wind projects due to the presence of some Tier-1 and Tier-2 suppliers in Scotland.
Installation and commissioning	The supply chain provides some Tier-1 services and products that support construction, installation, and logistics activities for foundations, offshore substations, and offshore cables.
Operations and maintenance	The Scottish supply chain has the ability to provide various O&M services. Identified companies can provide various Tier-1 operation and maintenance support e.g. CTVs, SOVs and O&M bases.

Table 5-4: Summary of Scottish supply chain capability

5.4.2.1 Professional Service

The professional service component work package includes pre-development activities and services required for the development of an offshore wind project, as described below in Table 5-5.

Categories	Component Name	Capability
Project Management	Project assistance	Medium
	Communications	N/A
	Legal and regulatory advisors	Medium
	Procurement support	Low
	Financial services	Medium
	Quality inspections	N/A
	Transportation / installation package management	Low
	Insurance providers	Low
Environmental Studies	Environmental main consultant	Medium
	Benthic Surveys	Low
	Fish & Shellfish surveys	Medium

Categories	Component Name	Capability
	Ornithological surveys	Medium
	Marine mammal surveys	Medium
	Human impact studies	Medium
	Environmental impact assessments	Medium
	Onshore Environmental Study	Medium
Site Investigations	Geophysical and geotechnical consulting	Medium
	Geotechnical and geophysical (G&G) campaign	Medium
	Offshore and Onshore laboratory testing (chemical solution)	Medium
	Hydrological survey	Low
	Metocean and resource measurements	Medium
	UXO survey	High
	Preliminary Technical studies (e.g. project conceptual, local supply chain and ports infrastructure)	Medium
	Navigational risk studies	Medium
Engineering	Civil engineering advisory	Medium
	Electrical engineering services	Low
	Subsea services	High
	FEED/Feasibility studies	High
	Design engineering- substructures	Medium
	Port redevelopment	Low

Table 5-5: Professional Services Breakdown

The analysis highlights that the Scottish supply chain can provide almost all Professional Service activities and services at a tier-1 level as major offshore wind service providers have established entities in the region. Due to Scotland's historic Oil and Gas activity, a number of companies can provide services linked to environmental studies and site investigations. In addition, major engineering firms have set up offices in key locations (Arup, Ramboll, Global Maritime etc.) supporting offshore activities; O&G and offshore wind.

5.4.2.2 Wind Turbine Generator

The wind turbine generator (WTG) package is the key component of any offshore wind generation project. The increasing offshore wind market size has contributed to the consolidation of the European and American offshore wind WTG Original Equipment Manufacturers (OEMs) – Vestas, Siemens Gamesa Renewable Energy (SGRE) and General

Electric (GE) – dominating the WTG market. However, in China, there is a handful of key WTG OEMs, with Ming Yang Smart Energy (MYSE) and GoldWind having dominated the local market. It is worth mentioning that both companies have started marketing their products in the EMEA region. Specifically, MYSE has secured several deals to supply components for several European demonstration projects.

Tier 1		**Tier 2**	
Component name	Capability	Component name	Capability
Nacelle	N/A	Gearbox	N/A
		Nacelle cover	N/A
		Bearings	N/A
		Control System	N/A
		Other equipment	N/A
Blades	N/A	Coating and corrosion protection	N/A
		Rotor auxiliary systems	Low
		Blade bearings	Low
Tower	N/A	Coating and corrosion protection	N/A
		Tower parts	N/A
		Flanges	Low

Table 5-6: Wind Turbine Generator Breakdown

The analysis indicates that there are a few components that can be provided by the local Scottish supply chain. A key component with future capability is the tower parts as Global Energy Group (GEG) plans to establish a new tower manufacturing facility at the Port of Nigg. The financial decision on the tower manufacturing facility has yet to be finalized at the time of writing. GEG has provided secondary steel and anchors to offshore wind projects but has yet to provide tower sections to any offshore wind project.

Regarding the supply of blades and nacelles, there are no established Tier-1 suppliers for these components. However, a potential supplier of blades is ACT Blade, established in 2015. ACT Blade has designed a light blade that can be used at any offshore wind project reducing the project’s LCOE. However, the company has yet to establish a manufacturing facility and has not yet signed a contract to provide its product to offshore wind projects. Considering the nacelle, there are a few Scottish suppliers that provide bearings and other components to onshore wind turbines, this service is transferable to the offshore wind market, but significant infrastructure investments will be required.

5.4.2.3 Balance of Plant

The balance of plant package includes components and equipment required for all physical infrastructure required to moor the floater to the seabed as well as connect the unit to the grid infrastructure. However, for the purpose of this study, the mooring system has been studied as an individual package given Scotland's long-lasting oil and gas history. This package also includes the offshore substation. The representation of this package can be seen in Table 5-7.

Tier-1		Tier-2	
Component Name	**Capability**	**Component Name**	**Capability**
Semi-submersible platform (steel)	N/A	Buoyant hull	Low
		Truss frame	Low
		Horizontal plate/heave plate	Low
		I-tube/J-tube	Low
		Ballast system	N/A
		Davit cranes	Low
		Misc. tertiary structures	Low
Dynamic Export Cables	N/A	Buoyancy modules	Low
		Bend stiffeners	Low
Static Export Cables	Low	Connector set & Copper wire rod	N/A
		Cable protection accessories	Medium
Dynamic Inter-Array Cables	Low	Buoyancy modules	Low
		Bend stiffeners	Low
		Connectors	N/A
		Cable protection accessories	Low
Offshore Sub Station	N/A	Electrical systems	Low
		Steel Structure	Low
		HVDC transmission system	N/A
		Facilities and subsystems	N/A

Table 5-7: Balance of Plant Breakdown

The analysis concludes that the existing Scottish supply chain is constrained regarding the support of manufacturing activities linked to the balance of plant. In addition, the existing supply chain has limited capabilities across all identified Tier-1 and Tier-2 categories. However, there is some capability regarding the subsea cables required for floating wind projects. Hydro group has supplied the inter array cables for the Hywind Scotland project. This area of the Scottish supply chain could be a future opportunity as Oceaneering could position themselves as dynamic inter array suppliers for future FOW projects.

The existing supply chain has also some Tier-2 suppliers that can provide buoyancy modules and other accessories required for the installation and commissioning of the cabling and the floating structure. These services can be supported by the existing supply chain primarily due to Scotland's oil and gas heritage. Although there are no Tier-1 suppliers that can procure the floating wind structure, there are suppliers that can provide structural components such as a buoyant hull, truss frame, heave plate and I-tube/J-tubes. Providing a holistic manufacturing package could be a potential capability of the Scottish supply chain. The owner of the port of Ardesier has expressed its interest in establishing a steel manufacturing facility to support the manufacturing of concrete foundations as part of the port's master plan. In a similar fashion, other port owners could establish steel facilities with the view of manufacturing local steel floaters.

5.4.2.4 WECs

Package Sub-category	**Tier-1**		**Tier-2**	
	Component Name	Current Capability	Component Name	Current Capability
Floating hull	Buoyant hull (multiple)	N/A	Steel plates	Low
			Stiffeners, girding, etc.	Low
			Other structural materials (FRP, composite, others)	N/A
			Fixed ballast (concrete, other)	N/A
	PTO equipment	N/A	Mooring drums	N/A
			Seals	N/A
			Bearings and guide	N/A
	Mechanical to electric PTO option	N/A Low	Rotary hydraulic pump	Low
			High pressure hydraulic equipment (valve, pipping, manifolds, other)	Low
			High pressure hydraulic accumulators	Low
			High pressure hydraulic motor	Low
			Generators	N/A
			Frequency converter	N/A

Package Sub-category	Tier-1		Tier-2	
	Component Name	Current Capability	Component Name	Current Capability
			Step-up transformers	N/A
			Control systems	N/A
	SCADA systems	Low	high level controller	N/A
			DAQ system	N/A
			Sensors (loads, temperature, PTO specific equipment, motion sensors, external pressure sensors)	N/A
			Comm (connect to fibre optics from umbilical cable)	N/A
	I-tube	Low		
	Ballast system	N/A	Pumps	N/A
			Pipping, reservoir	N/A
	Deck equipment	Low	Hatch	N/A
			Ladders, crew access structure, others	N/A

Table 5-8: WEC breakdown

Package Sub-category	Tier-1		Tier-2	
	Component Name	Current Capability	Component Name	Current Capability
Submersible hull, disc shape (steel)	Buoyant hull	N/A	Steel plates	Low
			Stiffeners, girding, etc.	Low
			Other structural materials (FRP, composite, others)	N/A
			Fixed ballast (concrete, other)	N/A
	Joints	N/A	Structural mechanical elements (steel)	N/A
			Large bearings, linear guides	N/A

Package Sub-category	Tier-1		Tier-2	
	Component Name	Current Capability	Component Name	Current Capability
			Large seals, membranes, shock absorbers	N/A
	PTO equipment	N/A	Mooring drums	N/A
			Seals	N/A
			Bearings and guide	N/A
			Direct drive generators	N/A
			Linear to rotary mechanical assembly	N/A
	SCADA systems	Low	High level controller	N/A
			DAQ system	N/A
			Sensors (loads, temperature, PTO specific equipment, motion sensors, external pressure sensors)	N/A
			Comm (connect to fibre optics from umbilical cable)	N/A
	I-tube	Low		
	Ballast system	N/A	Pumps	N/A
			Pipping, reservoir	N/A
	Deck equipment	Low	Hatch	N/A
			Ladders, crew access structure, others	N/A

Table 5-9: WEC Option 2 - Multi-body WECs (such as Mocean)

5.4.2.5 *Mooring and Anchoring System (M&A System)*

The mooring and anchoring system package includes the components required to secure the floater to the seabed. This package consists of the mooring line which is made of a selection of materials (steel chain, wire ropes, fibre and synthetic ropes) and the anchors. Commonly used anchors are the drag-embedded and suction-bucket anchors. However, there are other types of anchors, such as driven piled anchors, that can be used for more challenging seabed environments. The representation of this package can be seen in Table 5-10.

Tier-1		Tier-2	
Component Name	**Capability**	**Component Name**	**Capability**
Mooring line	Medium	Chain	N/A
		Wire rope	Medium
		Synthetic fibre rope (elastic)	Low
		Synthetic fibre rope (non-elastic)	Low
Subsea Mooring Connectors	N/A	Shackles	N/A
		Connecting link	N/A
		Triplates	N/A
		Swivels	N/A
		Clump weights	Low
		Mid-line buoyancy elements	Low
Anchoring System	Medium	Drag embedment	Medium
		Suction bucket	Low

Table 5-10: Mooring and Anchoring Breakdown

The Scottish supply chain can support the mooring and anchoring systems necessary for floating offshore wind projects due to the presence of Tier-1 and Tier-2 suppliers in Scotland. The supply chain can provide offshore wind farms with Tier-1 components such as the mooring line and anchors. Notably, Isleburn (now Global Energy Group) has supplied the suction bucket anchors for the Hywind Scotland project.

Companies in Scotland also manufacture mooring line Tier-2 subcomponents such as rope and Tier-2 accessories such as clump weights and mid-line buoyancy elements. Bridon-Bekaert has already established a partnership with BW Ideol with the aim to further develop its synthetic line design.

5.4.2.6 Installation and Commissioning (I&C)

The installation and commissioning package consists of all the vessels and equipment required for the assembly, launch, WTG integration, tow-to-site and commissioning of the floater, including the installation of the cabling (array and export), offshore substation and mooring system. The representation of this package can be seen at Table 5-11.

Package Sub-category	**Tier-1**		**Tier-2**	
	Component Name	Current Capability	Component Name	Current Capability
Offshore foundation installation	Heavy lift vessel	Low	Foundation installation equipment	Low
			Shackles	N/A
	Anchor handling tug vessel	Medium		
Offshore Substation Installation	Offshore crane vessel	Low	Crane	N/A
			Auxiliary cranes	N/A
			Gangway	N/A
Offshore Cable Installation	Cable-laying vessel	Medium	ROV	High
			Cable-handling equipment	N/A
			Crane	N/A
	Cable burial	Low	Cable burial vessel	N/A
			Cable plough	Low
			Trenching ROV	Low
			Vertical injector	N/A
	Cable pull-in	Low	Barge	Medium
			ROV	High
			Messenger wire	N/A
			I-tube/J-tubes	N/A
			Winches	N/A
			Quadrant	N/A
			Floats	N/A
	Electrical termination and testing	Low	Cable fault risk assessment	Low
Port Construction	Port Services	Low	Quayside upgrades	Low
			Channel dredging	N/A

Package Sub-category	Tier-1 Component Name	Tier-1 Current Capability	Tier-2 Component Name	Tier-2 Current Capability
			Lay-down area development /expansion	Low
			Cranes	Low
			Personnel Facilities	Low
General Offshore Installation Services	Installation support	Low	Service operating vessel (SOV)	Low
			Barge	Medium
			Supply vessel	Low
			ROV	High
	Marine coordination	N/A	Marine management system software	N/A
			Marine coordination centre	N/A
	Weather forecasting and metocean data	N/A, Low	Weather forecast report	N/A
			Wave buoy	N/A
			Current meter	N/A
			Lidar	Low
			Anemometer	Low

Table 5-11: Installation and Commissioning Breakdown

The analysis of the Scottish supply chain reveals Scotland's installation and commissioning capabilities. The supply chain provides both services and products that support offshore foundation installation, offshore substation installation, offshore cable installation, port construction and offshore logistics. The Scottish supply chain provides some tier-1 foundation services, by supplying heavy-lift vessels and anchor-handling vessels while it also supports Tier-1 offshore substation services with the supply of offshore crane vessels. Offshore cable installation is also supported by companies in Scotland providing Tier-1 components: cable laying vessels, cable burial services, and cable pull-in services.

The supply chain supports Tier-2 installation equipment. Tier-1 port construction services and Tier-2 subcomponents that support these services are also provided by companies in Scotland with experience in offshore construction and O&G development. Many of these companies offer sea-based support services and Tier-2 components, barges, and remotely operated vessels (ROVs), that enable these services.

5.4.2.7 Operations and Maintenance (O&M)

The operations and maintenance package includes services required once the wind farm is commissioned. This supply chain package includes different types of vessels required for the crew and equipment to be transferred to the project site. A representation of this package can be found in Table 5-12.

Operations and Maintenance		Capability
Offshore Logistics	Crew transfer vessel (CTV)	Low
	Service operation vessels (SOV)	Low
Maintenance services	Ports and harbour base operations	High
	Substation maintenance and service	Low
	Turbine maintenance and service	High
	Structural integrity management	Medium
	ROV	High
	Cable inspection and repair	High

Table 5-12: Operations and Maintenance Breakdown

The analysis highlights that the Scottish supply chain has the ability to provide various O&M services. Identified companies can provide various Tier-1 operation and maintenance support, supplying crew transfer vessels and software to monitor structural integrity and components' performance. It should be noted that the Scottish supply chain has vast experience due to the region's O&G history. North Star is an example of a Scottish vessel provider who decided to enter the OW market awarding shipbuilding contracts for four (4) SOVs. North Star has already secured a long-term contract for its first SOV with Equinor. The contracted SOV will support the construction phase of the Dogger Bank A/B/C projects.

5.4.3 Supply Chain Translation to WEC Projects

OWC has compiled a list of WEC project requirements that work in coordination with floating wind technology. Here is a comprehensive breakdown of the components:

Industry Group	Technical Concept: FOW	Technical Concept: WEC	% Local Supply Chain
Iron & Steel	• Floater Steel • Secondary Steel • Steel for Tower	• Floater Steel • Secondary Steel	28%

Industry Group	Technical Concept: FOW	Technical Concept: WEC	% Local Supply Chain
Other metals	• Anchor Steel	• Anchor Steel	100%
Electrical equipment	• Inter array cables • Offs Export Cables • Ons. Export Cables • OSS Transformers • OSS Converters • OnSS Transformers • OnSS Converters	• Inter array cables • Offs Export Cables • Ons. Export Cables • OSS Transformers • OSS Converters • OnSS Transformers • OnSS Converters	14%
Machinery & equipment	• WTG Generator • WTG Rotor • WTG Nacelle • WTG Hub • Onshore Crane	• Power-Take Off System	10%
Other manufacturing	• Mooring system	• Mooring system (polyester line)	100%
Repair &maintenance	• Vessels (ie tug boats, anchor handling tug vessel, SOV, etc.) • Personnel	• Vessels • Personnel	75%
Accommodation	--	--	100%
Financial services	• Team of 5+		100%
Insurance & pensions	--		100%
Legal activities	• Team of 5+		100%
Accounting & tax services	• Team of 5+		100%
Head office and consulting services	• Team of 50+		100%
Research & development	• Team of 10+	• Team of 10+	100%
Advertising & market research	• Team of 3+	• Team of 3+	100%
Rental &leasing services			100%
Travel & related services	• Travel for surveys, operations etc.		100%

Industry Group	Technical Concept: FOW	Technical Concept: WEC	% Local Supply Chain
Business support services			100%

Table 5-13: Supply chain breakdown

This review of the Scottish supply chain has highlighted the following:

- There are significant synergies or potential for synergies between floating wind and wave energy supply chains
- There are a number of gaps in the Scottish supply chain which presents an opportunity for supply chain capability development and supply chain growth, bringing wider benefits to the region and the industry as a whole in Scotland
- Combined floating wind and wave industries, could help contribute significantly to this growth by providing the pipeline required for supply chain investment. ScotWind projects in general are starting to drive this change (we are seeing interest in suppliers to set-up facilities in Scotland and ports are developing expansion plans) but these require a significant pipeline to get the go-ahead. If floating wind can help kick-start the wave energy industry, the number of units, mooring lines and anchors as well as vessels and port facilities would substantially increase, consolidating this pipeline and driving significant benefits to the Scottish supply chain

5.5 Economies of Scale

An often-touted benefit for any developing technology is the ability to realise economies of scale (or volume production). This section examines what that actually means and where the benefits could lie for floating wind and wave energy developers alike, with a focus on potential sharing scenarios. The potential mutual benefits here for wind and wave energy developers focus on combining resources used in the production of sub-systems used in each technology. Some of these additive effects are simple to visualise, such as using the same size mooring chain/rope and therefore being able to order larger quantities. Others are more involved and require a more integrated approach between the projects, such as aligning on steel tube sizes to simplify overall fabrication.

With increased production volume, benefits can be realised in the following areas:

- Material costs: in this case the primary focus is on steel. For smaller projects there can be a considerable step change in increasing steel volume as this will allow the purchaser to go direct to the mill for steel plate. As projects go larger the returns for additional volume decrease in a non-linear manner to the point that the savings become negligible when moving between a 1-2GW project for example. Note that different geometries and materials will have their own step change points, and non-linear relationships, but most will align with steel plate to provide a simple means for consideration.
- Variable costs: in this case the primary variable cost is that of the labour involved with the fabrication of structures. In general, with any project the process becomes more efficient as you build more and more units and “learn by doing”; however, this benefit is virtually exhausted after ~10 units. Further improvements in variable cost

come about when a more significant volume of components is being manufactured and it is worthwhile putting time into optimisation of production techniques, technology and methods. Akin to automotive assembly where significant investment is put into automated tooling, but over the number of units produced the reduction in labour costs more than outweighs this. Another factor related to variable costs is the potential to buy in components from lower cost areas, if the order volume is great enough.

- CAPEX of facilities/equipment. This is related to investment in equipment and tooling to produce the required components. Commonality of parts has the potential to reduce the tooling setup for a WEC device for example – as well as associated bond costs. Increased volume also spreads the CAPEX across more units resulting in lower unit costs.

In terms of material costs in this application, the addition of WECs, which corresponds to a smaller capacity (100MW), smaller overall units and therefore low steel weight, than the wind component assessed (500MW), it could be argued that the benefit of economies of scale could have a reduced impact here. Variable costs have the potential to be exploited by using similar sized components, but again, given the existing scale of the floating wind project and indeed the industry, the additional WEC capacity is not going to result in sginificant overall savings (however, the benefit to the WEC developer should be noted).

Therefore, to realise these types of benefits, the scale of the wider industry pipeline of potential projects needs to be considered alongside a more detailed assessment of the feasibility of aligning component types/sizes or using a hybrid platform.

5.6 Industry Pipeline

Wind and wave shared projects can help to establish and grow supply chain capabilities, as shown in Section 5.4. Co-located projects would lead to increased deployment numbers. The wave energy technologies will add to the supply chain capabilities of the marine renewable industry, due to different requirements from the floating wind industry, which is a positive impact on the industry pipeline. However, the floating wind supply chain will be already facing challenges in the next years, particularly in Scotland, due to the scale of projects awarded. Therefore, it is key that when considering the additional supply chain requirements of the wind industry, the focus is put on the synergies with existing and fast-developing industry pipelines such as wave energy. In a situation where ports, component manufacturers (such as for mooring lines), construction yards, grid connections, operating vessels, etc., are already relatively under pressure due to the growing offshore wind industry, it is required that the objective of other marine renewables technologies does not collide, but rather aligns to create synergies in multiple sectors, as explained in Section 5.1 and 5.4, and also presented through the Impact Assessment in Section 6.

An increased industry pipeline is achievable, however it is key that the first few co-location projects can prove the expected benefits. It is only after demonstrating that the co-location can have an overall positive impact, economically for the stakeholders but also socially for the community, that the sector will be able to grow. Once this industry maturity and increased levels of renewable energy and deployment numbers are achieved, the supply chain can continue to grow. In doing so, the commercial risk of the investments could decrease, leading to further growth of the industry pipeline.

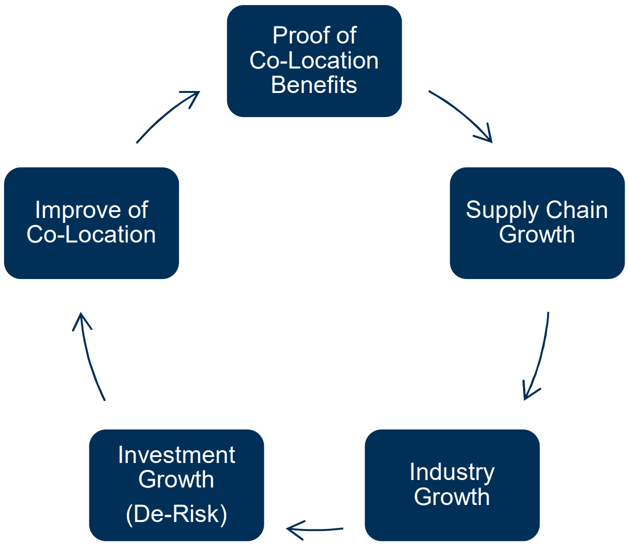


Table 5-14: Industry Pipeline growth key steps simplified

5.7 Project Development

The baseline project development phase for the wave energy project is assumed to be very similar to the floating wind one, as the assumed level of wave technology maturity for the scenarios considered in this study is 1 GW worldwide.

The required environmental surveys are expected to be similar for both the technologies, however, for the wave development, it is expected that bird impact and visual impact would be minor topics. In contrast, an underwater noise analysis of the operational phase and ongoing monitoring would need to be added for wave energy developments.

For the geophysical and geotechnical surveys, there would be differences between wave and wind technologies only if the type of foundation selected (drag embedded anchors or piles) are different, which is dependent on multiple factors such as seabed conditions, water depth and therefore preferred mooring configuration (taut, semi-taut or catenary). The base geophysical and geotechnical costs will be similar and therefore can present synergies in the case of co-location of the technologies.

For the measurement campaigns, the wave technology would not require an in-depth LIDAR campaign that would be associated with an offshore wind development. This is because the focus would be on measurement taken by wave buoys which are distributed within the wave farm area. The wind characterisation would be less detailed than the one done for offshore wind, as the wind is not responsible for yield aspects and the WEC technology remains close to the surface or even submerged. The current measurement would be valuable to a wave energy developer.

The design phases certainly present differences in terms of complexities between wind and wave project development, where the former comprises of a higher number of engineering packages (such as the aerodynamic assessment) and interfaces, such as the one between the WTG and tower or the tower and floater. Since a relatively advanced technology maturity has been assumed for wave technology in this study, the added development costs and timescales which would be required due to the existing lower Technology Readiness Level of wave with respect to wind, is not accounted for in the ranking of scenarios in this study.

In terms of the team size, as wave developments of such scale are not present yet or in progress for the immediate future, given the overall similarities of most of the development topics, it has been assumed that a core management team of similar size would be required, with a reduction for the wave technology to account for some of the reduced complexity in the design, as explained above.

Table 5-15 presents a qualitive summary of the benefits and challenges associated with shared project development that have been identified.

Stakeholder	Benefits	Challenges
Project Developers	- Seabed leasing - Surveys - EIAs - Development of best practices - Project pipeline - Combined stakeholder engagement - Potentially more viable sites	- Integration of multiple technology developers - Interface management - Project technology risk
Technology Developers	- Risk reduction - Project pipeline - Accelerated development	- Limitations on floating platform technology - Restrictions on electrical supply format - Sub-optimal sites as the focus will likely be on wind
Industry and Suppliers	- Cost reduction - higher volumes - Larger projects - greater stability and forecasting - Development of best practices	- Potentially new geometry and tooling
Transmission	- May help with power smoothing due to wind generating profile combined with WEC equivalent	- Integrating WEC and WTG on common systems due to step change coming from WTG/IACs - O&M activity alignment and impact to availability of both technologies to meet OFGEM targets - Availability of suitable software models to assess pre/post fault performance and grid compliance in industry software
Regulatory and political	- Overall environmental impact reduction - Seabed leasing / usage - Combined EIA assessments	- New technology or application of tech may lead to longer review times
Project Impact	- Variety in O&M activity - Potentially reduced environmental impact overall	- Depending on WEC technology, there may be more noise and/or visual impact

Table 5-15: Benefits and challenges of shared project development

The benefits across all stakeholders typically focuses on the potential to share services, share risks and increase future forecasting and pipelines. This is an area where combined wind and wave development can bring stability to each party. The combined development activities

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(surveys, consenting, stakeholder engagement) will aid the development of best practices. The concept of co-development is not without challenges though. The addition of wave energy technology into the mix will be seen as a risk by developers and brings an added layer of complexity and a new set of interfaces to be managed. This will always present a challenge and a reservation in early combined projects, largely due to the number of unknown obstacles on the development pathway.

6 Economic Impact Assessment

Beyond the techno-economic modelling activity (Section 4), which provides conclusions with regard to the economic attractiveness of the projects to the developers, and beyond the potential non-quantifiable benefits to technology, stakeholders and industry pipeline (Section 5), the co-location of wind and wave could also bring economic benefits for the society (e.g. jobs, gross value added GVA, supply chain development, etc.), rather than from the energy developer perspective only. These economic benefits will be estimated through the Economic Impact Assessment presented in this section.

The aim of this section is to describe the economic assessment methodology using the 'Input-Output' method, including how the multipliers work, what they consist of, and how to interpret the results. The information (including the official tables) described next in this section is developed and updated by the Scottish Government[3]. The purpose of the tables is to provide a complete picture of the economic impact in the Scottish economy by investing in different sectors.

6.1 Multipliers

If there is an increase in final use for a particular industry output, it is possible to assume that there will be an increase in the output of that industry, as producers react to meet the increased use; this is the direct effect. As these producers increase their output, there will also be an increase in use of their suppliers and so on down the supply chain; this is the indirect effect. As a result of the direct and indirect effects the level of household income throughout the economy will increase as a result of increased employment. A proportion of this increased income will be re-spent on final products; this is the induced effect. The ability to quantify these effects is important as it allows economic impact analyses to be carried out on the Scottish economy.

There are two types of multipliers available that covers the description above:

- Type I multiplier: sum together direct and indirect effects in the economy by investing in a specific sector,
- Type II multiplier: it considers the direct and indirect effects of the investment plus it also includes the induced effects.

It is important to highlight that since the economic assessment models (official data) are generally used to model the impacts of changes on the domestic economy, the first step in generating the symmetric tables is to extract the valuation and imports tables from the combined 'Use Table' at purchasers' price. After removing imports, taxes and subsidies, and reallocating margins, it is left with 'Domestic Supply' and 'Use Tables' at basic prices.

[3] https://www.gov.scot/publications/about-supply-use-input-output-tables/pages/introduction/

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6.2 Definitions of Multipliers and Effects Used in the Model

Output Multipliers

The output multiplier for an industry is expressed as the ratio of direct plus indirect (plus induced if Type II multipliers are used) output changes to the direct output change due to a unit increase in final use. So that multiplying a change in final use (direct impact) for an individual industry's output by that industry's Type I output multiplier will generate an estimate of direct + indirect impacts upon output throughout the Scottish economy.

Employment Multipliers

The employment multiplier, expressed as full time equivalent or FTE, is the ratio of direct plus indirect (plus induced if Type II multipliers are used) employment changes to the direct employment change. In other words, if you have the change in FTE employment for the industry, the employment multiplier can be used to calculate the change in FTE employment for the economy as a whole.

Employment Effects

Employment effects show the direct plus indirect (plus induced if Type II multipliers are used) employment change to the direct output change due to a unit increase in final use. In other words, if you have the change in output for the industry, the employment effect can be used to calculate the change in FTE employment for the economy as a whole.

GVA Multipliers

The GVA multiplier is expressed as the ratio of the direct plus indirect (plus induced if Type II multipliers are used) GVA changes to the direct GVA change. In other words, if you have the change in GVA for the industry, the GVA multiplier can be used to calculate the change in GVA for the economy as a whole.

GVA Effects

The GVA effect is expressed as the direct plus indirect (plus induced if Type II multipliers are used) GVA changes to the direct output change, due to a unit increase in final use. In other words, if you have the change in output for the industry, the GVA effect can be used to calculate the change in GVA for the economy as a whole.

6.3 Methodology

The ‘multipliers’ and ‘effects’ are going to be used so it is possible to understand the potential benefits of combining wave and floating offshore wind energy in Scotland and to assess the possible impact in the wider economy such as in jobs, GVA, and income. Figure 6-1 presents a general diagram of the dynamics of the economic assessment.

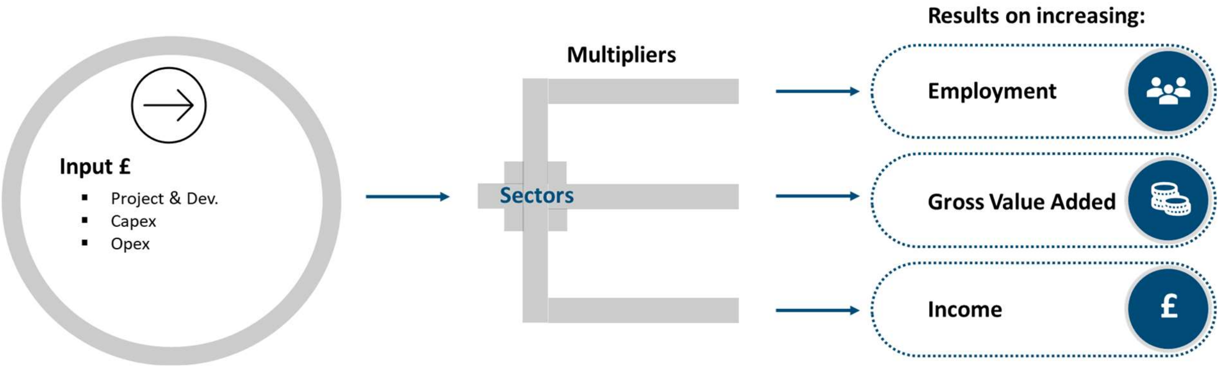

Figure 6-1: Diagram of the economic impact

For the specifics of this project, the economic assessment calculation will use the following formula,

$$Ec = I * M * Sc$$

Ec the Economic impact in employment, GVA or Income in Scotland

I the Investment (CAPEX, OPEX or Development) in GBP for each sector of the industry

M the multiplier/effect for each industry group as issued by the Scottish Government

Sc the estimated percentual of the goods or services supplied locally

6.4 Inputs and Limitations

This section describes the inputs and possible limitations of the economic assessment for this project. The inputs used in this project are described below:

- For the investment, as it needs to be split by industry group to increase the accuracy of the results, it was assessed by estimating the amount of materials/inputs or services needed for each industry group (group's costs details in Appendix B). Its estimation is based on the selected scenarios and the consultant's analysis and estimations of the required material, service and/or labour.
- The multiplier/effect for each industry group as issued by the Scottish Government.
- Finally, to measure the impact of the investment in Scotland, it is important to estimate what investments will be sourced locally for each industry group. The adopted methodology was based on research for industry category and checking if it was possible to be produced or delivered by a Scottish firm. Based on that, it was assumed that if it was possible to be sourced in Scotland it would be sourced locally.
- The costs will be assumed at current prices.

There are some limitations in this model. The supply chains for any project vary according to the investor's strategies and contractors that the developers are going to use. For this project it is assumed that the best scenario possible is the case where all possible goods and services will be supplied locally. This is unlikely to happen in the real world. Therefore, this scenario assumes that the developers are incentivised to maximise Scottish content in the value chain.

Another point that needs to be highlighted is the possible impact of any imported goods in the process or production chain of any goods. According to the official 'Input-Output Methodology Guide' (Scottish Government – V7) imports, taxes and subsidies are not considered in the analytical tables, therefore it is only possible to measure the impacts of changes exclusively on the domestic economy.

6.5 Selected Industry Groups

The selected industry groups are based on the most likely sectors of the industry that will be affected by the investment and development of projects combining wave and floating offshore wind energy in Scotland. Figure 6-2 presents the observed industries of this study.

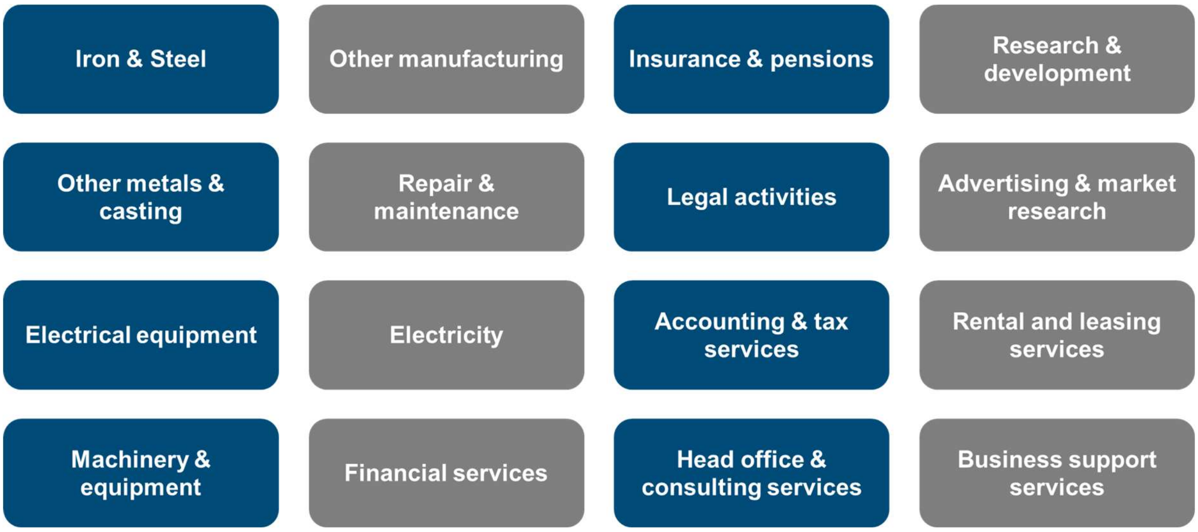

Figure 6-2: List of Industries[4]

From these sectors of the industry, the following requirements of goods and services are expected (more details in Annex A):

- Iron & Steel: Floater Steel, Secondary Steel, Steel for Tower
- Other metals & casting: Anchors Steel
- Electrical equipment: Inter-array cables, Offs. Export Cables, Ons. Export Cables, OSS Transformers, OSS Converters, OnSS Transformers, OnSS Converters, Substation
- Machinery & equipment: WTG Generator, WTG Rotor, WTG Hub, WTG Nacelle (1 of the following per each WTG)
- Other manufacturing: Mooring Chain
- Repair & maintenance: repair and maintenance of the power plant(s)
- Electricity: electricity power for its operation
- Financial services: for its operation
- Insurance & pensions: for its operation
- Legal activities: for its operation
- Accounting & tax services: for its operation
- Head office & consulting services: for its operation
- Research & development: pre-development costs
- Advertising & market research: for its operation
- Rental and leasing services: for its operation

[4] UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007)

- Business support services: for its operation

6.6 Results

The results described in this section are based on the industry requirements and cost breakdown for each scenario as described in Sections 4.6 and 5.4. The full results including the breakdown per industry group and scenario can be seen in Appendix B. Table 6-1 presents a summary of the results for each scenario and their impact on Income, GVA and Employment.

	WIND			WAVE		
Scenarios	**Total Impact in Income (£m) - Direct + Indirect + Induced**	**Total Impact in GVA (£m) - Direct + Indirect + Induced**	**Total Impact in Employment (persons) - Direct + Indirect + Induced**	**Total Impact in Income (£m) - Direct + Indirect + Induced**	**Total Impact in GVA (£m) - Direct + Indirect + Induced**	**Total Impact in Employment (persons) - Direct + Indirect + Induced**
Base Case (WTG)	278.81	476.48	7,622	-	-	-
Base Case (WEC)	-	-	-	127.23	230.01	3,570
Indirect Synergies. No asset sharing	306.12	528.08	8,466	205.27	385.85	6,060
Versatile Platform	305.40	527.35	8,448	218.74	403.17	6,285
Shared Landfall & Onshore Substation	305.69	524.71	8,394	209.13	390.40	6,064
Shared Offshore Substation	288.26	492.48	7,870	105.37	201.07	3,078
Shared Offshore Substation & Vessels	288.26	492.48	7,870	90.64	168.74	2,621
Shared Offshore Substation, Vessels & Versatile Platform	287.25	491.10	7,844	109.52	199.43	3,099
Fully Shared	294.86	500.83	8,043	47.09	86.24	1,389

Table 6-1: Total Impact in the Scottish Economy per scenario

Each scenario has its own specificities and level of investment, so the results are a reflection of it. The following points can be highlighted from the results:

- In line with the size of the investment, the total impact in Income varies between 341.95 (£m) in the Fully Shared scenario to 524.15 (£m) in the Versatile Platform scenario.
- The impact on Gross Value Added (GVA) can reach approximately 930 (£m), also in line with the size of the investment.
- With regards to employment, the total number of full-time employees varies from 3,570 to 14,733 with Iron & Steel and Rental and leasing services representing (for the majority of the scenarios) approximately 45%.

7 Feasibility Assessment

The final stage of the study focused on assessing the feasibility of the different sharing scenarios including identification of key risks relating to the sharing of assets and activities and potential mitigations. The assessment broadly follows the steps as set-out in Figure 7-1.

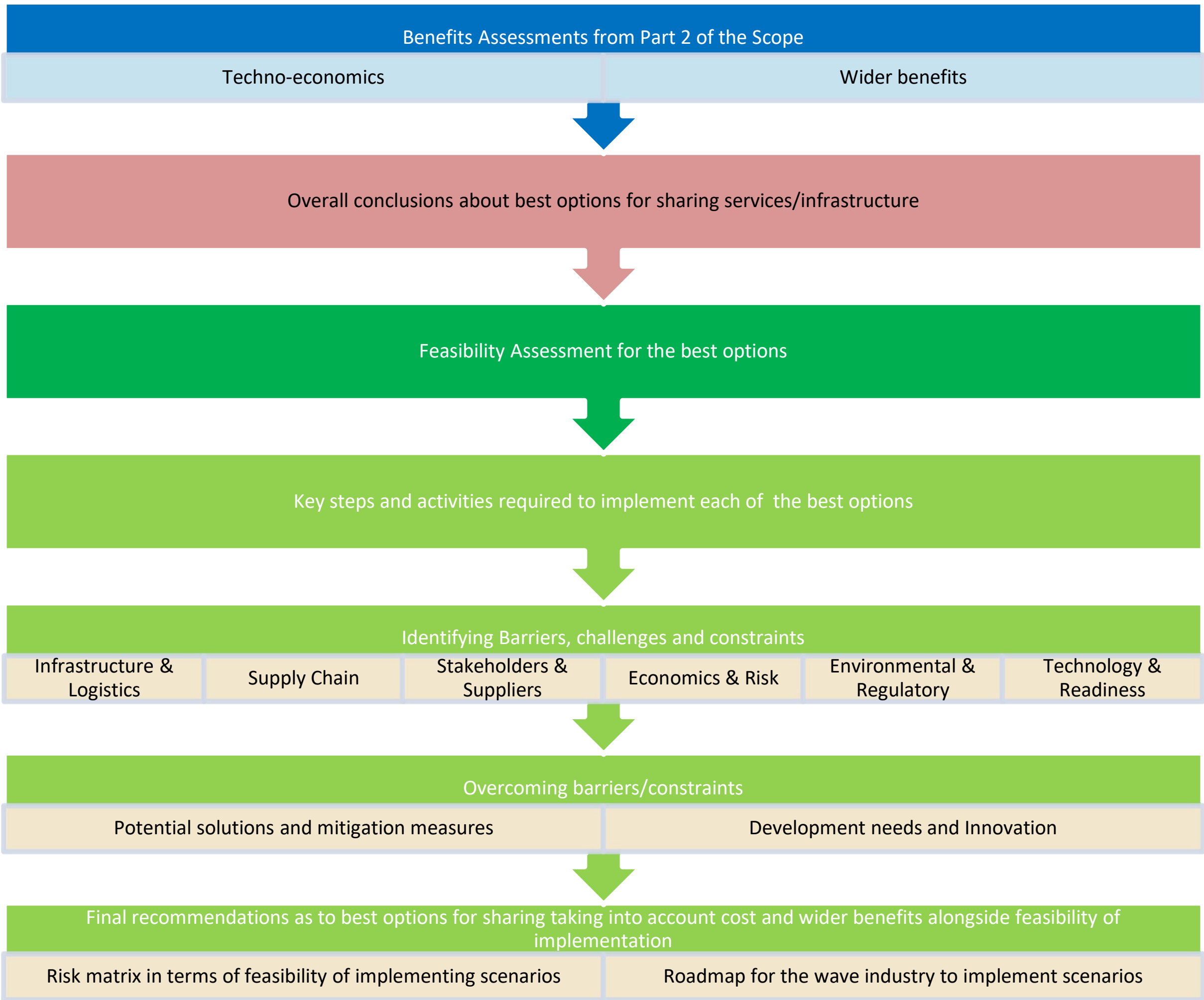

Figure 7-1: Feasibility Assessment Methodology

7.1 Challenges and Barriers

The main challenges and barriers, perceived and real, are discussed in this section, following the topics specified in Figure 7-1.

7.1.1 Infrastructure and Logistics

Firstly, there is a need to understand the O&M and installation requirements of the two technologies to understand to what extent these can be shared. E.g. can the same vessels that are used for FOWTs be utilised, or are the requirements too different, would the same crew be able to be used or is additional training needed? The requirements may vary quite substantially between different technology designs and this needs to be factored into a broader understanding of the opportunities for collaboration.

The potential to share vessels exists in all phases of the project lifecycle from:

- Array cables
- Assembly and marshalling ports
- Anchoring
- Mooring lines
- Physical platforms

It is anticipated that some categories will be more compatible than others and being able to specify these compatibilities and any limitations will be an important part of strategy development to hone in on the optimal sharing configurations for WTG and WEC projects.

Would assembly and O&M ports that are suitable for floating wind also be suitable for wave or are there additional requirements. Generally it is assumed in this study that floating wind projects would have the more onerous requirements but this needs to be confirmed.

Can transmission infrastructure (such as inter-array cables and export cables) be shared or do WECs and WTGs need to operate at different voltages that prevent this possibility (discussed in 8.1.6). This requires further investigation as to the specific electrical infrastructure sizes and weights that would need to be added to the floating wind platform to understand whether it could fit in the WTG tower, and then how to integrate the system without any negative impacts in terms of outages.

Likewise for operational switching for routine and ad-hoc maintenance with regard to O&M requirements of both technologies, even if there can be shared assets in IAC and switchgear, gaining a greater understanding on the impact on availability figures would have to be assessed against OFGEM targets.

Is it feasible to share mooring/anchor infrastructure. The implications on design and design risk need to be considered, as well as the feasibility in terms of device spacing. At high level it seems that there is milage in investigating this aspect, given the typical WTG device spacing and WEC sizes, but this will depend ultimately on both WTG and WEC size as well as optimal layout design for the wind turbines considering the site wind resource characteristics. Mooring line configurations also need to be considered and the influence of water depth on these arrangements.

Can platforms be shared – check for existing hybrid/integrated platforms already on the market e.g. Marine Power Systems, Floating Power Plant, Hexicon, and develop deeper understanding of the pros and cons of these structures from the WTG and WEC perspectives. The implications for design, design risk but also design complexity as well as WTG and WEC device performance need to be considered. It may be that the negatives of such an arrangement can be outweighed by the benefits but this needs to be tested utilising metrics such as LCOE to provide an holistic view of the benefits.

7.1.2 Supply Chain/Suppliers

A key question relating to supply chain is whether components such as anchors, platforms, cables etc. be common between the technologies, thereby saving costs through economies of scale and enabling capability development and growth in the local supply chain. This requires detailed investigation into the components and subcomponents, and different design ideas across both markets. Innovative thinking may be required based on an understanding of the needs and drivers for the different technology designs to determine where elements can be standardised or modularised to realise supply chain benefits. Engagement with the supply chain would also be required to understand how the potential benefits of standardisation and modularisation can be maximised.

A key uncertainty is around the availability of suppliers for hybrid/integrated platforms and alignment with the expected delivery timeline. It may be that the first types of sharing scenarios implemented need to be less ambitious in terms of the level of sharing to allow time for hybrid platform design and innovation to progress and the supply chain to become ready for manufacture of these systems.

7.1.3 Stakeholders

If buy-in of floating wind developers is not achieved, wave-wind collocation projects will not be possible so this is an absolutely critical aspect in terms of feasibility. Given the relative immaturity of floating wind technology, developers may be averse to increasing the complexity and perceived risk of their projects. Close management of the needs of floating wind developers and clear evidence of the benefits is required to ensure they are onboard. However, with the right engagement strategy and a solid evidence base as to the opportunity, floating wind developers are likely to be more willing to engage because of the existing need for innovation and out of the box thinking to realise commercially viable projects, especially for projects at sites in very harsh metocean conditions which poses unique challenges for floating wind technologies.

Other key considerations relating to wider stakeholder groups are as follows:

- There is a need for regular communication with technology developers and manufacturers to ensure that the chosen technology is feasible. E.g. if new designs such as hybrid/versatile platforms are used.
- Need to ensure alignment with government subsidies where possible as this could be key to ensuring investment.
- Must ensure that no components of the project have adverse impacts on consenting. Need early engagement with consenting bodies to determine what studies will be required. Early engagement with environmental contractors to determine environmental impacts and if there are any areas where impacts are increased due to the sharing scenario.
- Need regular communication with port authorities to ensure there are suitable port facilities available.

7.1.4 Economics & Risk

A key question from a commercial perspective is will investors be put off by the perceived risk of a novel project like this. This type of project can benefit from the lack of general risk aversity of floating wind investor profiles but a lack of knowledge/understanding of the wave industry and the validity of the technology may be a barrier to communication. Lack of experience of wave technology developers could be mitigated by partnership with more experienced project developers.

Complications of splitting costs of the shared assets, site lease, data collection, consent, design, procurement, project management, and more could put off developers from entering into partnerships such as this. However, the initial results clearly show that there is room for both parties to benefit from sharing scenarios, and the offshore wind developers are used to negotiating complex contracts. Detailed modelling clearly identifying the cost and wider benefits through the sharing activities would enable easier translation of this into a price charged to the WEC developer for use of assets/other sharing aspects. Levels of sharing can also be tailored depending on risk appetite, with some elements enabling more independence between WTG and WEC developers and lower risk of the WEC project negatively impacting the WTG project. For example, maintenance agreements that favour the WTG project so that the WEC only benefits from equipment sharing when this is not already in use by the WTG project.

7.1.5 Environmental & Regulatory

A key question from the consenting perspective is whether submission of the wave and wind projects under a single consent is possible and, if so, will the time savings be significant or will this in fact complicate the consenting process and expand the reach of the EIA and mitigations required. Early stakeholder engagement with the regulators is recommended to understand the concerns that they have, and these can then be investigated and addressed through studies to reduce risk once at the consenting stage.

If transmission architecture is to be shared, this will ideally need to be agreed early on as grid connection agreements are obtained very early on in the process. However, these can be modified subsequently, and if the WEC project is small in comparison the modification may not be substantial. Furthermore, there is the potential for WECs to capitalise on spare capacity in the existing WTG system so that an overall increase in infrastructure size of rated capacity is not required, although the benefits of this approach would need to be investigated in terms of the capacity factor improvement overall, balanced against the costs of the WEC project. The transmission rules and regulations in the UK are complex and these need detailed consideration to understand barriers to shared projects.

7.1.6 Technology and Readiness

In order to establish the TRL of the topology solution that would offer most synergies across a project with shared IACs and/or transmission OFTO assets (i.e. Scenarios 11, 12, 13, 14, and 16), a desktop review of the most common wave energy devices in development was undertaken, such as those from AWS, Mocean and Corpower Ocean. Unfortunately, little information in terms of their actual electrical system characteristics is available publicly, likely as a measure to retain IP in-house as much as possible. However, previous studies commissioned by WES [15] reported that future WEC arrays at around 33kV voltage level would be seen in the mid-term future, progressing from use of 0.69, 6.6, and 11kV previously used for dedicated onshore wave energy connections. One example of this progression is the Hi-Wave 5 project off the coast of Portugal which utilised and laid a 6.6kV connection to onshore grid in readiness for use of the Corpower Ocean C4 WEC in October 2022. The feasibility of utilising the same cable systems as collocated WTGs would be dependent on the system voltage level being similar. If not, the Wave Energy Converters would then have to be stepped up in voltage using dedicated transformers to either 33kV or the now industry standard 66kV for turbine array voltage.

Being mindful of the projected wave project COD, it should also be noted that there is a lot of work happening in the industry via the Carbon Trust Hi-VAS R&D project [16] to foster this voltage level growth due to bigger WTG nominal ratings of 18MW+ being discussed to aid the drive towards NetZero 2050 targets. The Carbon Trust suggests that the offshore wind industry will soon have to transition to 132 kV IACs in order to keep pace with turbine developments. This would make incorporation of WECs onto the same cable system as the WTGs even more challenging. The introduction of a WEC transformer then introduces further losses into the energy park system along with the IAC losses and WTG transformers (due to load and no-load losses) thus further reducing the generation capacity being seen at the Offshore Grid Entry Point at the offshore substation.

Furthermore, additional cognisance for spatial and weight distribution would be required to incorporate a transformer for the WECs, thus potentially increasing the size of the hybrid platform needed and the required widths for egress routes including door swing of any weatherproof enclosure it is to be housed in. These transformer units including weatherproof enclosures are typically of dimensions 2.5 x 3 m and typically weigh up to 3700 kg (when filled with oil). This could impact the Centre of Gravity of the floating platform for both the WEC and WTG.

There are further technical considerations that would require specialist data and investigation. For example, the interaction of harmonics between the WEC and WTG could lead to heating effects on the shared cable or their associated terminations. Even if the approach was for independent arrays for WEC and WTG, there would still need to be some form of voltage transformation for the WECs before the arrays are connected to the shared OSS so that shared export cables could be utilised.

WECs require switchgear for electrical protection and isolation via operational switching. Further assessment would be required to determine whether this could be achieved by sharing the WTG's switchgear located in the tower or whether a dedicated WEC switchgear is needed. If the latter is true, it could be achieved either via a sub-sea modular design [17] or a system located adjacent to the transformer above water, albeit additional spatial footprint and mass to consider adjacent to a WEC transformer. Note that current sub-sea designs from that of Siemens seem to be limited to 38kV so the TRL of a viable solution of 66kV or above is deemed very low and would have more financial impact than other above water switchgear solutions. In order to evaluate these options, the loss of generation revenue due to taking part or all the combined WEC/WTG array offline to carry out maintenance tasks would need to be balanced against the benefits of sharing switchgear.

The first stage of assessing whether the road maps between WEC and WTG in the future align at some point would be to obtain indicative electrical characteristics for the next generation of Wave Energy Converters. This would allow electrical models to be incorporated in industry software to gain an understanding of the dynamic behaviour of both WTG and WEC together with regards to (but not limited to) harmonics and electrical loading of the cables as well as power smoothing as highlighted previously.

In terms of the scale of technology readiness as adapted by Offshore Wind Innovation Hub for a shared IAC/OFTO, for combined WEC/WTG solutions this would be between Levels 1-2 where the upper limit is defined as *'Technology concept formulated: Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies'*. This being attributed to the TRL of one technology lagging behind the other due to the exponential growth of wind turbine nominal ratings and R&D activities to drive offshore wind LCOE costs down. An example in a real-industry scenario would be the West of Duddon Sands windfarm offshore that became fully operational in 2014. Its WTGs were 3.6MW Siemens SWT platforms with 120m diameter rotor where in the 8 years since, Siemens (and others) are now in the midst of developing 15MW+ WTGs with rotors in excess of 222m for installation campaigns starting in 2024 for other projects.

Due to the developments of WTG nominal ratings, the most feasible sharing scenario with WECs and WTGs appears, at least initially, (due to barriers discussed above) to be to start sharing electrical assets from the point of the offshore substation platform and back to shore from there, where WEC would have their own IAC system but would have been brought on board via J-Tubes to their own switchgear with separate voltage level to the WTGs, and then stepped up via dedicated transformer on the OSS to be common to the export system for the WTGs with some form of redundancy factored in via operational switching between WEC and WTG clusters. From then on all infrastructure on the Onshore Substation is also common.

7.1.7 Co-Location Wind Farm Layout

7.1.7.1 Floating Wind Mooring Layouts

In terms of co-locating wind and wave assets the most challenging factor will be positioning the two technologies within the same site. There is a proposal that the WECs are positioned around the outside of the floating wind array with a view to reducing the wave heights experienced within the site. Further analysis would have to show the potential benefits of this, but in terms of layouts this is likely the easiest option and would still enable the main electrical infrastructure to be shared connecting in at the offshore substation, as discussed in the previous section as likely the most feasible electrical assets sharing configuration.

In the event that WECs are interspersed with the FOWTs the surface spacing is unlikely to be the driving issue. Surface spacing would likely comprise of a 50m exclusion zone around each WEC or WTG and a 100m minimum vessel corridor – total 200m. Consideration would need to be given to the WTG and WEC drift under load relative to the nominal position. This will be highly foundation and mooring system dependent. The 200m spacing would represent a minimum desirable in all cases including a potential mooring line failure case.

If catenary moorings are used then these will drive the WTG and WEC spacing as seen in section 3.2.4. The use of taut or semi-taut moorings would mitigate this further. Anchors being close to one another would be a potential geotechnical challenge – although in the majority of cases spacing of a 20m or more would be sufficient depending on soil properties and assuming it is only two anchors that are adjacent. Anchors would also need to avoid IAC and export cables, further complicating this consideration. Anchor sharing has the potential to mitigate any issues in this respect, although presents a greater requirement in terms of integrated design.

7.1.7.2 Vessel Access Constraints

When co-locating wind and WEC assets the ideal case would be that both assets were installable and maintainable / accessible by the same vessel(s). Floating wind sites in development for ScotWind are considering CTV and/or SOV access to floating foundations. This is not something that has been explored widely in the wave energy sector to date, with towing a device to port for any fault much more likely. This could potentially hinder O&M synergies, but will be heavily depend on WEC design. For example if a versatile platform was used the ability to access using the same methods is highly likely and provided access to WEC infrastructure was possible then some offshore maintenance could be realised.

7.1.7.3 Cable Routing

Any cable routing exercise will aim to minimise the length of cable between the two points that it is connecting. Using that as a base case, the next step is to apply the most appropriate installation parameters which are namely: to use suitable course alterations that consider the burial tool (~200-600m), keeping a buffer (50-100m) from other subsea obstacles (anchors, mooring lines, other cables, wrecks), selecting areas with suitable conditions for burial (e.g. sandy with large depth to bedrock), minimising crossings with other assets or large bedforms (e.g. sandwaves), etc.

In terms, of cable routing and floating assets, there is one additional constraint, the azimuths of the dynamic cables. It is defined as the angle from the I-tube from which the dynamic cable will approach the floater. The total length of dynamic cable section is often around 3-4 times the water depth. These two factors essentially dictate where the cable routing starts and ends with respect to the floating asset and its mooring lines.

The cable azimuths will need to be determined following a dynamic analysis. The main criteria that is given to ensure that dynamic cable damage is avoided are:

- Clashing: The dynamic cables must not clash with either the mooring lines or other dynamic cables. It is likely that a minimum of at least 30deg from any other asset will be required to ensure that line clashing is avoided.
- The cable's mechanical limits are not surpassed: the main ones that are considered are the cable's bend radius/curvature, tension, compression, and sidewall pressure.
- Fatigue life: which must be greater than the project's lifetime (25-35years) and including a safety factor

All three of the above points are driven primarily by the hydrodynamic effects of the waves and current on both the dynamic cable itself and on the floating asset. Hence, much like the position/azimuth of the mooring lines/anchors, the selection of the cable azimuth will be dependant on the expected metocean of the site.

Any umbilical/dynamic cable connected to a wave device is expected to be treated similarly to that for floating wind. The I-tube position will need to be positioned as close to the extremities of the device as possible to ensure the dynamic catenary is, for the most part, away from the underside of the wave device. This allows for much simpler first end or second end pull-in operations (i.e. when the cable end is transferred from the vessel to the floater).

Whether there is space to install a wave device in between two floating turbines is unlikely going to be guided by cable routing and installation. However, the feasibility of including a wave device needs to be considered and mitigated from an early stage to ensure that the cable can be installed in each position. This means that the wave device must have a suitable I-tube location(s), it must have convenient azimuth options for the routing and must have suitable access for the CLVs to follow the route (e.g. impeding mooring lines or floating cable catenaries). The latter point is, perhaps, the most important as not having suitable access will complicate cable installation operations significantly and ultimately could make them unviable.

It is therefore essential that from the earliest stages of design there is a clear alignment between the mooring line angles and cable azimuths (for both the floating turbines and the wave devices) that will allow for routing and vessel accessibility throughout the entire array cable section. This is in addition to any other local constraints in the area (anthropogenic, geological, geotechnical, archaeological, commercial, etc.).

7.1.8 IAC Sharing and Layout Considerations Summary

With respect to the specific sharing scenarios modelled, the feasibility of IAC sharing and layout configurations is discussed further in this section. The key points are:

- Different voltages preferred for WTG and WECs due to the different scale of devices.
- WTG IAC voltage only expected to increase whereas WEC single device scale is limited by wave geometry so this problem will remain.

- 15MW WTGs have generators at 6.6kV which runs through switchgear and transformer before connecting to IAC.
- WECs ideally output at 6.6 or 11kV as it is a challenge to find room for placing 33kV transformer within individual devices.
- The cost model assumes 66kV cables for WTGs, and 33kV for WECs when in a stand-alone configuration (which is optimistic). So when combined an assumption is made that either the existing WTG transformer can be used, or an additional transformer added to the WTG tower or platform.
- WTG transformers (66kV) are small enough to sit in the nacelle or tower, so potentially feasible a second transformer could also fit, especially given the increasing scale of WTGs, but note that the additional weight may have an impact on the platform design.

Table 7-1 provides a summary of the different scenario configurations with respect to aligning voltages for IAC sharing and the feasibility for each.

Configuration	Requirement	Feasibility
Versatile platform	Would need 6.6/11 to 66kV transformer and other electricals on the platform	Reasonable as no WTG there so should be room and weight not likely to cause issue.
Radial	Would need 6.6/11 to 66kV transformer and other electricals on WTG platform/inside tower	Further investigation needed to understand compatibility, but transformer size should be feasible.
Shared platform	As above	Integrated design so solution should be possible.
Individual WECs on WTG string	Needs to output at 66kV	Infeasible given lack of space in PA WECs. Although other WEC designs may be able to do this.
Individual, independent WECs	Lower voltage may be preferable for PAs.	Cable length, costs and losses need to be assessed for lower voltages at this project scale.

Table 7-1 Summary of sharing configurations relating to IAC sharing opportunities

In terms of spacing of WECs between WTGs to enable IAC sharing as well as anchor sharing the following points are key:

- The spacing between WECs should be chosen to avoid significant negative interaction resulting in power losses. One report suggests 78 m [3] is sufficient, another suggests 100 - 200 m [2] is sufficient, but further study is required to confirm this. This is especially important for versatile/shared platform designs were WEC units will be in very close proximity.

- If the WECs are to be placed between WTGs, there should be a minimum spacing of 200 m between WECs and WTGs (50 m exclusion zone around each plus 100 m vessel corridor)
- This may depend on the mooring line length – however at this water depth the moorings are expected to be contained within the exclusion zone
- Cable laying constraints and constraints on cable azimuths may lead to difficulties placing WECs between WTGs
- Alternatively, if IACs are not shared, the WECs can be on external rows and this way may reduce the wave loading on the WTGs – however the extent of this effect is uncertain
- WTG spacing is dependent on wind rose and resource characteristics. Typical configurations can range from say 5x10D to 7x8D where D is rotor diameter. For a 15 MW machine, D~235 m. This leads to WTG spacings as seen below in Figure 7-2.
- With WTG to WEC spacings of 200 m and WEC to WEC spacings of up to 200 m, there is always space for at least 4 WECs between each WTG without significant negative interaction, and possibly more devices. In the cost model, 5 devices are assumed to help facilitate shared mooring without requirement to increase mooring lines compared to the model assumptions.

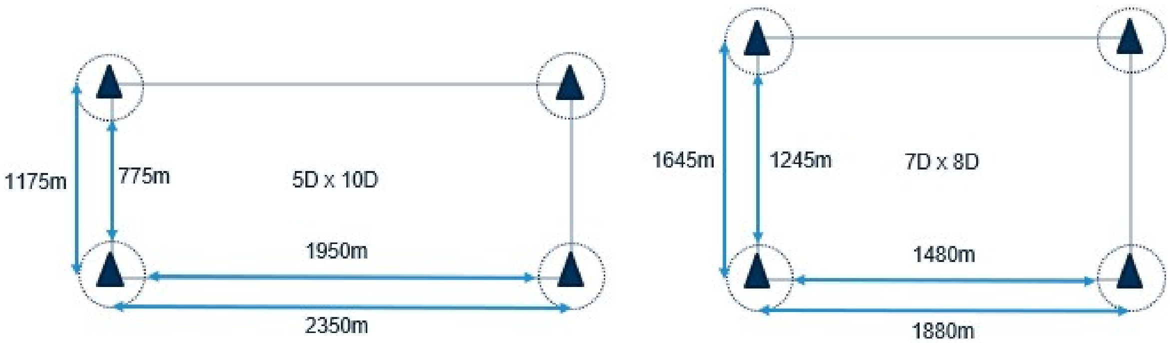

Figure 7-2 Indicative layouts for WTG locations with more and less unidirectional wind resource.

7.2 Overcoming Barriers

Following identification and discussion of the key uncertainties and challenges for implementation of sharing scenarios, this section discusses the ways to overcome issues. The key issues relating to each focus sharing scenario are also specified along with key next steps for investigating the feasibility of each of these, see Table 7-2. Key strategies for overcoming barriers are:

- Dissemination activities to raise awareness of potential benefits across the stakeholder groups and alignment with a wide range of stakeholder objectives
- Engagement activities to understand concerns and work on mitigations/solutions

- Targeted investment, research and development activities to validate benefits assessment and demonstrate feasibility
- Ownership configuration that maintains control of project development with WTG developer with as much as possible the WEC activities independent
  - For example, finding ways to make use of vessels/equipment etc. while not in use by WTG developer, split ownership so that WTG developer simply receives a payment for sharing from the WEC developer rather than having to organise the sharing activities directly
- Careful timing and consideration of scale of collaboration activities – again this can help to limit risk placed on WTG developer
- Incentives from government/transmission/environmental stakeholders. This could be in terms of leasing round or benefits in the seabed rental for improved seabed usage, benefits in the CFD schemes and OFTO/TNUoS arrangements.
- Clear supply chain benefits demonstrated. Developing a more detailed pipeline of potential level of projects that could be implemented in Scotland on a sharing basis and how that could drive supply chain growth and increased local content.
- Clear cost reductions demonstrated and validated

Scenario	Description	Key concerns	Key steps
3	No asset sharing	Ability to make use of installation/O&M equipment without negatively impacting on WTG activities	Detailed study on installation and maintenance logistics – optimisation across WTG and WEC assets Gauge stakeholder appetite across the various sharing aspects included
4	Versatile platform, separate projects	Design of a modular unit that is suitable for both WTG and WEC at reduced cost, and timeline for this Scale of impact on supply chain that could be achieved	Weight of versatile platform – can this be reduced? Detailed study on design and supply chain needed.
6	Onshore substation and cable route shared	Increased risk for WTG developer	Gauge developer interest and perceived risks to develop mitigation strategies Understand regulatory aspects with NG
7	Full transmission shared (not IACs)	Increased risk for WTG developer Regulatory requirements/grid integration	Understand regulatory aspects with NG. Development of solution that enables WTG developer to be disconnected from WEC risk – small cost to make substation compatible but no further responsibility?
9	As per 6 but with greater collaboration on non-asset sharing	Same as 6 and 3. Greater collaboration results in greater risk. Closer proximity of devices (same site) increases complexity/risk	Assessment of site configuration options would help to establish lower risk options and benefits of these (wave damping by being on edge of site), improved seabed usage etc.
10	As per 9 but with versatile platform (not IACs)	As per 9 and 4. Closer proximity of devices (same site) increases complexity/risk	As per 9.

16	Fully shared (inc. platform and IACs)	IAC sharing feasibility needs consideration, as well as platform design and simultaneous optimisation for WTG and WEC. All risk taken by single developer.	Detailed study on shared platform design required.

Table 7-2 Key considerations for feasibility with respect to the focus scenarios

7.3 Risk Matrix

A summary of key risks relating to sharing elements of wave and wind projects is provided in Table 7-3.

Stakeholder	Risk description	Risk Level	Mitigation options
WTG Developer	Added complexity to what is already considered a high risk project	High	Strategies that limit risk for WTG (more independence in project development). Stakeholder engagement, dissemination, detailed studies.
WEC Developer	WECs and WTGs cannot connect to shared IACs	High	More detailed electrical studies required to determine if this is feasible. The added cost and weight of transformers may be unacceptable. Alternative sharing options may be preferable and can still provide benefits to both parties.
WEC and WTG developers	Novel nature of project reduces bankability in the eyes of investors	High	Stakeholder engagement, dissemination, detailed studies. Incremental increases in sharing over a portfolio of projects.
WTG developer	Lack of perceived benefit to them	Medium	This study has helped to demonstrate that the benefits are likely to be mutual between WTG and WEC developers, regardless of the level of sharing. Dissemination and raising awareness of the benefits to all stakeholder groups from an early stage is key.
WEC Developer	Baseline LCOE assumed in model may not be achievable within timeframe modelled.	Medium	Requires 1GW deployment worldwide. Investigate sensitivity of model results to changes in baseline LCOE. Understand route to market for combined projects.

Table 7-3 Key risks for WEC-WTG sharing

8 Scenario Ranking

8.1 Scoring Methodology

The four previous sections assessed the LCOE, wider benefits, economic impact, and feasibility respectively. The final stage is to bring all of these factors together to produce a combined score, allowing the scenarios to be ranked against each other with all factors considered as shown in Figure 8-1: Scenario Ranking MethodologyFigure 8-1.

Figure 8-1: Scenario Ranking Methodology

For the LCOE scoring the quantitative assessment was already conducted as outlined in Section 4. These scores were then adjusted to a 1 to 5 scale by setting the maximum LCOE scenario to a score of 1, the minimum LCOE scenario to a score of 5, and linearly interpolating the LCOEs for the remaining scenarios between these two limits. The same approach was taken for the economic impact assessment scores – these scores were then included as part of the wider benefits weighted matrix.

A qualitative approach was taken to both the wider benefits and the feasibility whereby each scenario was given a score from 1 to 5 in each category with 1 being the least beneficial/feasible and 5 being the most. For each category, the requirements to achieve a certain score were clearly defined so that there is a qualitative justification for each score in the matrix. The scores in each category were then combined according to a weighting (see Section 8.2 for more detail) to give overall scores out of 5 (one score for wider benefits and one score for feasibility) which were then adjusted to ensure a range of 1 to 5 between the scenarios. The chosen weightings can be easily adjusted should this be deemed necessary.

Once each of the four categories has been scored from 1 to 5, they can then be combined into a single score from 1 to 5 which can be used to rank the scenarios against each other

8.2 Criteria Weighting

The six categories considered in the wider benefits criteria matrix are power export/ transmission, technology performance, supply chain, economic impact assessment (this analysis was conducted for a chosen subset of the scenarios), perceived level of risk, and seabed usage. The scores (excluding the economic impact assessment) are based on qualitative assessments of each scenario based on OWC's experience. The weightings chosen for each category, along with the scores, are shown in Figure 8-2. These scores were then adjusted to range from 1 to 5.

		Category weightings						
		Power Export/ Transmission	Technology Performance	Supply Chain Benefits	Economic Impact Assessment	Perceived Level of Risk	Seabed Usage	Total
Scenario		20%	30%	20%	10%	10%	10%	100%
1	Base case (WTG)	1	1	1	1	5	1	1.40
2	Base case (WEC)	1	1	1	1	5	1	1.40
3	Indirect synergies. No asset sharing	1	1	2	4.84	5	2	2.08
4	Versatile platform	1	1	4	5	3	2	2.30
5	Shared OnSS	2	1	2	N/A	4	2	1.70
6	Shared landfall & OnSS	2	1	3	4.79	4	2	2.38
7	Shared OffSS	4	2	3	2.14	1	3	2.61
8	Shared OffSS and versatile platform	4	2	5	N/A	3	3	3.00
9	Shared OffSS & vessels	4	4	3	1.8	4	4	3.58
10	Shared OffSS, vessels and versatile platform	4	3	5	2.14	3	4	3.61
11	Shared IACs	3	4	4	N/A	1	4	3.10
12	Shared IACs & anchors	3	4	4	N/A	1	4	3.10
13	Shared IACs, anchors and versatile platform	3	3	5	N/A	1	4	3.00
14	Shared PTO	3	3	4	N/A	1	4	2.80
15	Hybrid platform, separate IACs	3	5	4	N/A	2	4	3.50
16	Fully Shared	3	5	4	1	1	5	3.60
17	Base Case	1	1	1	1	5	1	1.40

Figure 8-2: Wider benefits weighted matrix

The six categories considered in the feasibility criteria matrix are infrastructure and logistics, supply chain, stakeholder and suppliers, economics and risk, environmental regulatory, and technology and readiness. Again, the scores are based on qualitative assessments of each scenario based on OWC's experience. The weightings chosen for each category, along with the scores, are shown in Figure 8-3. These scores were then adjusted to range from 1 to 5.

		Category weightings						
		Infrastructure and Logistics	Supply Chain	Stakeholder & Suppliers	Economics & Risk	Environmental Regulatory	Technology & Readiness	Total
Scenario		15%	15%	20%	15%	15%	20%	100%
1	Base Case (WTG)	5	5	5	5	5	5	5.00
2	Base Case (WEC)	5	4	4	3	4	3	3.80
3	Indirect synergies. No asset sharing	4	4	4	5	1	5	3.90
4	Versatile platform	3	3	2	2	2	2	2.30
6	Shared landfall & OnSS	5	5	4	4	2	4	4.00
7	Shared OffSS	5	4	3	3	2	4	3.50
9	Shared OffSS & vessels	4	3	2	3	3	3	2.95
10	Shared OffSS, vessels and versatile platform	3	2	1	2	4	2	2.25
16	Fully Shared	3	1	1	1	4	1	1.75

Figure 8-3: Feasibility weighted matrix

8.3 Scenarios Ranking

In order to narrow down the scenarios, an initial ranking was done by combining the weighted scores in both the wider benefits (excluding the economic impact assessment) and LCOE. The results of this are shown in Figure 8-4. This ranking was used to determine the optimal scenarios to take forward to the economic impact assessment and feasibility assessment.

	Scenario	Wider Benefits 5-Scale	LCOE 5-Scale	Total	Total 5-scale
		40%	60%	100%	-
1	Base case (WTG)				
2	Base case (WEC)				
3	Indirect synergies. No asset sharing	1.00	2.41	1.85	**1.85**
4	Versatile platform	1.00	1.00	1.00	**1.00**
5	Shared OnSS	1.38	1.70	1.57	**1.57**
6	Shared landfall & OnSS	1.76	1.79	1.78	**1.78**
7	Shared OffSS	3.10	2.35	2.65	**2.65**
8	Shared OffSS and versatile platform	4.24	1.81	2.78	**2.78**
9	Shared OffSS & vessels	5.00	3.38	4.03	**4.03**
10	Shared OffSS, vessels and versatile platform	5.00	2.70	3.62	**3.62**
11	Shared IACs	4.24	4.92	4.65	**4.65**
12	Shared IACs & anchors	4.24	4.93	4.65	**4.65**
13	Shared IACs, anchors and versatile platform	4.05	4.38	4.25	**4.25**
14	Shared PTO	3.67	4.86	4.38	**4.38**
15	Hybrid platform, separate IACs	5.00	4.87	4.92	**4.92**
16	Fully Shared	5.00	5.00	5.00	**5.00**
17	Base Case				

Figure 8-4: Scenario ranking (before considering economic impact assessment or feasibility)

Having narrowed down the scenarios, the final scenario ranking was conducted, considering the economic impact assessment as part of the wider benefits, and considering the feasibility. The results are shown in Figure 8-5 and Figure 8-6.

	Scenario	Wider Benefits 5-Scale	LCOE 5-Scale	Feasibility 5-Scale	Total	Total 5-Scale
		10%	60%	30%	100%	-
1	Base case (WTG)					
2	Base case (WEC)					
3	Indirect synergies. No asset sharing	1.00	2.41	4.82	**2.99**	**3.69**
4	Versatile platform	1.56	1.00	1.98	**1.35**	**1.00**
6	Shared landfall & OnSS	1.77	1.79	5.00	**2.75**	**3.29**
7	Shared OffSS	2.39	2.35	4.11	**2.88**	**3.50**
9	Shared OffSS & vessels	4.91	3.38	3.13	**3.46**	**4.45**
10	Shared OffSS, vessels and versatile platform	5.00	2.70	1.89	**2.69**	**3.19**
16	Fully Shared	4.96	5.00	1.00	**3.80**	**5.00**

Figure 8-5: Scenario ranking (considering all aspects)

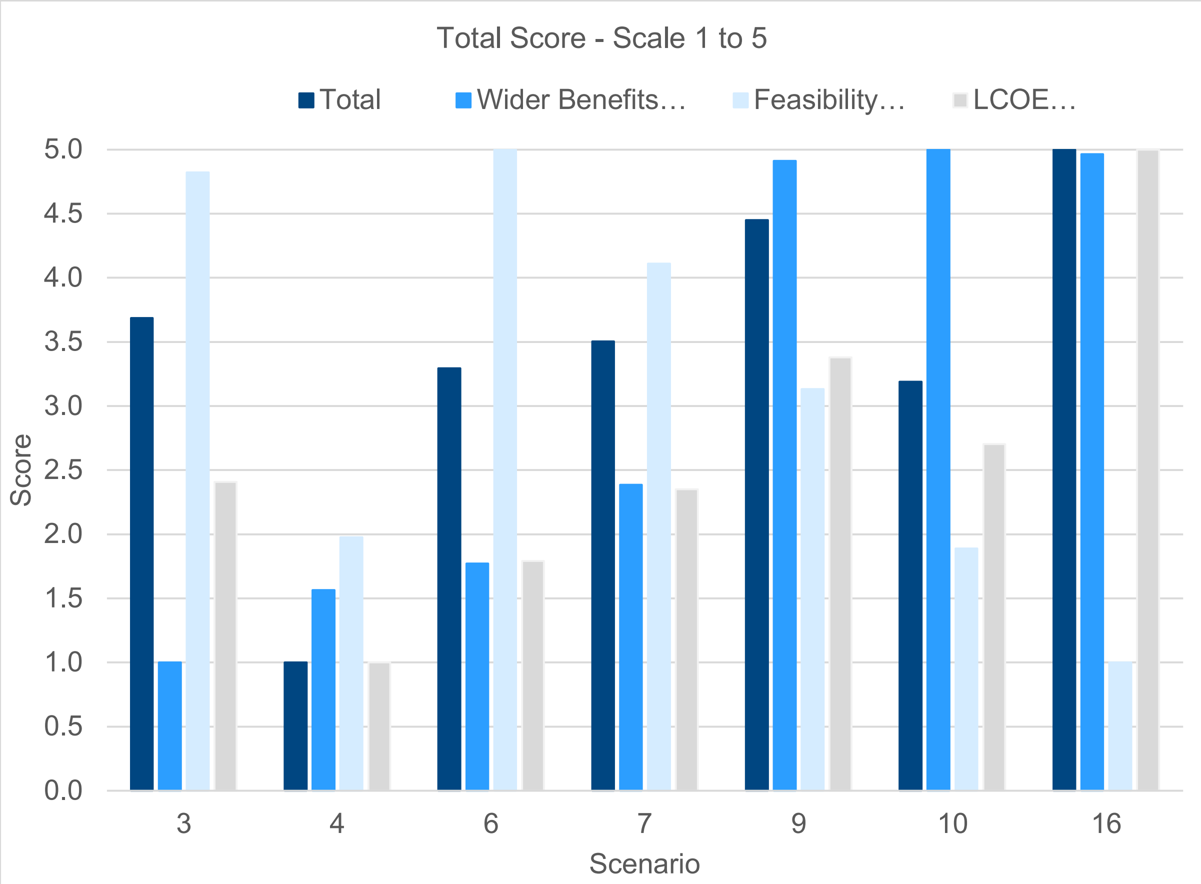

Figure 8-6: Final scenario rankings

Scenario 4 ranks the lowest, mainly because it has the highest LCOE of the scenarios but it also performs poorly in the other categories too. This suggests that the use of versatile platforms could be less advantageous when used in a stand alone project, although the model and supply chain assumptions around this case are potentially conservative in the model, as discussed with respect to the sensitivity cases in Section 4.7.8. Further study is needed on the supply chain benefits that could be realised for this scenario alongside technical feasibility of designing such a platform to investigate this initial result. Scenario 16 ranks the highest due to the significant LCOE saving and wider benefits that can be achieved through full sharing. However, it scores the lowest on feasibility and so with a higher weighting of this category it could be outperformed by other scenarios. The other scenarios generally offer a more balanced approach across the categories and could offer a reasonable compromise at least initially for implementing sharing scenarios.

The balance between cost benefits, wider benefits and feasibility is likely to shift as the context changes and the industry matures. Scenario 16 could be considered the ultimate option in terms of maximising benefits but a more stepwise approach may be required to first build the capabilities and experience to make this option viable. Lower risk, more immediately feasible sharing scenarios could be utilised in the shorter term to demonstrate validity of project sharing elements, and drive a consensus towards this approach and greater collaboration between the wave and wind industries.

9 Roadmap and Next Steps

The Roadmap consists of 4 key themes for successfully progressing to implementation of shared projects:

- Dissemination
- Detailed Studies
- Stakeholder Engagement
- Strategy Development and Refinement

These are presented in Figure 9-1 in three stages, starting with results validation and strategy development, moving through a refinement stage to select the preferred sharing scenarios and then finalising the strategy for implementation of these.

As part of the roadmap, the timeline for realising sharing opportunities is important to factor in, to ensure alignment with the relevant ScotWind developments. Key timeline elements are as follows:

- Relevant ScotWind projects expected to bid in to 2029 CFD
- Key engineering/supplier engagement ~ from 2027
- WEC project needs to start process ~ 2024/25

Across the sharing scenarios, the stage at which the WEC developer becomes involves can vary. However, for any transmission system sharing the WEC developer needs to engage early enough for the basic elements to be incorporated into the substation/transmission system design. Similarly, projects sharing floating platforms need to engage much earlier to enable proper development of the combined solution.

Given the anticipated shorter duration of consenting for WEC projects, and the long timeline envisaged for the floating wind projects in ScotWind due to the level of maturity of the floating wind industry compared to the timing of the ScotWind option agreement process, there is a timeframe of one to two years before wave projects would need to be initiated. This provides the timeline to better understand the sharing opportunities, to develop the details, prove/validate the benefits and refine the strategy and the specific sharing configurations to pursue.

Note that another key step for the wave projects is to engage with regulators in order to enable project start in 2024/2025. For example if a designated leasing round will be required by CES then early engagement is imperative for alignment of the option agreement timeline as these processes have a long lead time to develop, especially if additional Marine Spatial Planning is required. This aspect for implementation is covered in the first step where we recommend engagement with a broad range of stakeholders is initiated from the outset to best understand the risks, challenges, timelines, as well as the extent of the opportunities on offer.

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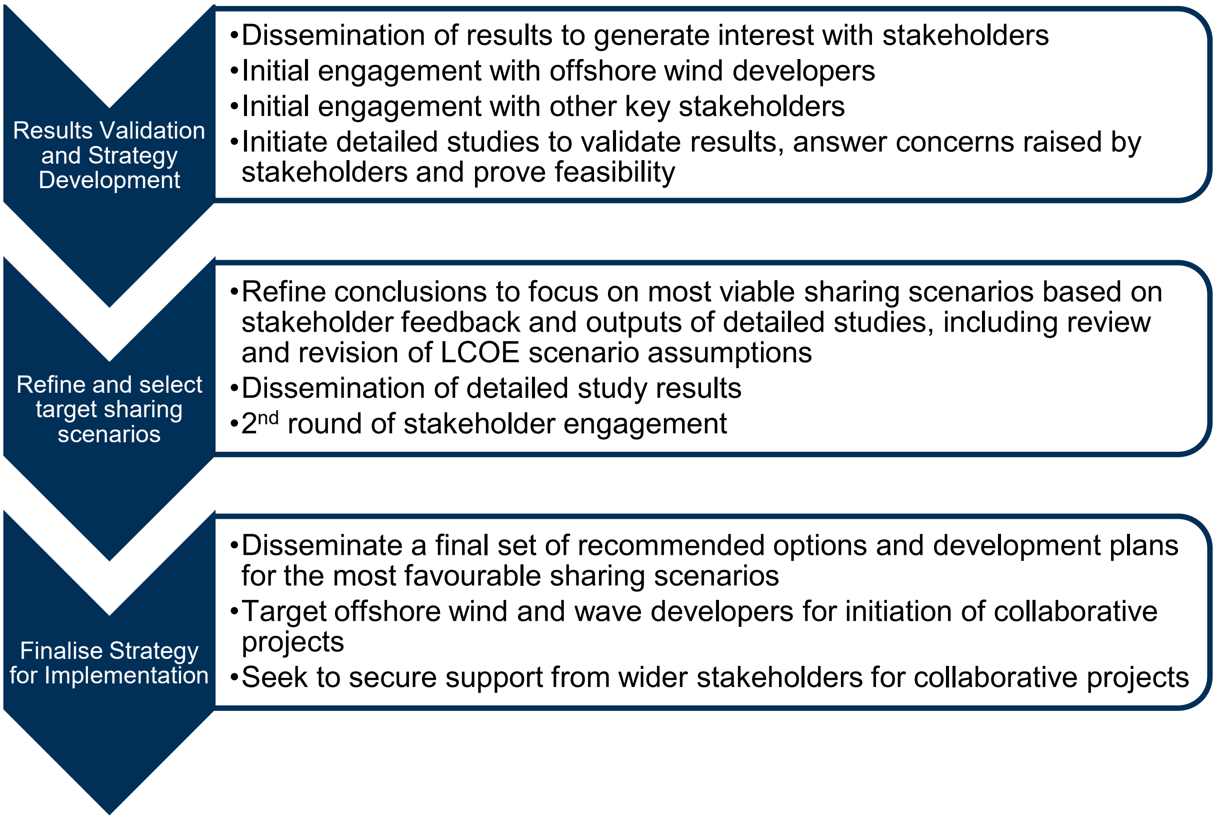

Figure 9-1 Roadmap for implementation of sharing scenarios

9.1 Engagement Activities

The complexities of a wave-wind collocation project mean that there is a large number of stakeholders who will have interest in the project. Therefore, early engagement with these stakeholders is essential.

Given the importance of ensuring the support of floating wind projects, arranging initial meetings with floating wind developers is key. As discussed previously, ScotWind projects present the best opportunity for this given the timing and the amount of floating projects that secured leases. Developers should be engaged to make them aware of the benefits available to them and to understand their biggest concerns so that they can be eased. Developers to engage with include:

- NW and Shetland sites where wave conditions are strongest
- Northland (floating and fixed wind sites)
- Magnora
- OWPL (fixed wind)
- Ocean Winds
- Mainstream
- ESB

Aside from ScotWind developers, there are a number of other opportunities and interested parties that could be engaged with. For example:

- Simply Blue (track record for wind and wave project development)
- Lease winners and site locations in recent/upcoming leasing rounds such as INTOG (big winners were Flotation Energy and Cerulean Winds) and Celtic Sea (launch in mid-2023)
- The wider pool of floating wind developers outside of Scotland

As well as developers, there are a number of other key stakeholders who need to be engaged to ensure their support and cooperation. This includes:

- Crown Estate
- National Grid and SHE-T
- OFGEM
- Marine Scotland
- Scottish Government

9.2 Dissemination

There are a number of floating wind conferences taking place around the UK and Europe this year at which the findings of this study could be presented to facilitate initial discussions. Some of the most relevant and widely attended events are:

- Floating Offshore Wind 2023 – RenewableUK. 4th-5th October 2023, Aberdeen (abstract deadline 24th March)
- European Wave and Tidal Energy Conference (EWTEC 2023). 3rd-7th September 2023, Bilbao
- Global Offshore Wind 2023 – Renewable UK. 14th-15th June 2023, London
- Offshore & Floating Wind Europe 2023 – Reuters. 9th-10th October 2023, London
- Renewable Power Generation and Future Power Systems Conference 2023 – IET. 15th-16th November 2023, Glasgow (abstract deadline 26 May 2023)

9.3 Detailed Studies Proposed

The findings of this study highlighted a number of areas in which more detailed studies are required to determine the feasibility and level of impact of certain aspects of sharing between wave and wind projects. It is recommended that more detailed studies are undertaken in the following areas to improved understanding:

- The feasibility of electrical systems integration such as sharing of IACs, power take-off and platforms
- The feasibility of versatile and hybrid platform designs including the current state of supply chain
- The benefits of versatile and hybrid platform designs
- The feasibility of employing modularity and standardisation across wind and wave components

- Quantification of the wave damping effect of WECs on floating WTGs in various spatial configurations and across different site conditions

10 Conclusions

This study has investigated a range of sharing scenarios and compared these to base case independent wave and wind projects. The benefits as well as risks of each sharing scenario has been analysed with respect to cost/LCOE, qualitative wider benefits, economic impact and feasibility.

Key conclusions are as follows:

- There is potential for significant cost reductions to be achieved:
    - Cost reductions of ~7% could be achieved for WTG developers by sharing aspects of their projects with WEC developers
    - Cost reductions close to 40% could be achieved for WEC developers
    - From a combined project perspective, the cost reduction could be around 12%.
- Scenarios which combined the most sharing options together achieved the greatest reduction, but sharing of IACs or platforms had little additional benefit beyond what could already be achieved.
- Even without sharing assets the overall cost reduction could be around 3%, which is worth considering given the competitive nature of CFD rounds.
- The initial model results indicate that using a versatile platform for WEC devices could be less favourable from a cost perspective compared to other scenarios, but further work is needed to assess the specific costs of such a platform for this application, as well as investigating how many WEC units can be integrated into one platform to properly understand the opportunities and limitations with respect to this option. The sensitivity analysis completed during this study indicated that platform weight may have a lower impact on the model results but the results are highly sensitive to the number of units if that results in a lower number of platforms overall. Furthermore, if the number of platforms is kept constant but the number of units is increased while the capacity of these reduces, this could result in more optimal energy capture and the versatile platform scenarios becoming comparably, or even more favourable than other scenarios .Consequently it is worth investigating the details of the versatile platform case in greater detailed to enable improved, more realistic assumptions to be made and the full potential benefits to be determined. In a qualitative sense there are clear potential benefits to this type of system with respect to installation and O&M, as well as enabling the smaller, more optimised units to the wave conditions to still be used within larger scale projects. All factors that make further investigation of this topic very worthwhile, despite the initial conclusions using conservative assumptions. Also note that despite the conservative assumptions, cost benefits were still seen in most of the versatile platform scenarios compared to the base cases, so it is just the level of cost reduction that can be achieved that needs further detailed study.

- There is a broad range of sharing scenarios that generate cost reduction, providing flexibility in terms of selecting which to prioritise, factoring in the feasibility, stakeholder perspectives, perceived risks and wider benefits aspects.
- There is significant potential for wider benefits with respect to WECs improving availability and for shared platform design. This should be investigated further to understand feasibility and cost as it may be especially attractive to wind developers given the harsh metocean conditions for some ScotWind projects and the negative impact this will have on floating wind projects.
- The WEC configuration selected, which is partially linked to the device type, has a clear impact on the cost reductions that can be achieved (i.e. comparing across the different scenarios), and further study would be beneficial to understand the level of cost reductions that can be achieved for different WEC device types. This could play a part in converging an a preferred device type/configuration for larger scale projects and/or a better understanding of which conditions (both site and project related) are preferable for the different WEC types.
- IAC sharing has clear cost benefits, but the feasibility and risks of combining these assets needs to be investigated further, both from a technical perspective but also in terms of the practicalities of implementation.
- The model currently considers combined capacity of the base case WEC and WTG projects when sharing. An alternative would be to look at whether the WEC capacity can be assumed within the WTG capacity given the different alignments of wave and wind resources. This could result in increased cost reduction through increased capacity factor.
- Achieving stakeholder buy-in through dissemination and engagement activities will be key to successful implementation of sharing scenarios
- It is recommended to initiate dissemination and engagement activities straight away, given the timelines for tapping into potential ScotWind opportunities, and factoring in the additional studies that are needed to help develop the details of sharing solutions and bring stakeholders to a place of understanding and comfort with the level of risks involved.
- Scenarios 3, 6, 7, 9 and 16 all indicate a reasonable compromise across LCOE, wider benefits and feasibility, albeit with quite different combinations of pros and cons across these categories. These could provide a starting point for further strategy development in terms of the optimal scenarios to select for promoting WEC-WTG collaboration. Elements of Scenarios 11/12/14/15 should also be kept in consideration as the highest cost reduction options.
- There is growing evidence that wave devices could have positive benefits on floating wind through either reducing motions of the platforms or improving weather window characteristics for maintenance activities.
    - Further studies should look into both the optimal configuration/positioning of WECs when separate from the WTG platforms so as to maximise this benefit whilst also maintaining WEC performance, as well as the integrated platform solution. Similarly a dedicated solution is required to tailor the WEC and platform design to maximise the shared benefit whilst maintaining WEC performance.

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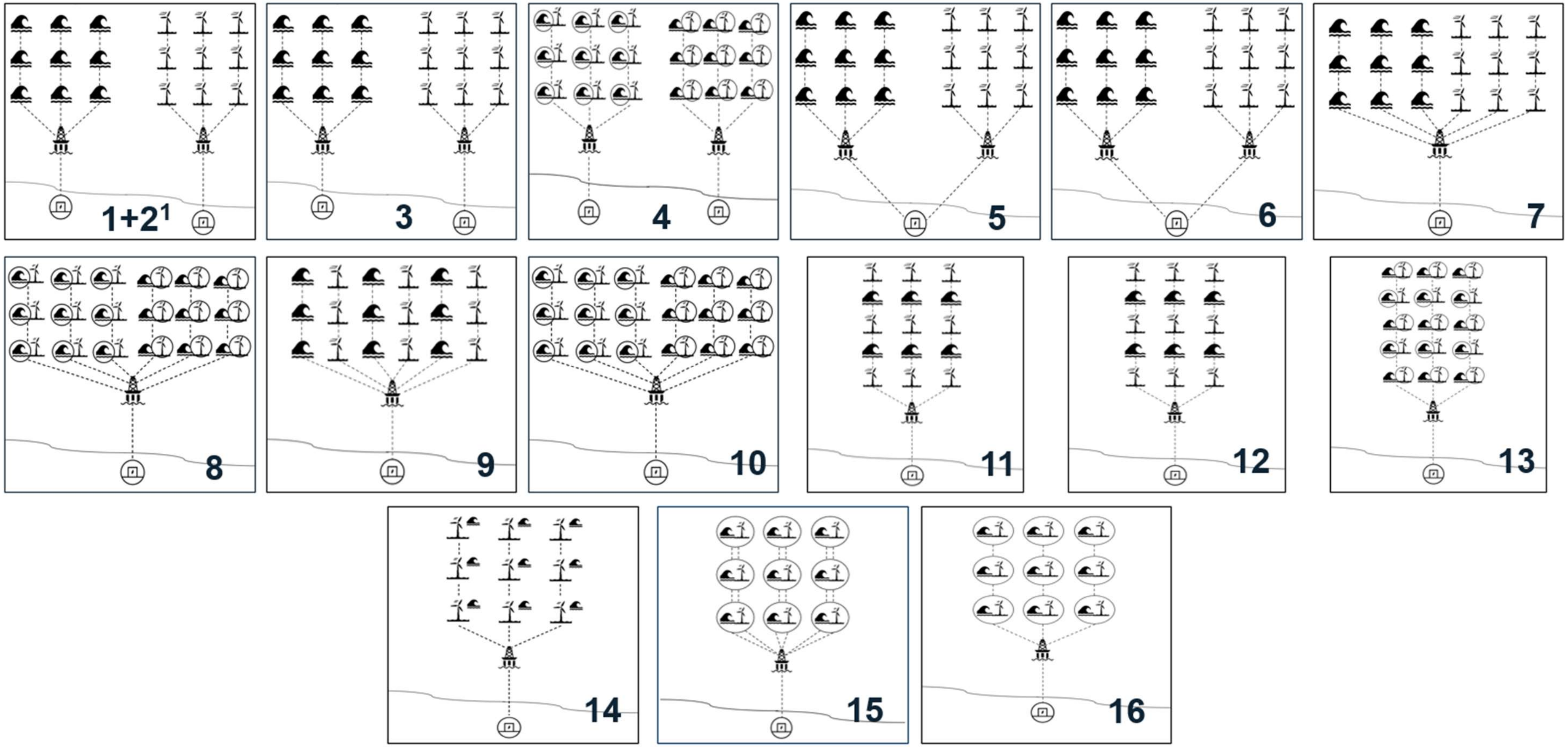
12 Appendix A

Component	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Spatial							Adjacent	Adjacent	Same site	Same site	Same site	Same site	Same site	Same site	Same site	Same site
Assets				VPs	OnSS	Landfall, onshore cables & OnSS	All tran. (except IACs)	All tran. (except IACs) & VPs	All tran. (except IACs)	All tran. (except IACs) & VPs	All tran.	All tran. & anchors	All tran., anchors & VPs	All tran. & PTO	All tran. (except IACs), HPs & anchors	All tran., HPs & anchors
Development			Surveys		OnSS consent	Onshore consent and surveys	Consent for all tran.	Consent for all tran.	Lease, surveys & consent	Lease, surveys & consent	Lease, surveys, consent & design	Lease, surveys, consent & design	Lease, surveys, consent & design	Fully shared	Fully shared	Fully shared
Supply chain			Small benefit to WEC	EoS due to use of VPs	OnSS	All onshore parts	All tran.	All tran. & VPs	All tran.	All tran.	Shared except WEC platform	Shared except WEC platform	Fully shared	Shared except WEC platform	Fully shared	Fully shared
Installation			Vessels & ports		OnSS	All onshore parts	All tran.	All tran.	All tran., vessels & ports	All tran., vessels & ports	Fully shared	Fully shared	Fully shared	Fully shared	Fully shared	Fully shared
O&M			Vessels & ports		OnSS	All onshore parts	All tran.	All tran.	All tran., vessels & ports	All tran., vessels & ports	Fully shared	Fully shared	Fully shared	Fully shared	Fully shared	Fully shared
Ownership			Independent but cooperative		Wave dev pays wind dev	Wave dev pays wind dev	Wave dev pays wind dev	Wave dev pays wind dev	Wave dev pays wind dev	Wave dev pays wind dev	One project	One project	One project	One project	One project	One project

VP – Versatile platform. OnSS – Onshore substation. OSS – Offshore substation. Tran. – Transmission infrastructure. PTO – Power take-off. HP – Hybrid platform. EoS – Economies of scale. Dev - developer



1 - This scenario corresponds to the baseline projects combined. Scenario 1 denotes the wind project independently and scenario 2 denotes the wave project independently. The two scenarios combined are also labelled as scenario 17

13 Appendix B

13.1 Base Case (WTG)

Table 1 – Investment in Wind Impact per Industry (BASE CASE (WTG))

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect persons	Induced persons	Total persons
Iron & Steel	62.86	8.45	71.31	81.43	20.71	102.14	1,632	277	1,909
Other metals & Casting	3.94	0.53	4.47	5.55	1.30	6.85	107	17	124
Electrical equipment	21.16	2.84	24.01	29.38	6.97	36.35	446	93	539
Machinery & equipment	21.61	2.90	24.51	30.88	7.12	38.00	436	95	531
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	17.62	2.37	19.99	32.23	5.80	38.03	586	78	664
Rental and leasing services	41.07	5.52	46.59	90.59	13.53	104.12	1,343	181	1,524
CAPEX total	**188.35**	**25.32**	**213.66**	**300.46**	**62.05**	**362.50**	**5,041**	**830**	**5,871**
Repair & maintenance	13.94	1.87	15.82	21.03	4.59	25.63	179	61	240
OPEX total	**13.94**	**1.87**	**15.82**	**21.03**	**4.59**	**25.63**	**179**	**61**	**240**
Financial services	3.64	0.49	4.13	7.04	1.20	8.24	69	16	85
Legal activities	2.42	0.33	2.74	3.91	0.80	4.71	66	11	77
Head office & consulting services	28.76	3.87	32.62	42.88	9.47	52.35	860	127	987
Advertising & market research	1.49	0.20	1.69	3.89	0.49	4.38	70	7	77
Rental and leasing services	4.10	0.55	4.66	9.05	1.35	10.40	134	18	152
Travel & related services	3.07	0.41	3.49	7.26	1.01	8.27	119	14	133
DEVEX total	**43.48**	**5.84**	**49.33**	**74.03**	**14.32**	**88.35**	**1,318**	**193**	**1,511**
Total	**245.78**	**33.03**	**278.81**	**395.52**	**80.97**	**476.48**	**6,538**	**1,084**	**7,622**

13.2 Base Case (WEC)

Table 2 – Investment in Wave Impact per Industry (BASE CASE (WEC))

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	12.60	1.69	14.29	16.32	4.15	20.47	327	56	383
Other metals & Casting	1.06	0.14	1.21	1.50	0.35	1.85	29	5	34
Electrical equipment	15.07	2.03	17.10	20.93	4.97	25.89	318	66	384
Machinery & equipment	6.73	0.90	7.64	9.62	2.22	11.84	136	30	166
Other manufacturing	10.05	1.35	11.40	15.21	3.31	18.52	246	44	290
Construction	15.77	2.12	17.89	28.84	5.20	34.04	524	70	594
Rental and leasing services	31.47	4.23	35.69	69.40	10.37	79.76	1,029	139	1,168
CAPEX total	**92.75**	**12.47**	**105.22**	**161.82**	**30.56**	**192.37**	**2,609**	**410**	**3,019**
Repair & maintenance	6.82	0.92	7.73	10.28	2.25	12.53	87	30	117
OPEX total	**6.82**	**0.92**	**7.73**	**10.28**	**2.25**	**12.53**	**87**	**30**	**117**
Financial services	1.28	0.17	1.45	2.46	0.42	2.88	24	6	30
Legal activities	0.85	0.11	0.96	1.37	0.28	1.65	23	4	27
Head office & consulting services	8.87	1.19	10.06	13.22	2.92	16.14	265	39	304
Advertising & market research	0.52	0.07	0.59	1.36	0.17	1.53	24	2	26
Rental and leasing services	-	-	-	-	-	-	-	-	-
Travel & related services	1.08	0.14	1.22	2.54	0.35	2.90	42	5	47
DEVEX total	**12.58**	**1.69**	**14.28**	**20.96**	**4.15**	**25.10**	**378**	**56**	**434**
Total	**112.15**	**15.07**	**127.23**	**193.06**	**36.95**	**230.01**	**3,074**	**496**	**3,570**

13.3 Indirect Synergies. No asset sharing

Table 3 – Total Impact per Industry (Indirect Synergies. No asset sharing)

Total	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect persons	Induced persons	Total persons
Iron & Steel	86.52	11.63	98.15	112.08	28.50	140.58	2,246	381	2,627
Other metals & Casting	4.46	0.60	5.06	6.29	1.47	7.76	121	20	141
Electrical equipment	47.71	6.41	54.12	66.24	15.72	81.96	1,005	210	1,215
Machinery & equipment	31.39	4.22	35.61	44.85	10.34	55.19	633	138	771
Other manufacturing	30.13	4.05	34.18	45.60	9.93	55.53	737	133	870
Construction	61.76	8.30	70.06	112.95	20.34	133.30	2,053	272	2,325
Rental and leasing services	92.15	12.39	104.54	203.25	30.36	233.61	3,014	406	3,420
CAPEX total	**354.12**	**47.60**	**401.72**	**591.26**	**116.66**	**707.92**	**9,809**	**1,560**	**11,369**
Repair & maintenance	14.90	2.00	16.90	22.47	4.91	27.38	191	66	257
OPEX total	**14.90**	**2.00**	**16.90**	**22.47**	**4.91**	**27.38**	**191**	**66**	**257**
Financial services	4.92	0.66	5.58	9.50	1.62	11.12	93	22	115
Legal activities	3.27	0.44	3.71	5.28	1.08	6.36	89	14	103
Head office & consulting services	37.62	5.06	42.68	56.10	12.39	68.50	1,126	166	1,292
Advertising & market research	2.01	0.27	2.28	5.25	0.66	5.91	94	9	103
Rental and leasing services	29.81	4.01	33.82	65.76	9.82	75.58	975	131	1,106
Travel & related services	4.15	0.56	4.71	9.80	1.37	11.17	161	18	179
DEVEX total	**81.78**	**10.99**	**92.77**	**151.69**	**26.94**	**178.63**	**2,538**	**360**	**2,898**
Total	**450.80**	**60.59**	**511.39**	**765.43**	**148.51**	**913.93**	**12,538**	**1,986**	**14,524**

Table 4 – Investment in Wind Impact per Industry (Indirect Synergies. No asset sharing)

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	67.05	9.01	76.06	86.86	22.09	108.95	1,741	296	2,037
Other metals & Casting	3.40	0.46	3.86	4.79	1.12	5.91	92	15	107
Electrical equipment	22.51	3.03	25.54	31.26	7.42	38.68	474	99	573
Machinery & equipment	22.76	3.06	25.82	32.53	7.50	40.03	459	100	559
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	28.37	3.81	32.18	51.88	9.35	61.23	943	125	1,068
Rental and leasing services	48.50	6.52	55.02	106.98	15.98	122.96	1,586	214	1,800
CAPEX total	**212.68**	**28.59**	**241.27**	**344.69**	**70.06**	**414.75**	**5,786**	**938**	**6,724**
Repair & maintenance	13.94	1.87	15.82	21.03	4.59	25.63	179	61	240
OPEX total	**13.94**	**1.87**	**15.82**	**21.03**	**4.59**	**25.63**	**179**	**61**	**240**
Financial services	3.64	0.49	4.13	7.04	1.20	8.24	69	16	85
Legal activities	2.42	0.33	2.74	3.91	0.80	4.71	66	11	77
Head office & consulting services	28.76	3.87	32.62	42.88	9.47	52.35	860	127	987
Advertising & market research	1.49	0.20	1.69	3.89	0.49	4.38	70	7	77
Rental and leasing services	3.85	0.52	4.36	8.48	1.27	9.75	126	17	143
Travel & related services	3.07	0.41	3.49	7.26	1.01	8.27	119	14	133
DEVEX total	**43.23**	**5.81**	**49.04**	**73.46**	**14.24**	**87.70**	**1,310**	**192**	**1,502**
Total	**269.85**	**36.27**	**306.12**	**439.19**	**88.90**	**528.08**	**7,275**	**1,191**	**8,466**

Table 5 – Investment in Wave Impact per Industry (Indirect Synergies. No asset sharing)

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	19.47	2.62	22.09	25.22	6.41	31.64	506	86	592
Other metals & Casting	1.06	0.14	1.21	1.50	0.35	1.85	29	5	34
Electrical equipment	25.19	3.39	28.58	34.98	8.30	43.28	531	111	642
Machinery & equipment	8.62	1.16	9.78	12.32	2.84	15.16	174	38	212
Other manufacturing	10.05	1.35	11.40	15.21	3.31	18.52	246	44	290
Construction	33.39	4.49	37.88	61.07	11.00	72.07	1,110	147	1,257
Rental and leasing services	43.65	5.87	49.52	96.27	14.38	110.65	1,428	192	1,620
CAPEX total	**141.44**	**19.01**	**160.45**	**246.57**	**46.59**	**293.17**	**4,024**	**623**	**4,647**
Repair & maintenance	0.95	0.13	1.08	1.44	0.31	1.75	12	4	16
OPEX total	**0.95**	**0.13**	**1.08**	**1.44**	**0.31**	**1.75**	**12**	**4**	**16**
Financial services	1.28	0.17	1.45	2.46	0.42	2.88	24	6	30
Legal activities	0.85	0.11	0.96	1.37	0.28	1.65	23	4	27
Head office & consulting services	8.87	1.19	10.06	13.22	2.92	16.14	265	39	304
Advertising & market research	0.52	0.07	0.59	1.36	0.17	1.53	24	2	26
Rental and leasing services	25.97	3.49	29.46	57.27	8.55	65.83	849	114	963
Travel & related services	1.08	0.14	1.22	2.54	0.35	2.90	42	5	47
DEVEX total	**38.55**	**5.18**	**43.73**	**78.23**	**12.70**	**90.93**	**1,227**	**170**	**1,397**
Total	**180.95**	**24.32**	**205.27**	**326.24**	**59.61**	**385.85**	**5,263**	**797**	**6,060**

 Confidential

13.4 Versatile Platform

Table 6 – Total Impact per Industry (Versatile Platform)

Total	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect persons	Induced persons	Total persons
Iron & Steel	84.71	11.39	96.09	109.74	27.91	137.64	2,199	373	2,572
Other metals & Casting	5.01	0.67	5.68	7.05	1.65	8.70	135	22	157
Electrical equipment	44.81	6.02	50.83	62.22	14.76	76.98	944	198	1,142
Machinery & equipment	31.39	4.22	35.61	44.85	10.34	55.19	633	138	771
Other manufacturing	46.63	6.27	52.90	70.58	15.36	85.94	1,140	206	1,346
Construction	61.76	8.30	70.06	112.95	20.34	133.30	2,053	272	2,325
Rental and leasing services	80.14	10.77	90.91	176.75	26.40	203.15	2,621	353	2,974
CAPEX total	**354.44**	**47.64**	**402.08**	**584.13**	**116.76**	**700.89**	**9,725**	**1,562**	**11,287**
Repair & maintenance	20.76	2.79	23.55	31.31	6.84	38.15	266	92	358
OPEX total	**20.76**	**2.79**	**23.55**	**31.31**	**6.84**	**38.15**	**266**	**92**	**358**
Financial services	4.92	0.66	5.58	9.50	1.62	11.12	93	22	115
Legal activities	3.27	0.44	3.71	5.28	1.08	6.36	89	14	103
Head office & consulting services	37.62	5.06	42.68	56.10	12.39	68.50	1,126	166	1,292
Advertising & market research	2.01	0.27	2.28	5.25	0.66	5.91	94	9	103
Rental and leasing services	34.88	4.69	39.57	76.93	11.49	88.42	1,141	154	1,295
Travel & related services	4.15	0.56	4.71	9.80	1.37	11.17	161	18	179
DEVEX total	**86.84**	**11.67**	**98.52**	**162.86**	**28.61**	**191.47**	**2,704**	**383**	**3,087**
Total	**462.04**	**62.10**	**524.15**	**778.31**	**152.21**	**930.52**	**12,695**	**2,037**	**14,732**

Table 7 – Investment in Wind Impact per Industry (Versatile Platform)

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	65.62	8.82	74.44	85.01	21.62	106.62	1,704	289	1,993
Other metals & Casting	3.94	0.53	4.47	5.55	1.30	6.85	107	17	124
Electrical equipment	22.51	3.03	25.54	31.26	7.42	38.68	474	99	573
Machinery & equipment	22.76	3.06	25.82	32.53	7.50	40.03	459	100	559
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	28.37	3.81	32.18	51.88	9.35	61.23	943	125	1,068
Rental and leasing services	48.50	6.52	55.02	106.98	15.98	122.96	1,586	214	1,800
CAPEX total	**211.79**	**28.47**	**240.26**	**343.60**	**69.77**	**413.37**	**5,764**	**933**	**6,697**
Repair & maintenance	13.94	1.87	15.82	21.03	4.59	25.63	179	61	240
OPEX total	**13.94**	**1.87**	**15.82**	**21.03**	**4.59**	**25.63**	**179**	**61**	**240**
Financial services	3.64	0.49	4.13	7.04	1.20	8.24	69	16	85
Legal activities	2.42	0.33	2.74	3.91	0.80	4.71	66	11	77
Head office & consulting services	28.76	3.87	32.62	42.88	9.47	52.35	860	127	987
Advertising & market research	1.49	0.20	1.69	3.89	0.49	4.38	70	7	77
Rental and leasing services	4.10	0.55	4.66	9.05	1.35	10.40	134	18	152
Travel & related services	3.07	0.41	3.49	7.26	1.01	8.27	119	14	133
DEVEX total	**43.48**	**5.84**	**49.33**	**74.03**	**14.32**	**88.35**	**1,318**	**193**	**1,511**
Total	**269.22**	**36.19**	**305.40**	**438.66**	**88.69**	**527.35**	**7,261**	**1,187**	**8,448**

Table 8 – Investment in Wave Impact per Industry (Versatile Platform)

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect persons	Induced persons	Total persons
Iron & Steel	19.09	2.57	21.65	24.73	6.29	31.02	496	84	580
Other metals & Casting	1.06	0.14	1.21	1.50	0.35	1.85	29	5	34
Electrical equipment	22.30	3.00	25.29	30.96	7.35	38.30	470	98	568
Machinery & equipment	8.62	1.16	9.78	12.32	2.84	15.16	174	38	212
Other manufacturing	26.55	3.57	30.12	40.18	8.75	48.93	649	117	766
Construction	33.39	4.49	37.88	61.07	11.00	72.07	1,110	147	1,257
Rental and leasing services	31.63	4.25	35.88	69.77	10.42	80.19	1,035	139	1,174
CAPEX total	**142.65**	**19.17**	**161.82**	**240.53**	**46.99**	**287.52**	**3,963**	**628**	**4,591**
Repair & maintenance	6.82	0.92	7.73	10.28	2.25	12.53	87	30	117
OPEX total	**6.82**	**0.92**	**7.73**	**10.28**	**2.25**	**12.53**	**87**	**30**	**117**
Financial services	1.28	0.17	1.45	2.46	0.42	2.88	24	6	30
Legal activities	0.85	0.11	0.96	1.37	0.28	1.65	23	4	27
Head office & consulting services	8.87	1.19	10.06	13.22	2.92	16.14	265	39	304
Advertising & market research	0.52	0.07	0.59	1.36	0.17	1.53	24	2	26
Rental and leasing services	30.78	4.14	34.91	67.88	10.14	78.02	1,007	136	1,143
Travel & related services	1.08	0.14	1.22	2.54	0.35	2.90	42	5	47
DEVEX total	**43.36**	**5.83**	**49.19**	**88.83**	**14.28**	**103.12**	**1,385**	**192**	**1,577**
Total	**192.82**	**25.92**	**218.74**	**339.65**	**63.52**	**403.17**	**5,435**	**850**	**6,285**

13.5 Shared Landfall & Onshore Substation

Table 9 – Total Impact per Industry (Shared Landfall & Onshore Substation)

Total	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	84.52	11.36	95.88	109.49	27.84	137.33	2,195	373	2,568
Other metals & Casting	4.46	0.60	5.06	6.29	1.47	7.76	121	20	141
Electrical equipment	58.83	7.91	66.74	81.69	19.38	101.07	1,240	259	1,499
Machinery & equipment	30.84	4.14	34.98	44.06	10.16	54.22	622	136	758
Other manufacturing	30.13	4.05	34.18	45.60	9.93	55.53	737	133	870
Construction	56.62	7.61	64.23	103.56	18.65	122.21	1,883	250	2,133
Rental and leasing services	88.60	11.91	100.51	195.42	29.19	224.61	2,898	391	3,289
CAPEX total	**354.01**	**47.58**	**401.59**	**586.11**	**116.62**	**702.73**	**9,696**	**1,562**	**11,258**
Repair & maintenance	18.57	2.50	21.07	28.01	6.12	34.13	238	82	320
OPEX total	**18.57**	**2.50**	**21.07**	**28.01**	**6.12**	**34.13**	**238**	**82**	**320**
Financial services	4.76	0.64	5.39	9.19	1.57	10.75	90	21	111
Legal activities	3.16	0.42	3.58	5.10	1.04	6.14	86	14	100
Head office & consulting services	36.33	4.88	41.22	54.18	11.97	66.15	1,087	160	1,247
Advertising & market research	1.94	0.26	2.20	5.08	0.64	5.72	91	9	100
Rental and leasing services	31.05	4.17	35.22	68.48	10.23	78.71	1,016	137	1,153
Travel & related services	4.01	0.54	4.55	9.47	1.32	10.79	156	18	174
DEVEX total	**81.25**	**10.92**	**92.17**	**151.50**	**26.76**	**178.26**	**2,526**	**359**	**2,885**
Total	**453.82**	**61.00**	**514.82**	**765.61**	**149.50**	**915.12**	**12,460**	**2,003**	**14,463**

Table 10 – Investment in Wind Impact per Industry (Shared Landfall & Onshore Substation)

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect persons	Induced persons	Total persons
Iron & Steel	66.05	8.88	74.93	85.56	21.76	107.32	1,715	291	2,006
Other metals & Casting	3.40	0.46	3.86	4.79	1.12	5.91	92	15	107
Electrical equipment	28.94	3.89	32.82	40.17	9.53	49.71	610	128	738
Machinery & equipment	22.49	3.02	25.51	32.13	7.41	39.54	454	99	553
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	25.80	3.47	29.27	47.19	8.50	55.69	858	114	972
Rental and leasing services	46.73	6.28	53.01	103.06	15.39	118.46	1,528	206	1,734
CAPEX total	**213.48**	**28.69**	**242.17**	**343.30**	**70.33**	**413.63**	**5,748**	**942**	**6,690**
Repair & maintenance	13.59	1.83	15.41	20.49	4.48	24.97	174	60	234
OPEX total	**13.59**	**1.83**	**15.41**	**20.49**	**4.48**	**24.97**	**174**	**60**	**234**
Financial services	3.56	0.48	4.04	6.88	1.17	8.05	67	16	83
Legal activities	2.37	0.32	2.68	3.82	0.78	4.60	64	10	74
Head office & consulting services	28.11	3.78	31.89	41.92	9.26	51.18	841	124	965
Advertising & market research	1.45	0.20	1.65	3.80	0.48	4.28	68	6	74
Rental and leasing services	3.91	0.53	4.44	8.63	1.29	9.92	128	17	145
Travel & related services	3.00	0.40	3.41	7.10	0.99	8.09	116	13	129
DEVEX total	**42.41**	**5.70**	**48.11**	**72.15**	**13.97**	**86.12**	**1,284**	**186**	**1,470**
Total	**269.47**	**36.22**	**305.69**	**435.94**	**88.77**	**524.71**	**7,206**	**1,188**	**8,394**

Table 11 – Investment in Wave Impact per Industry (Shared Landfall & Onshore Substation)

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	18.47	2.48	20.95	23.93	6.08	30.01	480	81	561
Other metals & Casting	1.06	0.14	1.21	1.50	0.35	1.85	29	5	34
Electrical equipment	29.90	4.02	33.92	41.51	9.85	51.36	630	132	762
Machinery & equipment	8.35	1.12	9.47	11.93	2.75	14.68	168	37	205
Other manufacturing	10.05	1.35	11.40	15.21	3.31	18.52	246	44	290
Construction	30.82	4.14	34.97	56.37	10.15	66.53	1,025	136	1,161
Rental and leasing services	41.87	5.63	47.50	92.36	13.79	106.15	1,370	185	1,555
CAPEX total	**140.53**	**18.89**	**159.41**	**242.80**	**46.29**	**289.10**	**3,948**	**620**	**4,568**
Repair & maintenance	4.99	0.67	5.66	7.52	1.64	9.16	64	22	86
OPEX total	**4.99**	**0.67**	**5.66**	**7.52**	**1.64**	**9.16**	**64**	**22**	**86**
Financial services	1.19	0.16	1.35	2.31	0.39	2.70	23	5	28
Legal activities	0.79	0.11	0.90	1.28	0.26	1.54	21	3	24
Head office & consulting services	8.22	1.11	9.33	12.26	2.71	14.97	246	36	282
Advertising & market research	0.49	0.07	0.55	1.27	0.16	1.43	23	2	25
Rental and leasing services	27.14	3.65	30.78	59.85	8.94	68.79	888	120	1,008
Travel & related services	1.01	0.14	1.14	2.38	0.33	2.71	39	4	43
DEVEX total	**38.84**	**5.22**	**44.06**	**79.35**	**12.79**	**92.14**	**1,240**	**170**	**1,410**
Total	**184.35**	**24.78**	**209.13**	**329.67**	**60.73**	**390.40**	**5,252**	**812**	**6,064**

13.6 Shared Offshore Substation

Table 12 – Total Impact per Industry (Shared Offshore Substation)

Total	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect persons	Induced persons	Total persons
Iron & Steel	72.49	9.74	82.23	93.91	23.88	117.79	1,882	320	2,202
Other metals & Casting	4.46	0.60	5.06	6.29	1.47	7.76	121	20	141
Electrical equipment	34.12	4.59	38.70	47.37	11.24	58.61	719	150	869
Machinery & equipment	27.52	3.70	31.22	39.33	9.07	48.39	555	121	676
Other manufacturing	30.13	4.05	34.18	45.60	9.93	55.53	737	133	870
Construction	25.77	3.46	29.24	47.14	8.49	55.63	857	114	971
Rental and leasing services	67.27	9.04	76.31	148.37	22.16	170.53	2,200	297	2,497
CAPEX total	**261.76**	**35.18**	**296.95**	**428.00**	**86.23**	**514.23**	**7,071**	**1,155**	**8,226**
Repair & maintenance	16.23	2.18	18.41	24.47	5.35	29.82	208	72	280
OPEX total	**16.23**	**2.18**	**18.41**	**24.47**	**5.35**	**29.82**	**208**	**72**	**280**
Financial services	4.37	0.59	4.96	8.45	1.44	9.89	83	19	102
Legal activities	2.90	0.39	3.29	4.69	0.96	5.65	79	13	92
Head office & consulting services	33.31	4.48	37.79	49.67	10.97	60.64	997	147	1,144
Advertising & market research	1.78	0.24	2.02	4.67	0.59	5.26	84	8	92
Rental and leasing services	22.94	3.08	26.02	50.59	7.56	58.15	750	101	851
Travel & related services	3.69	0.50	4.18	8.71	1.21	9.93	143	16	159
DEVEX total	**69.00**	**9.27**	**78.27**	**126.78**	**22.73**	**149.51**	**2,136**	**304**	**2,440**
Total	**346.99**	**46.64**	**393.62**	**579.25**	**114.31**	**693.56**	**9,415**	**1,531**	**10,946**

Table 13 – Investment in Wind Impact per Industry (Shared Offshore Substation)

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	64.08	8.61	72.69	83.01	21.11	104.12	1,664	282	1,946
Other metals & Casting	3.40	0.46	3.86	4.79	1.12	5.91	92	15	107
Electrical equipment	27.14	3.65	30.79	37.68	8.94	46.62	572	120	692
Machinery & equipment	21.95	2.95	24.90	31.36	7.23	38.59	443	97	540
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	20.75	2.79	23.54	37.95	6.84	44.78	690	91	781
Rental and leasing services	43.24	5.81	49.05	95.36	14.24	109.60	1,414	191	1,605
CAPEX total	**200.63**	**26.97**	**227.60**	**320.54**	**66.09**	**386.63**	**5,366**	**885**	**6,251**
Repair & maintenance	13.59	1.83	15.41	20.49	4.48	24.97	174	60	234
OPEX total	**13.59**	**1.83**	**15.41**	**20.49**	**4.48**	**24.97**	**174**	**60**	**234**
Financial services	3.37	0.45	3.82	6.51	1.11	7.62	64	15	79
Legal activities	2.24	0.30	2.54	3.62	0.74	4.35	61	10	71
Head office & consulting services	26.60	3.58	30.17	39.66	8.76	48.43	796	117	913
Advertising & market research	1.38	0.18	1.56	3.60	0.45	4.05	65	6	71
Rental and leasing services	3.46	0.47	3.93	7.64	1.14	8.78	113	15	128
Travel & related services	2.84	0.38	3.22	6.71	0.94	7.65	110	13	123
DEVEX total	**39.89**	**5.36**	**45.25**	**67.74**	**13.14**	**80.88**	**1,209**	**176**	**1,385**
Total	**254.10**	**34.15**	**288.26**	**408.78**	**83.71**	**492.48**	**6,749**	**1,121**	**7,870**

Table 14 – Investment in Wave Impact per Industry (Shared Offshore Substation)

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect £m	Induced £m	Total £m	Direct + Indirect persons	Induced persons	Total persons
Iron & Steel	8.41	1.13	9.54	10.89	2.77	13.67	218	37	255
Other metals & Casting	1.06	0.14	1.21	1.50	0.35	1.85	29	5	34
Electrical equipment	6.98	0.94	7.92	9.69	2.30	11.99	147	31	178
Machinery & equipment	5.58	0.75	6.33	7.97	1.84	9.81	113	25	138
Other manufacturing	10.05	1.35	11.40	15.21	3.31	18.52	246	44	290
Construction	5.02	0.68	5.70	9.19	1.65	10.84	167	22	189
Rental and leasing services	24.03	3.23	27.26	53.01	7.92	60.93	786	106	892
CAPEX total	**61.13**	**8.22**	**69.35**	**107.46**	**20.14**	**127.59**	**1,706**	**270**	**1,976**
Repair & maintenance	2.64	0.35	3.00	3.98	0.87	4.85	34	12	46
OPEX total	**2.64**	**0.35**	**3.00**	**3.98**	**0.87**	**4.85**	**34**	**12**	**46**
Financial services	1.00	0.13	1.14	1.94	0.33	2.27	19	4	23
Legal activities	0.67	0.09	0.75	1.08	0.22	1.29	18	3	21
Head office & consulting services	6.71	0.90	7.61	10.01	2.21	12.22	201	30	231
Advertising & market research	0.41	0.05	0.46	1.07	0.13	1.20	19	2	21
Rental and leasing services	19.48	2.62	22.09	42.95	6.42	49.37	637	86	723
Travel & related services	0.85	0.11	0.96	2.00	0.28	2.27	33	4	37
DEVEX total	**29.11**	**3.91**	**33.02**	**59.04**	**9.59**	**68.63**	**927**	**129**	**1,056**
Total	**92.88**	**12.48**	**105.37**	**170.48**	**30.60**	**201.07**	**2,667**	**411**	**3,078**

13.7 Shared Offshore Substation & Vessels

Table 15 – Total Impact per Industry (Shared Offshore Substation & Vessels)

Total	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	72.49	9.74	82.23	93.91	23.88	117.79	1,882	320	2,202
Other metals & Casting	4.46	0.60	5.06	6.29	1.47	7.76	121	20	141
Electrical equipment	34.91	4.69	39.60	48.47	11.50	59.97	736	154	890
Machinery & equipment	27.52	3.70	31.22	39.33	9.07	48.39	555	121	676
Other manufacturing	30.13	4.05	34.18	45.60	9.93	55.53	737	133	870
Construction	25.77	3.46	29.24	47.14	8.49	55.63	857	114	971
Rental and leasing services	55.25	7.43	62.68	121.86	18.20	140.07	1,807	244	2,051
CAPEX total	**250.54**	**33.67**	**284.21**	**402.59**	**82.53**	**485.12**	**6,695**	**1,106**	**7,801**
Repair & maintenance	14.47	1.94	16.41	21.82	4.77	26.59	185	64	249
OPEX total	**14.47**	**1.94**	**16.41**	**21.82**	**4.77**	**26.59**	**185**	**64**	**249**
Financial services	4.37	0.59	4.96	8.45	1.44	9.89	83	19	102
Legal activities	2.90	0.39	3.29	4.69	0.96	5.65	79	13	92
Head office & consulting services	33.31	4.48	37.79	49.67	10.97	60.64	997	147	1,144
Advertising & market research	1.78	0.24	2.02	4.67	0.59	5.26	84	8	92
Rental and leasing services	22.94	3.08	26.02	50.59	7.56	58.15	750	101	851
Travel & related services	3.69	0.50	4.18	8.71	1.21	9.93	143	16	159
DEVEX total	**69.00**	**9.27**	**78.27**	**126.78**	**22.73**	**149.51**	**2,136**	**304**	**2,440**
Total	**334.00**	**44.89**	**378.89**	**551.19**	**110.03**	**661.22**	**9,016**	**1,474**	**10,490**

Table 16 – Investment in Wind Impact per Industry (Shared Offshore Substation & Vessels)

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	64.08	8.61	72.69	83.01	21.11	104.12	1,664	282	1,946
Other metals & Casting	3.40	0.46	3.86	4.79	1.12	5.91	92	15	107
Electrical equipment	27.14	3.65	30.79	37.68	8.94	46.62	572	120	692
Machinery & equipment	21.95	2.95	24.90	31.36	7.23	38.59	443	97	540
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	20.75	2.79	23.54	37.95	6.84	44.78	690	91	781
Rental and leasing services	43.24	5.81	49.05	95.36	14.24	109.60	1,414	191	1,605
CAPEX total	**200.63**	**26.97**	**227.60**	**320.54**	**66.09**	**386.63**	**5,366**	**885**	**6,251**
Repair & maintenance	13.59	1.83	15.41	20.49	4.48	24.97	174	60	234
OPEX total	**13.59**	**1.83**	**15.41**	**20.49**	**4.48**	**24.97**	**174**	**60**	**234**
Financial services	3.37	0.45	3.82	6.51	1.11	7.62	64	15	79
Legal activities	2.24	0.30	2.54	3.62	0.74	4.35	61	10	71
Head office & consulting services	26.60	3.58	30.17	39.66	8.76	48.43	796	117	913
Advertising & market research	1.38	0.18	1.56	3.60	0.45	4.05	65	6	71
Rental and leasing services	3.46	0.47	3.93	7.64	1.14	8.78	113	15	128
Travel & related services	2.84	0.38	3.22	6.71	0.94	7.65	110	13	123
DEVEX total	**39.89**	**5.36**	**45.25**	**67.74**	**13.14**	**80.88**	**1,209**	**176**	**1,385**
Total	**254.10**	**34.15**	**288.26**	**408.78**	**83.71**	**492.48**	**6,749**	**1,121**	**7,870**

Table 17 – Investment in Wave Impact per Industry (Shared Offshore Substation & Vessels)

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	8.41	1.13	9.54	10.89	2.77	13.67	218	37	255
Other metals & Casting	1.06	0.14	1.21	1.50	0.35	1.85	29	5	34
Electrical equipment	7.77	1.04	8.81	10.78	2.56	13.34	164	34	198
Machinery & equipment	5.58	0.75	6.33	7.97	1.84	9.81	113	25	138
Other manufacturing	10.05	1.35	11.40	15.21	3.31	18.52	246	44	290
Construction	5.02	0.68	5.70	9.19	1.65	10.84	167	22	189
Rental and leasing services	12.02	1.62	13.63	26.50	3.96	30.46	393	53	446
CAPEX total	**49.91**	**6.71**	**56.62**	**82.05**	**16.44**	**98.49**	**1,330**	**220**	**1,550**
Repair & maintenance	0.88	0.12	1.00	1.33	0.29	1.62	11	4	15
OPEX total	**0.88**	**0.12**	**1.00**	**1.33**	**0.29**	**1.62**	**11**	**4**	**15**
Financial services	1.00	0.13	1.14	1.94	0.33	2.27	19	4	23
Legal activities	0.67	0.09	0.75	1.08	0.22	1.29	18	3	21
Head office & consulting services	6.71	0.90	7.61	10.01	2.21	12.22	201	30	231
Advertising & market research	0.41	0.05	0.46	1.07	0.13	1.20	19	2	21
Rental and leasing services	19.48	2.62	22.09	42.95	6.42	49.37	637	86	723
Travel & related services	0.85	0.11	0.96	2.00	0.28	2.27	33	4	37
DEVEX total	**29.11**	**3.91**	**33.02**	**59.04**	**9.59**	**68.63**	**927**	**129**	**1,056**
Total	**79.90**	**10.74**	**90.64**	**142.42**	**26.32**	**168.74**	**2,268**	**353**	**2,621**

13.8 Shared Offshore Substation, Vessels & Versatile Platform

Table 18 – Total Impact per Industry (Shared Offshore Substation, Vessels & Versatile Platform)

Total	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	70.68	9.50	80.18	91.56	23.28	114.84	1,835	312	2,147
Other metals & Casting	5.01	0.67	5.68	7.05	1.65	8.70	135	22	157
Electrical equipment	35.43	4.76	40.20	49.20	11.67	60.87	747	156	903
Machinery & equipment	27.52	3.70	31.22	39.33	9.07	48.39	555	121	676
Other manufacturing	46.63	6.27	52.90	70.58	15.36	85.94	1,140	206	1,346
Construction	25.77	3.46	29.24	47.14	8.49	55.63	857	114	971
Rental and leasing services	55.25	7.43	62.68	121.86	18.20	140.07	1,807	244	2,051
CAPEX total	**266.29**	**35.79**	**302.09**	**426.71**	**87.73**	**514.44**	**7,076**	**1,175**	**8,251**
Repair & maintenance	14.47	1.94	16.41	21.82	4.77	26.59	185	64	249
OPEX total	**14.47**	**1.94**	**16.41**	**21.82**	**4.77**	**26.59**	**185**	**64**	**249**
Financial services	4.37	0.59	4.96	8.45	1.44	9.89	83	19	102
Legal activities	2.90	0.39	3.29	4.69	0.96	5.65	79	13	92
Head office & consulting services	33.31	4.48	37.79	49.67	10.97	60.64	997	147	1,144
Advertising & market research	1.78	0.24	2.02	4.67	0.59	5.26	84	8	92
Rental and leasing services	22.94	3.08	26.02	50.59	7.56	58.15	750	101	851
Travel & related services	3.69	0.50	4.18	8.71	1.21	9.93	143	16	159
DEVEX total	**69.00**	**9.27**	**78.27**	**126.78**	**22.73**	**149.51**	**2,136**	**304**	**2,440**
Total	**349.76**	**47.01**	**396.77**	**575.31**	**115.22**	**690.53**	**9,397**	**1,543**	**10,940**

Table 19 – Investment in Wind Impact per Industry (Shared Offshore Substation, Vessels & Versatile Platform)

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	62.65	8.42	71.07	81.16	20.64	101.80	1,627	276	1,903
Other metals & Casting	3.94	0.53	4.47	5.55	1.30	6.85	107	17	124
Electrical equipment	27.14	3.65	30.79	37.68	8.94	46.62	572	120	692
Machinery & equipment	21.95	2.95	24.90	31.36	7.23	38.59	443	97	540
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	20.75	2.79	23.54	37.95	6.84	44.78	690	91	781
Rental and leasing services	43.24	5.81	49.05	95.36	14.24	109.60	1,414	191	1,605
CAPEX total	**199.74**	**26.85**	**226.59**	**319.45**	**65.80**	**385.25**	**5,344**	**881**	**6,225**
Repair & maintenance	13.59	1.83	15.41	20.49	4.48	24.97	174	60	234
OPEX total	**13.59**	**1.83**	**15.41**	**20.49**	**4.48**	**24.97**	**174**	**60**	**234**
Financial services	3.37	0.45	3.82	6.51	1.11	7.62	64	15	79
Legal activities	2.24	0.30	2.54	3.62	0.74	4.35	61	10	71
Head office & consulting services	26.60	3.58	30.17	39.66	8.76	48.43	796	117	913
Advertising & market research	1.38	0.18	1.56	3.60	0.45	4.05	65	6	71
Rental and leasing services	3.46	0.47	3.93	7.64	1.14	8.78	113	15	128
Travel & related services	2.84	0.38	3.22	6.71	0.94	7.65	110	13	123
DEVEX total	**39.89**	**5.36**	**45.25**	**67.74**	**13.14**	**80.88**	**1,209**	**176**	**1,385**
Total	**253.22**	**34.03**	**287.25**	**407.69**	**83.42**	**491.10**	**6,727**	**1,117**	**7,844**

Table 20 – Investment in Wave Impact per Industry (Shared Offshore Substation, Vessels & Versatile Platform)

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	8.03	1.08	9.11	10.40	2.65	13.05	208	35	243
Other metals & Casting	1.06	0.14	1.21	1.50	0.35	1.85	29	5	34
Electrical equipment	8.29	1.11	9.41	11.52	2.73	14.25	175	37	212
Machinery & equipment	5.58	0.75	6.33	7.97	1.84	9.81	113	25	138
Other manufacturing	26.55	3.57	30.12	40.18	8.75	48.93	649	117	766
Construction	5.02	0.68	5.70	9.19	1.65	10.84	167	22	189
Rental and leasing services	12.02	1.62	13.63	26.50	3.96	30.46	393	53	446
CAPEX total	**66.55**	**8.95**	**75.50**	**107.26**	**21.92**	**129.18**	**1,734**	**294**	**2,028**
Repair & maintenance	0.88	0.12	1.00	1.33	0.29	1.62	11	4	15
OPEX total	**0.88**	**0.12**	**1.00**	**1.33**	**0.29**	**1.62**	**11**	**4**	**15**
Financial services	1.00	0.13	1.14	1.94	0.33	2.27	19	4	23
Legal activities	0.67	0.09	0.75	1.08	0.22	1.29	18	3	21
Head office & consulting services	6.71	0.90	7.61	10.01	2.21	12.22	201	30	231
Advertising & market research	0.41	0.05	0.46	1.07	0.13	1.20	19	2	21
Rental and leasing services	19.48	2.62	22.09	42.95	6.42	49.37	637	86	723
Travel & related services	0.85	0.11	0.96	2.00	0.28	2.27	33	4	37
DEVEX total	**29.11**	**3.91**	**33.02**	**59.04**	**9.59**	**68.63**	**927**	**129**	**1,056**
Total	**96.54**	**12.98**	**109.52**	**167.63**	**31.80**	**199.43**	**2,672**	**427**	**3,099**

13.9 Fully Shared

Table 21 – Total Impact per Industry (Fully Shared)

Total	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	80.79	10.86	91.65	104.66	26.62	131.28	2,098	356	2,454
Other metals & Casting	3.40	0.46	3.86	4.79	1.12	5.91	92	15	107
Electrical equipment	25.99	3.49	29.48	36.08	8.56	44.64	548	115	663
Machinery & equipment	27.52	3.70	31.22	39.33	9.07	48.39	555	121	676
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	25.77	3.46	29.24	47.14	8.49	55.63	857	114	971
Rental and leasing services	45.99	6.18	52.17	101.43	15.15	116.58	1,504	203	1,707
CAPEX total	**229.54**	**30.85**	**260.40**	**363.82**	**75.62**	**439.44**	**6,145**	**1,013**	**7,158**
Repair & maintenance	13.81	1.86	15.67	20.83	4.55	25.38	177	61	238
OPEX total	**13.81**	**1.86**	**15.67**	**20.83**	**4.55**	**25.38**	**177**	**61**	**238**
Financial services	4.04	0.54	4.59	7.81	1.33	9.15	77	18	95
Legal activities	2.69	0.36	3.05	4.34	0.88	5.23	73	12	85
Head office & consulting services	32.88	4.42	37.30	49.03	10.83	59.86	984	145	1,129
Advertising & market research	1.65	0.22	1.87	4.32	0.54	4.86	77	7	84
Rental and leasing services	13.40	1.80	15.20	29.56	4.41	33.97	438	59	497
Travel & related services	3.41	0.46	3.87	8.06	1.12	9.18	132	15	147
DEVEX total	**58.07**	**7.81**	**65.88**	**103.11**	**19.13**	**122.24**	**1,781**	**256**	**2,037**
Total	**301.43**	**40.51**	**341.94**	**487.77**	**99.30**	**587.06**	**8,103**	**1,330**	**9,433**

Table 22 – Investment in Wind Impact per Industry (Fully Shared)

WIND	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	72.38	9.73	82.11	93.77	23.84	117.61	1,879	319	2,198
Other metals & Casting	3.40	0.46	3.86	4.79	1.12	5.91	92	15	107
Electrical equipment	25.99	3.49	29.48	36.08	8.56	44.64	548	115	663
Machinery & equipment	21.95	2.95	24.90	31.36	7.23	38.59	443	97	540
Other manufacturing	20.08	2.70	22.78	30.39	6.61	37.01	491	89	580
Construction	20.75	2.79	23.54	37.95	6.84	44.78	690	91	781
Rental and leasing services	43.24	5.81	49.05	95.36	14.24	109.60	1,414	191	1,605
CAPEX total	**207.78**	**27.93**	**235.71**	**329.70**	**68.45**	**398.15**	**5,557**	**917**	**6,474**
Repair & maintenance	13.59	1.83	15.41	20.49	4.48	24.97	174	60	234
OPEX total	**13.59**	**1.83**	**15.41**	**20.49**	**4.48**	**24.97**	**174**	**60**	**234**
Financial services	3.21	0.43	3.64	6.19	1.06	7.25	61	14	75
Legal activities	2.13	0.29	2.42	3.44	0.70	4.14	58	9	67
Head office & consulting services	26.38	3.55	29.93	39.34	8.69	48.03	789	116	905
Advertising & market research	1.31	0.18	1.48	3.42	0.43	3.85	61	6	67
Rental and leasing services	2.82	0.38	3.20	6.22	0.93	7.15	92	12	104
Travel & related services	2.70	0.36	3.07	6.39	0.89	7.28	105	12	117
DEVEX total	**38.55**	**5.18**	**43.74**	**65.01**	**12.70**	**77.71**	**1,166**	**169**	**1,335**
Total	**259.92**	**34.94**	**294.86**	**415.20**	**85.62**	**500.83**	**6,897**	**1,146**	**8,043**

Table 23 – Investment in Wave Impact per Industry (Fully Shared)

WAVE	Income			GVA			Employment		
TOTAL IMPACT PER INDUSTRY Industry	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect £m**	**Induced £m**	**Total £m**	**Direct + Indirect persons**	**Induced persons**	**Total persons**
Iron & Steel	8.41	1.13	9.54	10.89	2.77	13.67	218	37	255
Other metals & Casting	-	-	-	-	-	-	-	-	-
Electrical equipment	-	-	-	-	-	-	-	-	-
Machinery & equipment	5.58	0.75	6.33	7.97	1.84	9.81	113	25	138
Other manufacturing	-	-	-	-	-	-	-	-	-
Construction	5.02	0.68	5.70	9.19	1.65	10.84	167	22	189
Rental and leasing services	2.75	0.37	3.12	6.07	0.91	6.98	90	12	102
CAPEX total	**21.76**	**2.93**	**24.69**	**34.12**	**7.17**	**41.29**	**588**	**96**	**684**
Repair & maintenance	0.23	0.03	0.26	0.34	0.07	0.41	3	1	4
OPEX total	**0.23**	**0.03**	**0.26**	**0.34**	**0.07**	**0.41**	**3**	**1**	**4**
Financial services	0.84	0.11	0.95	1.62	0.28	1.90	16	4	20
Legal activities	0.56	0.07	0.63	0.90	0.18	1.08	15	2	17
Head office & consulting services	6.49	0.87	7.37	9.68	2.14	11.82	194	29	223
Advertising & market research	0.34	0.05	0.39	0.89	0.11	1.01	16	2	18
Rental and leasing services	10.58	1.42	12.00	23.33	3.49	26.82	346	47	393
Travel & related services	0.71	0.10	0.80	1.67	0.23	1.90	27	3	30
DEVEX total	**19.52**	**2.62**	**22.14**	**38.10**	**6.43**	**44.53**	**614**	**87**	**701**
Total	**41.51**	**5.58**	**47.09**	**72.56**	**13.67**	**86.24**	**1,205**	**184**	**1,389**

OWC, an ABL Group company, is a specialised independent consultancy offering project development services, owner's engineering and technical due diligence to the offshore wind industry, developing and realising projects across the globe.

OWC's core team possesses strong industry expertise which dates to the first offshore wind farm development in the UK. Since then, OWC has been involved in the majority of the major offshore wind projects in Europe, Asia and the US.

OWC offices: Boston, Cork, Edinburgh, Hamburg, London, New York, Seoul, Taipei, Tokyo and Warsaw.

Markets: Fixed and floating offshore wind, ocean energy, subsea cables and energy storage.