PivotBuoy

An Advanced System for Cost-effective and Reliable Mooring, Connection, Installation & Operation of Floating Wind

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D7.1 – Techno-economic model

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PP	Restricted to other programme participants (including the Commission Services)	
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EXECUTIVE SUMMARY

Levelized Cost Of Energy (LCOE) is a method to compare the costs of different generation technologies, which has been used by analysts to evaluate competitive technological options in the electricity market. The LCOE delivers the necessary payments according to an energy production that allows to recover the investment. The amount delivered represents, in real currency (Euros, Dollars, etc…), the cost per MWh (or whatever is the used energy unit) of projects of unequal life spans, size, different capital cost, fuel costs, operation and maintenance (O&M) cost, risk, return, and capacities.

For utilities and project developers, the calculation of LCOE represents a tool to support the selection of generation technologies. For governmental bodies, regulators and policymakers, it is a tool to support political decisions on how future energy needs will be met and which technologies to support. It can be used to determine economic efficiency and effectiveness, as well as performance or cost thresholds. It could also be used to identify areas for cost-savings.

The main objective of PivotBuoy is to demonstrate how it will be possible to reduce the cost of energy of floating wind by 50% through the validation of its innovative technology, an innovative subsystem that aims at reducing the costs of mooring systems and floating platforms, allow faster and cheaper installation and a more reliable and sustainable operation.

This report presents the LCOE model developed and to be implemented in PivotBuoy, aiming at calculating the economic benefits that this innovative solution can bring to the floating offshore wind industry. The analysis of the levelized cost of energy of PivotBuoy technology, does not aim only to perform a final assessment in the end of the project. As much as possible, it aims also to guide the design and engineering teams in a earlier stage of the project in order to find the optimal solution between technical requirements for a reliable solution but as cost effective as possible.

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1 INTRODUCTION

1.1 Purposes and Scope of Deliverable

This report provides the framework and description of structure that will serve as basis for the development of the Levelized Cost of Energy Model of PivotBuoy and its following implementation.

Section 2 presents an overview of the offshore wind industry, focusing on what has been the evolution in terms of installed capacity and costs. It gives a glance on what are the near future expectations for the cost evolution of floating offshore wind technologies. On this section is as well described what is the experience of PivotBuoy consortium on the calculation of Levelized Costs of Energy.

Section 3 presents the PivotBuoy LCOE Modularised Model, detailing what will be the main assumptions considered for the evaluation of PivotBuoy costs, the structure to be followed in order to identify and quantify all the Life-Cycle costs and the required input data to achieve it.

Finally, section 4 presents the identification of some high-level Key Performance Indicators that shall state the baseline for the evaluation of PivotBuoy economical success as well as to quantify its benefits.

1.2 References

1.2.1 Internal documents

[1] PivotBuoy Deliverable D4.1 – Test site environmental conditions, April 2018
[2] PivotBuoy Deliverable D2.1 - System requirements and design review criteria – PivotBuoy Basis of Design (BoD), May 2018.

1.2.2 External documents

[3] WindEurope Business Intelligence, Offshore Wind in Europe: Key trends and statistics 2018, February 2019
[4] International European Agency, H. Bahar, Offshore Wind, https://www.iea.org/tcep/power/renewables/offshorewind/, May 2019.
[5] Fraunhoffer ISE, Levelized Cost Of Electricity Renewable Energy Technologies, March 2018
[6] WindEurope, Floating Offshore Wind Energy a Policy Blueprint for Europe, October 2018
[7] The European Wind Energy Association, Wind Energy Scenarios for 2030, August 2015
[8] HSBC Global Research, Offshore Wind: New Giants of the Sea by 2021, April 2018 LEVELIZED
[9] International European Agency, Market Report Series: Renewables 2018 – Analysis and forecasts to 2023, October 2018

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1.3 Acronyms

Table 1-1: Acronyms

AEP	Annual Energy Production
CAPEX	Capital Expenditures
IEA	International Energy Agency
IRR	Internal Rate of Return
KPI	Key Performance Indicator
LCC	Life Cycle Costs
LCOE	Levelized Cost of Energy
NPV	Net Present Value
OPEX	Operational Expenditures
OW	Offshore Wind

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2 COST OF OFFSHORE WIND

2.1 Evolution of offshore wind deployment and cost

Grid-connected offshore wind capacity additions reached almost 4.5 GW in 2018, 15% higher than in 2017. Expansion shifted from the European Union to China: while EU additions declined by 16%, in China they more than tripled to 1.6 GW in 2018. For the first time, China installed more offshore capacity than any other country (1.6 GW), followed by the United Kingdom (1.3 GW) and Germany (0.9 GW) [3]. Europe surpassed 100 operating offshore wind projects in 2018, with 18 new sites being added, achieving a total of 2,649MW, and bringing the region's installed base to 18.5GW.

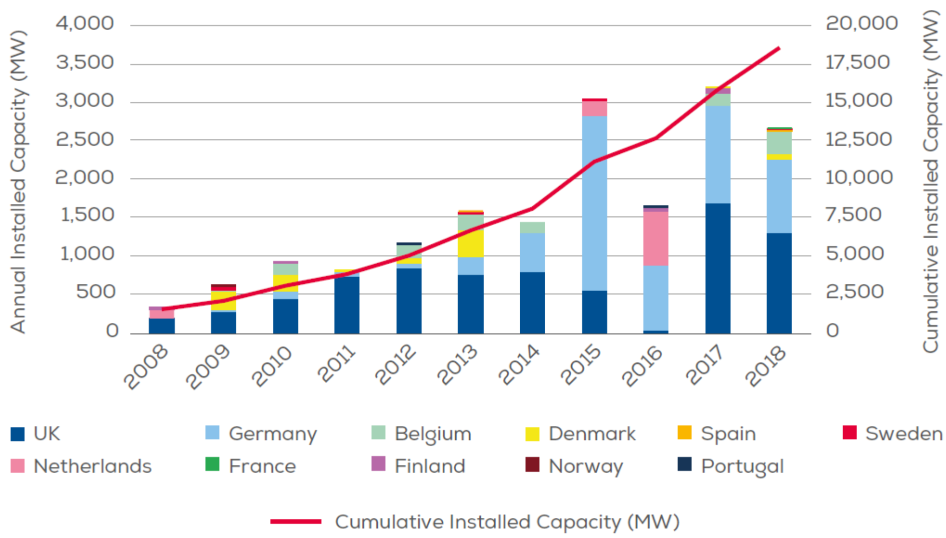

Figure 2-1: Offshore installed capacity in Europe (Wind-Europe, [3])

Nevertheless, offshore wind annual capacity additions need to more than quadruple by 2030. Despite positive technology developments and cost reductions, growth must accelerate for the technology to get fully on track with the Sustainable Development Scenario (SDS) [4].

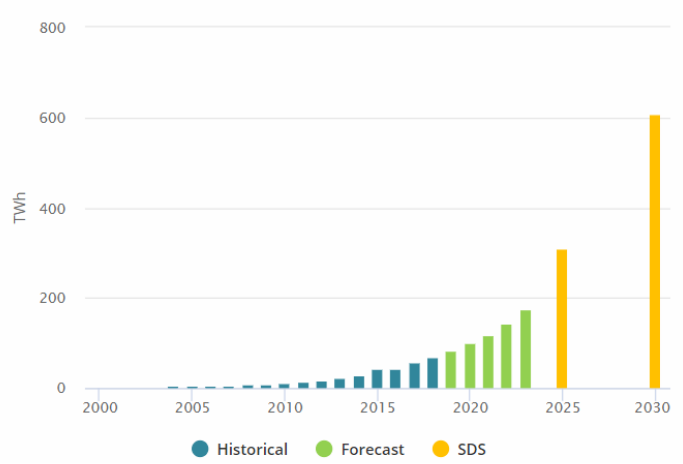

Figure 2-2: Offshore Wind Generation evolution in the World (IEA, [4])

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As the offshore wind industry keeps growing, the favourite among foundation types, with an 87% share by units installed in 2017 keeps being the monopile, which is expected to keep being the dominant technology in offshore wind up to 2020. This is a huge tubular steel structure up to 8m in diameter and up to 100m in length which is hammered vertically into the seabed to form the base on to which the turbine is subsequently mounted.

The richest offshore wind resource is located in deep waters, where attaching turbines to the seabed is not an easy neither cheap task. Floating offshore foundations offer the potential for less foundation material, simplified installation and decommissioning, and additional wind resource at water depths exceeding 50 m to 60 m. Longer-term, new markets such as west coast US and Japan that require floating foundations may drive cost competitive floating structures.

It is true that the use of competitive auctions has accelerated cost reductions for some renewable technologies, notably solar PV, onshore wind and offshore wind, establishing price benchmarks that are recognised worldwide. However, these prices cannot be consistently followed, as each country and technology has different resource potentials, financing conditions and auction designs.

It must be noted, however, that these auction prices are based on just a small portion of the total capacity to be commissioned under competitively determined remuneration schemes in the main-case forecast, so average prices may change with the announcement of new auctions. In addition, announced contract prices need to be verified as project delivery schedules and final costs may differ. Figure 2-3 presents the evolution of average auction prices in the last years and forecast for the next years, where it can be depicted that average auction prices for offshore wind to be commissioned in 2023 are around 80USD/MWh.

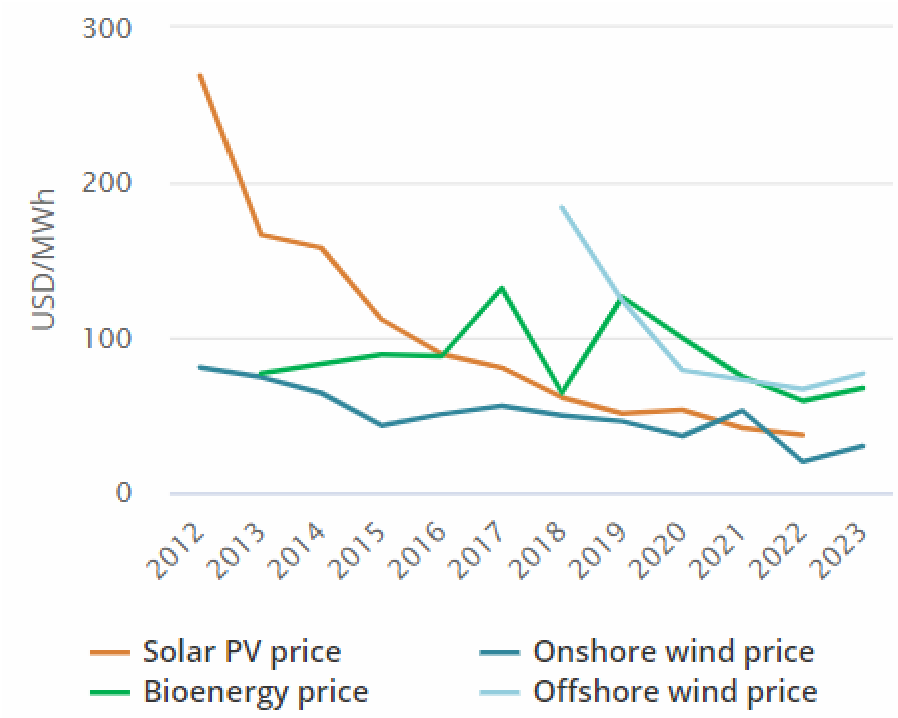

Figure 2-3: Average auction price by project by commissioning date (IEA, [9])

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However, comparisons between Levelized Costs of Energy (LCOE) and auction prices remain an important challenge. Limited availability of information on contract-winning projects makes it difficult to state with certainty that these tender-determined prices are becoming the standard benchmarks for renewable generation costs [9]. Although floating foundations are proven structures in O&G and oil majors are more comfortable with the technology than even leading offshore wind developers, floating technologies are still in the R&D phase and are still not cost-competitive. Current cost target for floating offshore wind is 120€/MWh by 2025 [8].

During the last decade, it has been demonstrated that speeding up the commercialisation of offshore wind technologies process means driving down costs and contributing to European competitiveness. According to [6], the right visibility in terms of volumes and industrialisation, may lead floating costs to tumble even faster than for bottom-fixed offshore wind, down from today's €180-200/MWh to reach €40-60/MWh by 2030. It sees floating offshore wind as a fast-maturing technology with huge potential but believes that dedicated policies are needed to ensure Europe harnesses its full potential.

The European Union is increasing the funding for research and innovation in floating offshore wind focused on cost-competitiveness, where PivotBuoy is an example, and aims to demonstrate how its new technology can bring costs of floating wind 50% down.

2.2 Levelized Cost of Energy

The LCOE has become a very practical and valuable comparative method to analyse different energy technologies in terms of cost. The LCOE calculation method is internationally recognized as a benchmark for assessing the economic viability of different generation technologies as well as of individual projects, and enables the comparison of different energy technologies with respect to their cost. The high level of transparency and clarity is one of the reasons why the cost metric has prevailed. At the same time the method is able to reflect the key factors of the production cost throughout the lifetime of the power plant in just one number. From an economic point of view, the LCOE contains the most important factors contributing to the economic evaluation of a project [5].

The main costs to be considered in the analysis are capital, financing costs, the cost of fuels (when existing, not in the case of PivotBuoy), fixed costs and operating and maintenance variables (O&M), using a specific plant factor, depending on the type of technology being studied.

A limitation of the LCOE metric is that it does not take into account that some costs can vary over time and from one place to another, depending on multiple and varied factors. For example, the existing generation in the place can be affected by the entry of a new project, displacing the existing generation depending on the technology, being able to vary the development cost of this new project. Another factor to consider is the capacity that is installed in a specific site, the demand that is there and the load capacity that the transmission system can support.

The LCOE is a methodology that allows to analyse different generation projects, which can be of different sizes or different technologies, and take them to a common unit of comparison. This comparison unit facilitates the decision making of the investor, allowing to evaluate and compare a portfolio of projects related to their costs. After the calculation of Life Cycle Costs (LCC) and after the

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assessment of expected energy generation and financing costs, the LCOE of PivotBuoy will be calculated according to the following equation:

$$LCOE = \frac{I_0 + \sum_{y=1}^{n} \frac{A_y}{(1+r)^y}}{\sum_{y=1}^{n} \frac{E_y}{(1+r)^y}} \tag{1}$$

Where:

- LCOE – Levelized Cost of Energy (€/MWh)
- I_0 – Investment costs (€)
- A_y - Annual costs in year y (€)
- E_y – Energy produced in year y (MWh)
- r – Interest rate (%)
- n – Project lifetime (1, 2, 3, …, n)

The total annual costs (A_y) are composed by fixed and variable costs for the operation, maintenance, servicing, repairs and insurance payments of the “powerplant”. The share of debt and equity can be explicitly included in the analysis by WACC over the interest rate. The interest rate depends on the amount of the equity, the return on equity over the lifetime, the borrowing costs and the share of the contributed debt, that in the case of PivotBuoy will be simulated with different values to assess its impact on the LCOE. Through discounting all expenditures and the quantity of electricity generated over the lifetime to the same reference date, the comparability of the LCOE is assured.

There is a wide span of existing tools that compute the LCOE of a given technology. These tools can vary in the level of detail that they can include, the objective of the exercise (LCOE optimization of a given technology or comparison between different technologies), and the availability of such tools (from general open source solutions that allow comparison of different technologies, to dedicated project specific developments).

Despite this wide range, they all propose to calculate the same metric (LCOE), often using the same definition. The main differences are in the assumptions imbedded in the model, the level of detail required of the input model, and the flexibility to estimate LCOE values using either rough estimates, typical of early phase projects, or innovative technologies, or using more accurate and detailed data, often only available later in the project lifetime.

In the PivotBuoy project, the focus is set on the innovative mooring solution for the floating foundation, and the resulting differences in LCOE when compared to other traditional floating foundation options.

Although the ambitions in PivotBuoy are clear, it is necessary to evaluate the results to come and compare it with other solutions that address floating offshore wind in the same scope. With that said, at least three high-level Key Performance Indicators (KPI) will be addressed along the project to evaluate the LCC associated to PivotBuoy as well as the LCOE, as soon as cost values start being clear.

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The first KPI is associated to the variation of final LCOE of PivotBuoy when compared to similar projects and it is identified in equation (2):

$$LCOE_{\%} = \frac{LCOE_{PivotBuoy} - LCOE_{Other\ solutions}}{LCOE_{Other\ solutions}} \cdot 100\% \quad (2)$$

The second KPI is associated to the share of Capital Expenditures (CAPEX), or investment costs, within the Life-cycle Costs of the project and it is identified in equation (3). This KPI is particularly important to provide investors an insight of how the payment plans shall be considered since it is obviously different to have a higher/lower share of the costs in an early stage of the project (normally associated to Design and Consent, Production and Acquisition, Installation and Commissioning), or during the period of Operation and Maintenance (costs identified as Operational Expenditures or OPEX).

$$CAPEX_{\%} = \frac{CAPEX_{PivotBuoy}}{LCC_{PivotBuoy}} \cdot 100\% \quad (3)$$

The third KPI is associated to the Energy Production and it is identified in equation (4). This KPI is particularly important to provide investors with an insight of what is the amount of expected energy production and what is the difference to projects using other similar solutions. High expected values of Energy production are a positive indicator of the technology productivity, but it also increases the risk of balancing costs (costs in energy contracts associated to the difference between the contracted energy and the delivered energy) if it does not provide the expected amount.

$$EnergyProduction_{\%} = \frac{EnergyProduction_{PivotBuoy}}{EnergyProduction_{Other\ solutions}} \cdot 100\% \quad (4)$$

Targets for each of these KPIs will be assessed during *Task* 7.2 – LCOE assessment of PivotBuoy concept and low-level KPIs will be defined taking into account the costs associated to the different stages of the project and its impact on the final LCOE.

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3 PIVOTBUOY LCOE MODEL

3.1 Objectives and Main Assumptions

As stated during the proposal stage, the main objective of this project is to reduce the cost of energy of floating wind by 50% through the validation of the "PivotBuoy", an innovative subsystem that aims at reducing the costs of mooring systems and floating platforms, allow faster and cheaper installation and a more reliable and sustainable operation.

With that said, the LCOE model developed for PivotBuoy aims at calculating the economic benefits that this innovative solution can bring to the floating offshore wind industry. The analysis of the levelized cost of energy of PivotBuoy technology does not aim only to perform a final assessment in the end of the project. As much as possible, it aims also to guide the design and engineering teams in an earlier stage of the project in order to find the optimal solution between technical requirements for a reliable solution but as cost effective as possible.

As known, PivotBuoy aims at the demonstration in real environment of a 1:3 scaled down system. The model that will be developed for the calculation of PivotBuoy energy cost will not only consider the system to be deployed onsite but will also consider the chosen design and materials applied to a real size system. This way, it will be possible to assess what would be the real economic benefits of the installation of a real size system or even a farm with PivotBuoy technology.

Although to be deployed at PLOCAN, an assessment of locations with characteristics favourable to the operation of PivotBuoy will be performed, in order to assess the impact of this technology during the installation, operation and decommissioning phases.

Identification of costs associated to bureaucracy (like legal permits, impact and environmental surveys, etc…), although to be considered in the overall cost, are out of the scope this project, and adequate values will be researched and used. A strategy is for example to index theses costs to the power or number of systems considered to be developed and deployed.

In this preliminary stage of the LCOE assessment, the following sections aim to describe the framework and structure of the model for the calculation of the levelized energy cost of PivotBuoy, that will later be implemented.

3.2 PivotBuoy Model

Figure 3-1 presents the modularised model that will be the framework for the calculation of PivotBuoy LCOE. As it can be depicted, and according to state-of-the art models for the calculation of LCOE, this model encompasses four main Modules: CAPEX, OPEX, Site Characteristics and Finance.

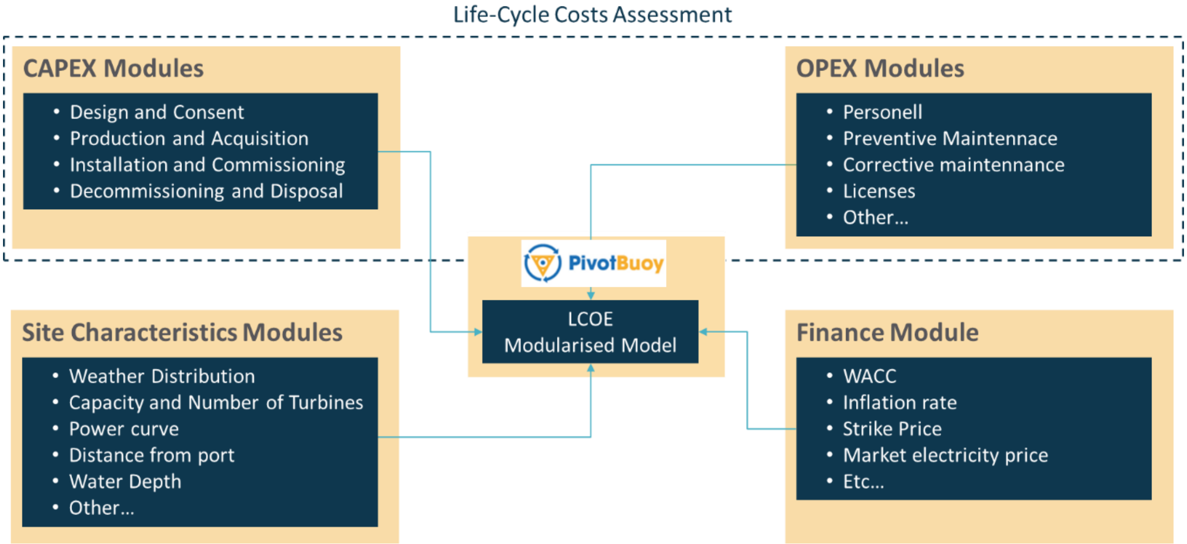

Figure 3-1: PivotBuoy LCOE Modularised Model

The CAPEX module will be looking at the costs necessary to permit, design, build, transport, install and dispose the PivotBuoy overall structure, while the OPEX module will be looking at the costs necessary to run and maintain it during the lifetime period of the project.

To calculate expected CAPEX and OPEX values during the assumed lifetime of a project where the PivotBuoy technology would be deployed in "real" operation, the main components and subcomponents of the life-cycle costs (LCC) for a floating Offshore Wind (OW) were identified, with custom fit to PivotBuoy characteristic and conditions. The decomposition of life-cycle costs is presented in Figure 3-2. More details can be found in section 3.3.

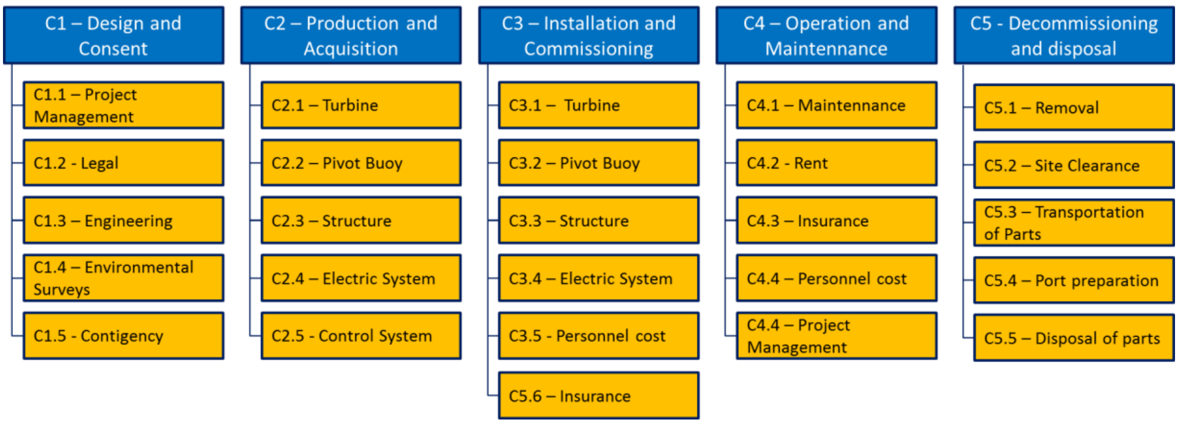

Figure 3-2: PivotBuoy Life-Cycle Costs

As known, the demonstration location will be in Spain, at the living laboratory of Oceanic Platform of the Canary Islands. In D4.1, PLOCAN has already characterized the test site environmental conditions including metocean data (wave, wind and currents) as well as bathymetry, seabed conditions and other

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relevant information. Resorting to this information, it will be analysed the impact of the Site Characteristics on the costs of the project, that between other contributions, will be looking to:

- Yearly weather conditions that combined with turbines characteristics will allow the assessment on expected Energy Generation during the years of operation.
- Distance to port to allow the calculation of costs related to transport of people and equipment for installation, operation maintenance and decommissioning.
- Water depth to allow the calculation of feasibility and required material to anchor and hold the PivotBuoy structure on the define location.

Finally, after looking to all the necessary costs to design, deploy, operate, maintain and dispose all the equipment, the Finance Module looks to the project financing costs and market prices, namely:

- Definition of the Weighted Average Cost of Capital (WACC), this means, the weighted average cost of the necessary money that needs to be collected from different sources to finance the project.
- Definition of inflation rate during the lifetime of the project
- Estimation of the strike price, this means, the price that will be payed by each unit of energy (GWh, MWh…) that will be generated by the project

Therefore, the tool to be used to calculate the LCOE will address detail the impacts of the floating foundation, from manufacture to decommission, of both the PivotBuoy and other traditional options.

WavEC's inhouse developed techno-economic model can be used to satisfy these requirements, and possibly expanded to include relevant areas not foreseen at this moment, or add increased complexity to the analysis, if deemed necessary. A brief overview of this model is given below.

WavEC's techno-economic model is designed to provide the LCOE and other economic indicators for ocean renewable energy projects. It is a parametric model to evaluate the LCOE and other indicators such as the project Internal Rate of Return (IRR) and the Net Present Value (NPV) depending on several factors including the project location, technology design, farm design and project costs.

For assessing the capital and operational expenditures in the present version, the techno-economic model allows the user to introduce its own estimates of the project CAPEX and OPEX based on the number of units and price. Then the user may introduce some cost reduction functions from scale, bulk or learning effects, for assessing the costs of first farms or different design variables.

Then, the model assesses the technology LCOE by assuming a discount rate and project lifetime. Then, it is also possible to define some financial parameters such as the level of incentives, debt, inflation rates, taxes, etc. to evaluate the project feasibility from an investor's perspective.

Finally, the model allows the user to perform a sensitivity and risk analysis on around 50 factors that affect the economic indicators. This last feature also permits the user to rapidly assess different scenarios and find optimal levels for critical design parameters.

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3.3 Life-Cycle Costs Assessment

To the costs summed up by Research and Development, Investment, Operation and Support, and Disposal Costs over the entire life cycle is given the name of Life-Cycle Cost (LCC). In other words, a Life-Cycle Cost is the total cost of a project from cradle to grave. An LCC Estimate is the estimated cost of developing, producing, deploying, maintaining, operating and disposing of a system over its entire lifespan.

The main components of the PivotBuoy LCC are distinguished and further decomposed to cost of subcomponents as shown in Figure 3-2. Throughout the model, the most up-to-date expressions for cost subcomponents will be employed. The life-cycle stages under which costs are categorized are defined as follows: Design and Consent (DC), Production and Acquisition (PA), Installation and Commissioning (IC), Operation and Maintenance (OC), and Decommissioning and Disposal (DD). Overall, the LCC is calculated as defined bellow:

$$LCC = C_{DC} + C_{PA} + C_{IC} + C_{OM} + C_{DD} \quad (1)$$

The costs associated with Design and Consent are related to the work of research and development to design the optimal solution for the wind farm as well as to the work needed to secure consent and manage the development process up to financial close. This component includes environmental surveys as well, that are one of the first tasks to be undertaken at a potential wind farm site. The surveys include bird, fish, marine mammal and habitat surveys as well as marine navigation studies, socio-economic surveys, commercial fishing, archaeology, noise analysis, landscape and visual assessment and aviation impact assessments. Although this component and its costs must be part of the Life-Cycle analysis, the calculation of PivotBuoy LCOE focuses on the impacts of the technology and attached structure on the overall costs. With this said, adequate costs will be considered for these components, and assumed similar between PivotBuoy and other existing solutions.

The stages of “Production and Acquisition”, “Installation and Commissioning” and “Operation and Maintenance” are the ones where the PivotBuoy technology aims to create bigger impact on the floating offshore wind industry. As presented in Deliverable 2.1 - *System requirements and design review criteria – PivotBuoy Basis of Design (BoD),* the main components of PivotBuoy and the structure to be used in the project can be divided in the following elements:

Table 3-1: PivotBuoy and Floating Platform structure main components

PivotBuoy	Floating platform
Anchor system	Masts
Mooring system	Mast/Buoy connection
PB bottom	Main Buoys ballast system
PB top	Nacelle adaptors
Mechanical connection	Secondary and Aux Systems
Power connection	
Secondary and Aux Systems	

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In the "Production and Acquisition" stage, the costs related to material, construction and assembly of all these components will be considered and a comparison will be made taking into account the several possibilities considered during the design stage. The LCOE calculation tool will allow to find the most cost-effective solution and economically guide in the future the selection of the most appropriate materials and designs (if assumed that two different designs can reach the same levels of technical productivity and reliability). During this stage, the necessary costs to acquire the turbine and assemble the electric and control systems that will allow the connection of the turbines to shore will also be calculated (cables, switchboards, switchgear, sensors, automation, etc…).

The drive for the development of the PivotBuoy does not only rely on the cost reduction for its production but as well on finding a solution easier and cheaper to install and commission onsite, when compared with other existing floating solutions. For the stage of "Installation and Commissioning", the costs associated with the transport and installation of the anchor, TLP and PivotBuoy will be considered, as well as the installation of structure and turbine (vessels, barges, fuel, cranes, tools, people, etc..). Costs associated with insurance of people (labour and life) and equipment necessary for the installation and commissioning will be as well considered.

Referring to *Task 6.4 – Assessment of Maintenance strategies-*, a deliverable will be provided in Month 8, *D6.4 - Optimal maintenance strategies for single point mooring systems* which will include the analysis of potential operation and maintenance strategies for single point mooring systems taking into account potential failures, weather conditions, accessibility and available vessels and infrastructure for maintaining the system. The outputs of this task will be considered in the "Operation and Maintenance" stage, where costs related to different strategies for preventive and periodical maintenance will be assessed. Costs related to corrective repairs, people and equipment (tools, software, licenses, boats, etc…) necessary to run and operate the systems will be estimated for the lifespan of the project (and potential commercial projects).

Finally, in the stage of "Decommissioning and disposal", costs associated to the disconnection of the system, its uninstallation, removal from site, transportation to land, preparation of port to receive all the systems and materials and later disposal of equipment and site clearance will be considered in the calculation of the LCC.

3.4 Input data

3.4.1 PLOCAN Site characteristics

The LCOE is very dependent on the site characteristics. These can be aggregated in three main groups: Wind Resource, Sea Conditions and Location, Grid Connection and local infrastructure.

3.4.1.1 Wind Resource

The wind resource is the driving factor of the Annual Energy Production (AEP) and therefore has a critical impact on LCOE. If time series of data are not available at the selected site, the wind resource is normally characterized using statistics in (e.g. using Weibull distribution with the avg. wind speed at measured height, Wind shear exponent and Weibull shape factor).

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At PLOCAN, the average wind speed is quite moderate (6.6m/s) which is adequate for testing conditions. Table 3-2 summarizes the yearly distribution based on simulated data:

Table 3-2: Mean monthly wind profile

	Mean speed (m/s)	Maximum speed (m/s)	Mean direction (°)
Average	*6.6*	*16.1*	*23*
January	6.8	18.4	46
February	6.6	16.6	33
March	6.7	17.7	19
April	6.9	16.8	13
May	6.6	13.6	12
June	6.9	14.3	13
July	7.9	14.4	14
August	7.2	13.8	15
September	5.9	12.7	17
October	5.6	16.2	21
November	6.1	18.9	32
December	6.5	20.4	46

A wind measurement system is currently being installed at PLOCAN's platform (1km away from the selected site) which will provide more accurate data (including wind speed, direction and turbulence level) during the design, installation and operational phase of the project. Also, the wind speed will be measured at the turbine and will be used to obtain the turbine power curve, which will be key in validating the influence of the PivotBuoy in its performance (including some of the key innovations such as passive yaw orientation and downwind configuration).

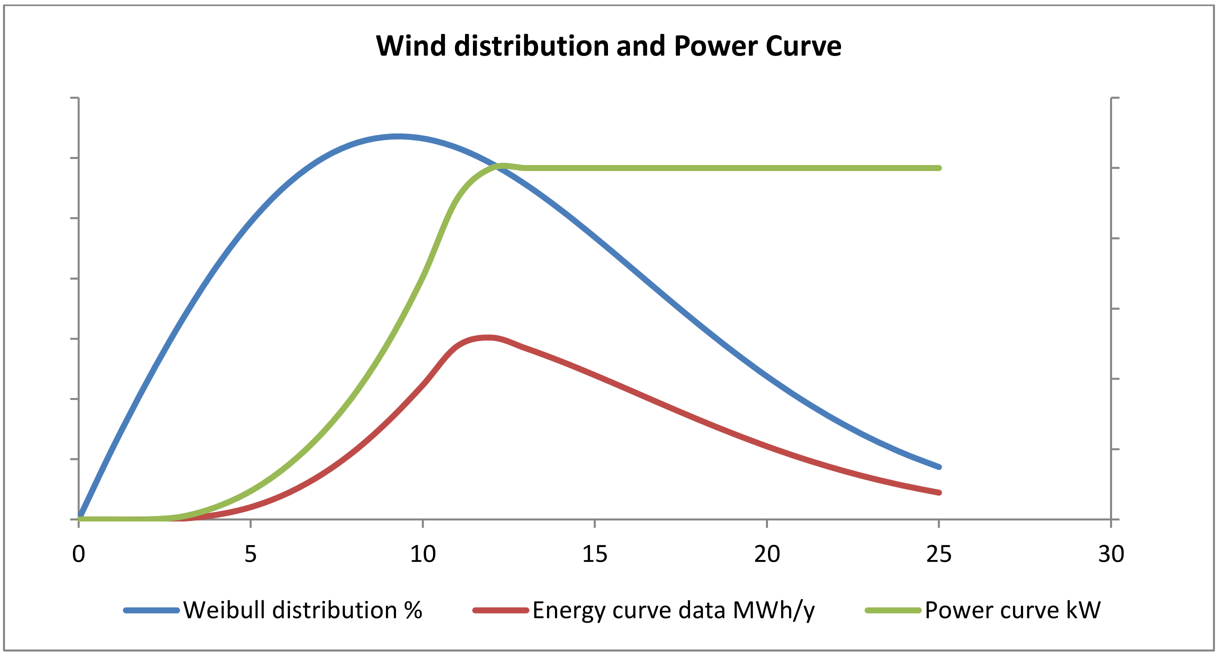

Figure 3-3: Example of wind distribution, power curve and energy production

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3.4.1.2 Other Environmental Conditions

There are other site environmental conditions which will influence the LCOE. The following list summarizes the key factors:

- **Wave conditions**: wave height, period and direction, during operation and particularly in extreme events.
- **Currents**: in single point mooring systems cross currents can induce a certain level of yaw deviation.
- **Tidal range**: which needs to be considered for the design of the mooring system
- **Water depth and type of seabed**: influencing the design of the mooring system and anchor.

Deliverable 4.1 [1] provides a more detailed information on test site environmental conditions. These factors will be monitored during the tests at PLOCAN and their influence on the LCOE assessed.

3.4.1.3 Location, grid connection and local infrastructure

The characteristics of the local infrastructure and socio-economic environment also influence the LCOE. The local port/ yard infrastructure and vessels, equipment and labour available are key in defining the manufacturing, assembly, transportation and installation strategies and cost.

Distance to the installation and O&M port also drive transport time and cost and influence the length of the weather windows for doing offshore operations. The required cable distance and characteristics of the grid connection are also a relevant factor in the definition of the electrical connection.

The following list summarizes the key factors which will be assessed during the project:

- **Manufacturing, Transport & Assembly Strategy:** port/ yard, transport, load-out, etc.
- **Installation strategy:** including type of vessels, distance to port, equipment required, subsea operations.
- **O&M strategy:** including transport time, weather windows, comparison of option of on-site O&M versus maintenance at port.
- **Grid connection:** defining the electric connection characteristics (cable distance, voltage)

During this project it will be possible to validate the assumed inputs in design phase with real data during the testing period. This learning will be then used at the end of the project to analyse a commercial case study for a full-scale floating wind farm in a more energetic site.

3.4.2 Components to be considered

This project will also allow refine the cost data of the different components and systems of the PivotBuoy and the floating platform. By building and installing a real prototype at sea the level of uncertainty in the cost assumptions will be reduced and it will be possible to identify the critical cost drivers and risks before building the full-scale commercial systems.

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The model will enable the comparison of different options in order to make design decisions to minimize the overall LCOE. Deliverable D2.1 provides a break-down of the different components and systems and operations developed within of the PivotBuoy system as well as other systems influencing the overall cost and performance (e.g. platform, turbine, manufacturing, installation and O&M strategies). For each of these items, cost information will be gathered based on the part-scale demo and then scaled-up for a full-scale commercial case. A list of the main cost items to be included is described below:

- Wind turbine
- Floating platform
    - Masts
    - Mast/Buoy connection
    - Main Buoys ballast system
    - Nacelle adaptors
- PivotBuoy system
    - Anchor system
    - Mooring system
    - PB bottom
    - PB top
    - Mechanical connection
    - Power connection
- Secondary and auxiliary systems
- Transport & assembly
- Installation and commissioning
- Operation and maintenance

Each of these cost centres will be characterized in terms of prize (€/unit), quantity (number of units) as well as scaling function for the assessment of commercial scale projects.

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4 CONCLUSIONS AND FUTURE WORK

This techno-economic model report provided the structure that will be the basis for the model which will be built for the assessment of PivotBuoy concept.

An initial overview of offshore wind evolution in the latest years as well as the predicted evolution for the following ones was presented in order to framework what is the current baseground market for PivotBuoy Technology in terms of expected costs. This research has shown that from today's €180-200/MWh cost for floating offshore wind, a target of 125€/MWh is expected by 2025 and an evolution to €40-60/MWh by 2030.

This model is delivered in a very early stage of the project but provides what are considered to be the main objectives for PivotBuoy Levelized Cost of Energy calculation, its main assumptions, and the structure that will lead the implementation of the model itself, namely through the assessment of the project life-cycle costs and required input information.

High-level Key Performance Indicators as the difference between PivotBuoys and other similar solutions LCOE, the share of Investment Costs (CAPEX) within the total costs of the project and the difference of expected energy production between PivotBuoy and other similar solutions, were identified in order to be possible to perform an evaluation of the techno-economic benefits of PivotBuoy when compared with other existing floating solutions. Next steps will include the definition of low-level KPIs associated to the costs of the different stages of the project.

Future work will be focused on the implementation of the PivotBuoy LCOE model, the identification and quantification of all the PivotBuoy costs, and the economic analysis of the solution to be deployed at PLOCAN (1:3 scale) as well as the extrapolation for a real size system and wind farm with several systems. The following deliverable, D7.2, to be delivered in month 32, will summarize the potential impact on LCOE of the innovations developed along the project. However, periodic updates of the LCOE assessment will be performed along the project.

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