Qualification of innovative floating substructures for 10MW wind turbines and water depths greater than 50m

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Definitions & Abbreviations	
FOWT	Floating Offshore Wind Turbine
LCA	Life Cycle Assessment
LCOE	Levelized cost of Energy
KPI	Key performance indicators
WP	Work Package

Executive Summary

This report summarizes the deliverables produced in work package 2: Concept Evaluation. The report also gives an overview of all the dissemination activities that have been carried out as part of the research, including publications and public presentations.

The work package has nine deliverables with each deliverable addressing a specific topic related to the evaluation of the floating concepts concerning economic aspects, environmental aspects, technical aspects and risk aspects.

- D2.1: General consideration for evaluation procedures
- D2.2 LCOE Tool description, technical and environmental impact evaluation procedure
- D2.3 LCOE cost tool
- D2.4 Technical and environmental impact evaluation tool (software)
- D2.5 Global evaluation procedure including risk
- D2.6 Economical, technical and environmental evaluation of Phase 1
- D2.7 Evaluation report Phase 2
- D2.8 Expected LCOE for floating wind turbines 10MW+ for 50 m+ water depth
- D2.9 Presentation of the methodology and results of the WP at a relevant conference

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1. Introduction

The objective of this deliverable is to present the main results obtained in work package (WP) 2 “Concepts Evaluation” and the main dissemination activities carried out within this WP.

The remaining document is structured in 9 sections. Sections 2 to 8 present the executive summaries of the deliverables of WP 2. Section 9 contains a table with the dissemination activities carried out within the WP 2. The conclusions of the document are provided in Section 10.

2 D2.1 General consideration for evaluation procedures

This deliverable covers the general considerations and specific information that will be collected from both concept developers and external sources and that will be taken into account for the evaluation process between the different floating technologies included in this project. This information will define the characteristics of the floating substructure concepts once they are integrated into an offshore wind farm and will be focused on providing the necessary data over their whole life cycle (manufacturing, transportation, installation, production, operation and maintenance and decommissioning) to prove they are realistic and that are closer to be introduced to the market.

A proposal for the evaluation procedure has also been described and will be carried out considering the results obtained from the LCOE tool, the environmental analysis and the technical evaluation, including risk considerations.

It is expected that this guideline will facilitate the selection process of two of the four floating concepts making a fair comparison between them.

3 D2.2 LCOE tool description, technical and environmental impact evaluation procedure

This document describes the Floating Offshore Wind Assessment Tool (FOWAT) by including a detailed description of the economic evaluation module, the environmental evaluation module and a description of the technical Key Performance Indicators (KPI) that are used in the evaluation. In accordance with the projects objectives, the Overall Evaluation Tool described here includes procedures to enable the calculation of the following aspects to be considered in both Phase I and Phase II evaluation of the concept designs:

- Economic assessment: LCOE calculation expressed in €/MWh and included in LCOE module of the Single Calculation Mode of the tool.
- Environmental assessment: Life cycle assessment (LCA) using 3 environmental indicators included in LCA module
- Risk evaluation: Technology risk assessment included in Risk Module

- Uncertainty assessment: Provides LCOE calculation considering an uncertainty range as per the inclusion of uncertainty ranges in some of the inputs used for the LCOE computation. This assessment is available in the LCOE Module in the Evaluation Mode of the tool
- Concepts designs ranking generator: calculation of the final evaluation ranking of the designs using the results of LCOE, LCA and Risk assessment (multi-criteria analysis). This operation is executed in the Multi-Criteria module.
- KPI information: Concept design technical description using key performance indicators and generation of a KPI .pdf report.

Section 2 of the report includes a brief review of existing available LCOE tools that have been taken into account to inspire the development of the LIFES 50+ evaluation tool. The aim of this section is to provide a general overview of existing and similar tools to calculate LCOE for offshore wind technology, but a thorough review and comparison of tools has been omitted.

Section 3 provides a general description of the tool and how it has been structured. Including the general description of the modules (LCOE, Risk, LCA, KPI report maker, Uncertainty and Multi-Criteria).

The LCOE calculation approach in section 4 will give and detailed description, which include methodology, general assumptions, life cycle cost of floating wind farms, energy production calculation approach, LCOE uncertainty approach and finally an overall description of the evaluation tool.

Further the LCA analysis will be dealt with in section 5 focuses on describing the methodology behind this assessment and the selection of 3 environmental impact indicators that are going to be calculated for the 4 concepts at each site (Global Warming Potential, Non-fossil abiotic depletion potential, Primary Energy consumption).

Section 6 provides a description and list of the technical Key Performance Indicators that have been selected to characterize the concept designs. These KPI will be used during the data collection process in order to verify the consistency of the data provided by the concept designers for the LCOE calculation. Besides, KPI will not be included in the multi-criteria decision methodology for selecting the 2 concept designs for Phase 2 evaluation.

Section 7 of this deliverable has provided a description of the Multi-criteria methodology that has been implemented in the tool to provide a single final ranking of the 4 concept designs using the following weighting factors:

- Economic Assessment-LCOE= 70%
- Risk Assessment= 20%
- Environmental Assessment - LCA= 10%

The Multi-Criteria module will store in the different matrix results of the LCOE and LCA calculation for each site and concept design. Each matrix will be treated in order to convert the absolute values (e.g. €/MWh for LCOE, or kg CO_2eq for LCA) into scores from 1 to 4 as explained in D2.5. There will be no need of further treatment of the outputs from the Risk module, as they will be expressed in the same dimensionless scoring system.

Section 8 gives a detailed case description of the LCOE module tool being tested by defining a FOWPP at a specific location and calculating its LCOE. The specifications of the components are based on available data from literature. However, some restrictions are related to the Lifes50+ project such as a minimum water depth of the location of 50 m and an offshore wind turbine with a rated power of 10 MW.

Finally, Section 9 concludes as follows: The aim of this deliverable is to describe modules that comprehend the LIFES 50+ Overall Evaluation tool named “Floating Offshore Wind Assessment Tool-FOWAT” that has been developed within this project to qualify the four concepts designs under an economic, environmental, risk and technical perspective. The objective of this deliverable is to provide the methodological framework used for the development for both LCOE and LCA modules, to describe the tools architecture and the data introduction Excel document and to provide a visual description of the Overall tool appearance and how the specific modules have been integrated.

As a final remark, it should be stated that the methodology that this document presents for the LCOE ranking considering the uncertainty has been proposed by IREC to the Evaluation Committee and its use within the project is subject to its approval by the end of M17 (October 2016).

4 D2.3 LCOE cost tool and D2.4 Technical and environmental impact evaluation tool (software)

Deliverables D2.3 and D2.4 are the software modules that comprehend the LIFES 50+ Overall Evaluation tool named “Floating Offshore Wind Assessment Tool- FOWAT” that has been developed within this project to qualify the four floating offshore wind turbine (FOWT) concepts under an economic, environmental, risk and technical perspective. The executable file of the FOWAT tool is available at LIFES50+ internal website and can be disclosed upon request prior notification of the tool authors (IREC, TECNALIA and ORE CATAPULT). The following subsections include a short description and screenshots of the FOWAT evaluation tool.

4.1 FOWAT: Overall Evaluation tool description

FOWAT is the acronym for Floating Offshore Wind Assessment Tool. It is used in the project to assess different floating substructures by a multi-criteria evaluation including LCOE, LCA, and Risk as well as an uncertainty determination and KPI assessment. The algorithms and equations that are implemented in the tool are based on the methodology explained in the deliverable D2.2.

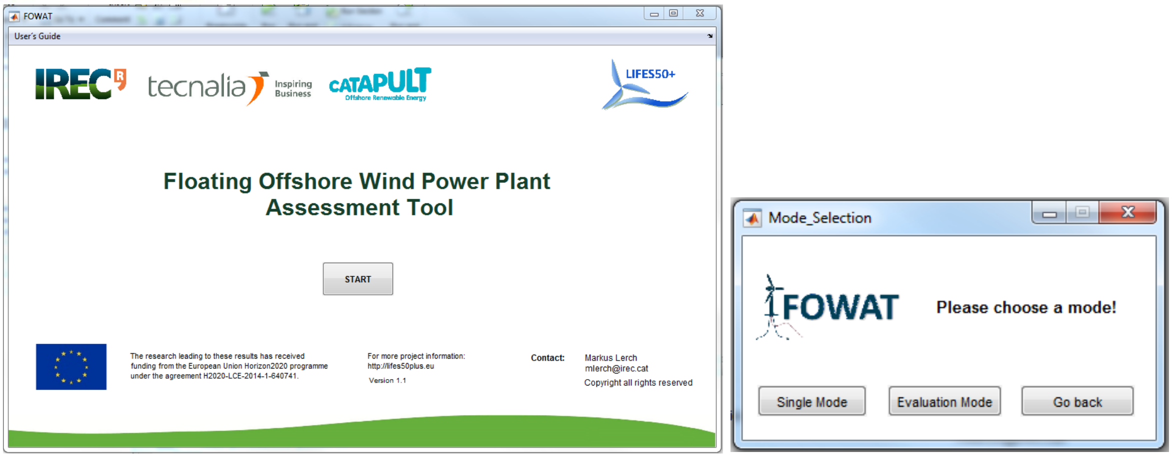

Figure 1: FOWAT tool main screen

The tool consists of two separate modes of operation. The first mode Single Mode is used to assess one floating offshore wind farm at a specific location. The user has to select a concept, a site and a specific wind farm capacity such as 1, 5 or 50 wind turbines. For this individual case, the LCOE, LCA and Risk assessment is performed as well as a KPI report produced. A single LCOE value for the floating offshore wind farm is calculated and a breakdown of costs is presented according to life cycle cost components, CAPEX, OPEX and DECEX. Furthermore, the energy production and losses in generation and transmission phase can be seen. The second mode Evaluation Mode, on the other hand, is used to assess all different concepts considering all three locations and to perform the ranking for the final selection. Here, no breakdown of costs or energy is shown since the LCOE calculation considers uncertainty ranges and a distribution of LCOE values is computed.

In the following sections at first the ´Single Mode´ is presented and afterwards the ´Evaluation Mode´ is described more in detail.

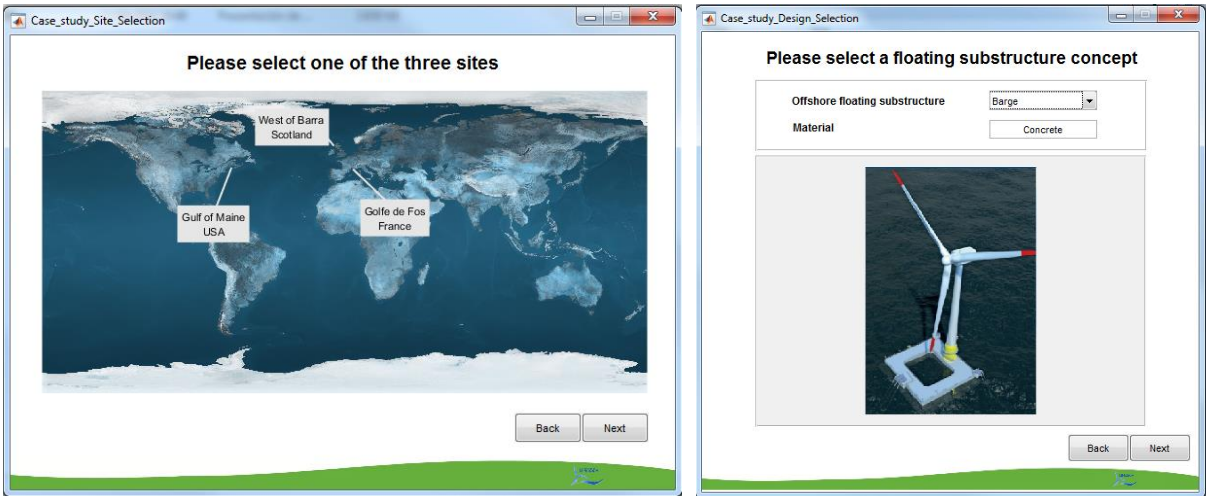

Figure 2: Site and Concept Selection

After starting the Single Mode the user has to select one of the three sites Gulf of Maine, West of Barra or Golfe de Fos. The next step is to choose one of the four floating substructure concepts and finally to select the desired wind farm capacity 10, 50 or 500MW. After all criteria for the calculation are defined the user is required to load the input data. The input data includes the information provided by the concept developers for their specific design as well data for the components of the floating offshore wind farm that are common such as turbine, substation and export cables.

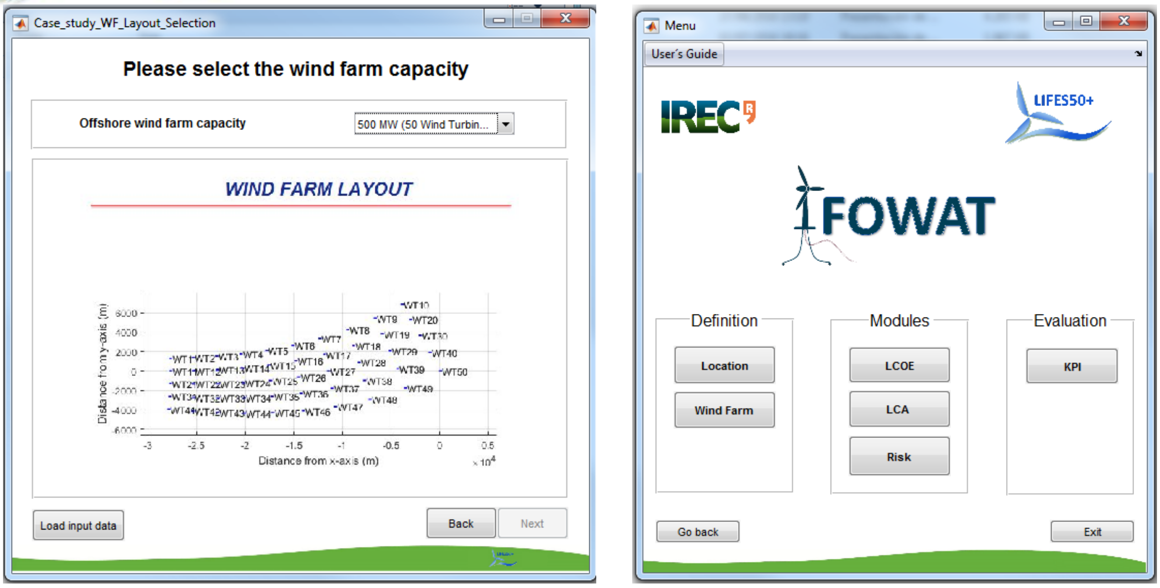

Figure 3: Wind Farm Capacity Selection and Menu

The Menu of the Single Mode shows all operations that can be performed in this part of the tool. It consists of the sections Definition, Modules and Evaluation.

The Location Definition is used to define the location of the FOWPP including General Data and Wind Conditions. General Data contains for example the name of the related country and ocean, the latitude and longitude as well as location specifications such as type of soil, distance to shore and water depths. In Wind Conditions the wind speeds are defined according to their probability of occurrence at the site and a Weibull distribution is shown for each wind direction. Figure 4: General Data and Wind Conditions shows both sections.

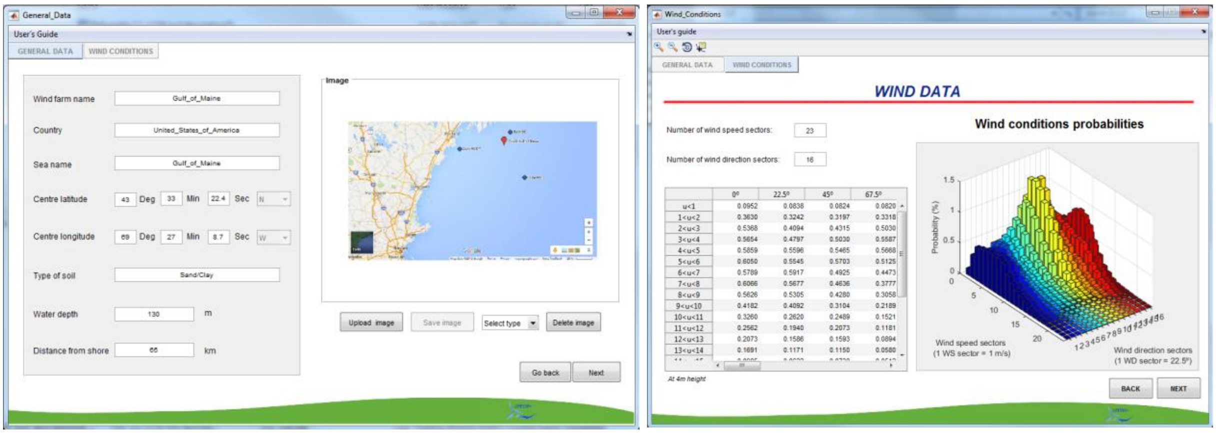

Figure 4: General Data and Wind Conditions

The second part of the Definition section concerns the wind farm and contains the sections Wind Turbine, Wind Farm Layout and Grid Connection. Wind Turbine contains information regarding the wind turbine and the floating substructure. The section Wind Farm Layout presents the pre-defined wind farm layout according to the chosen location and capacity. The section Grid Connection contains all necessary data concerning the collection grid, offshore substation and transmission grid such as nominal voltage, frequency, number of power cables, etc. A layout of the collection grid and the location of the substation are also shown.

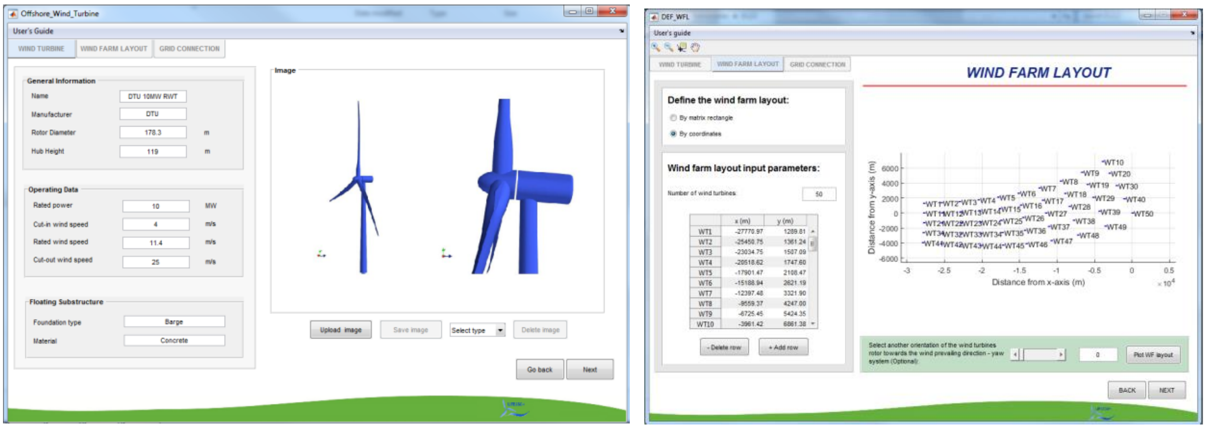

Figure 5: Wind Turbine Data and Wind Farm Layout

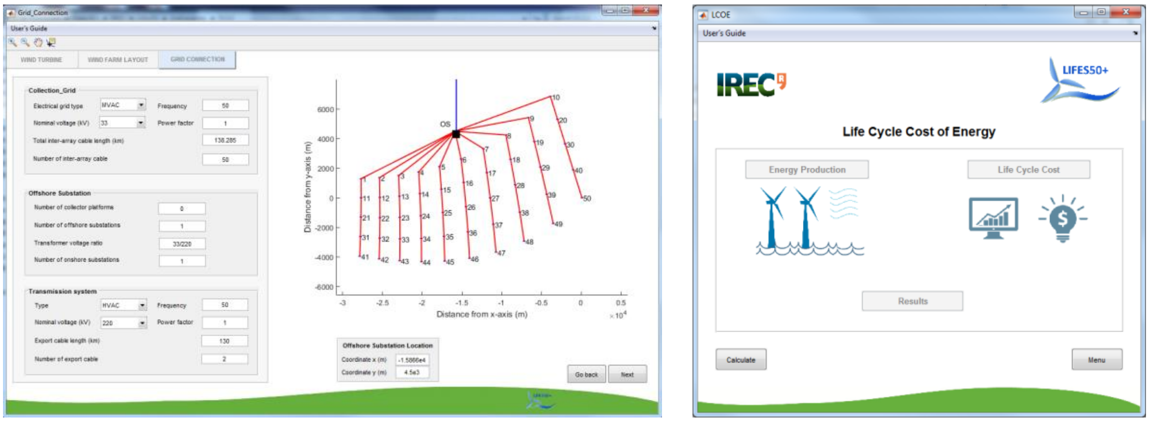

Figure 6: Grid Connection and LCOE Module

The LCOE module shown in Figure 6 consists of the Energy Production section and Life Cycle Cost section as well as the Results section. The LCOE module is used to calculate one LCOE value for the defined floating offshore wind power plant. The section energy production includes all parameters that are used to calculate the energy generation and losses in all components of the wind farm as well as the consideration of wake. The section Life Cycle Costs contains all cost parameters that are used for the calculation and that occur during the different life cycle phases. Some exemplary images of these sections are presented next.

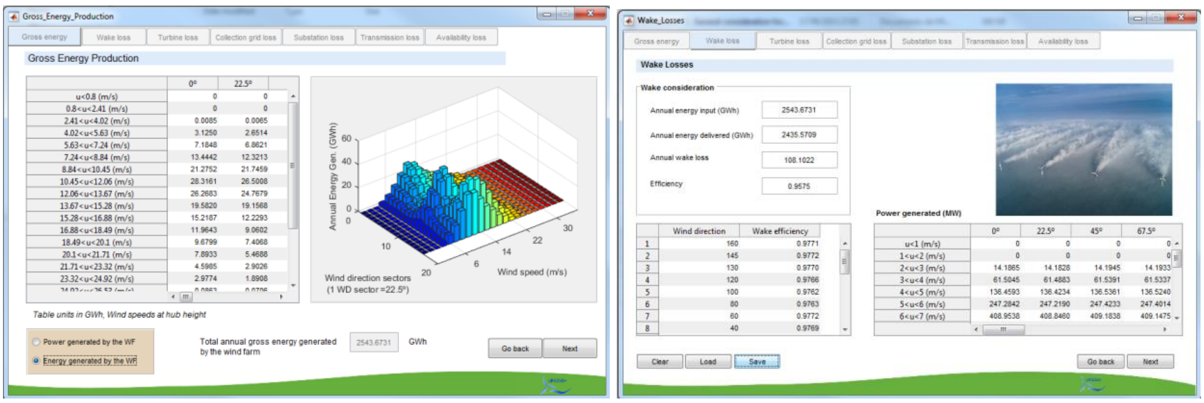

Figure 7: Gross Energy Production and Wake Losses

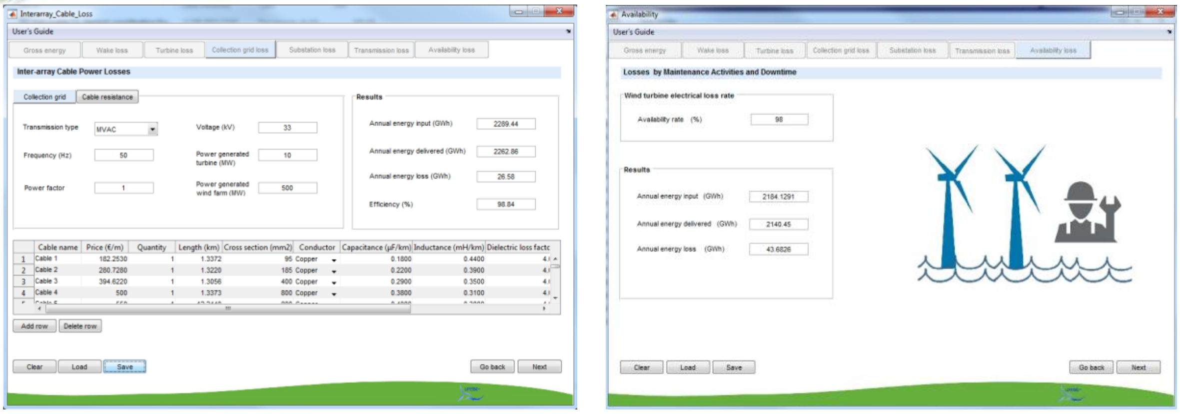

Figure 8: Collection Grid Losses and Availability Loss

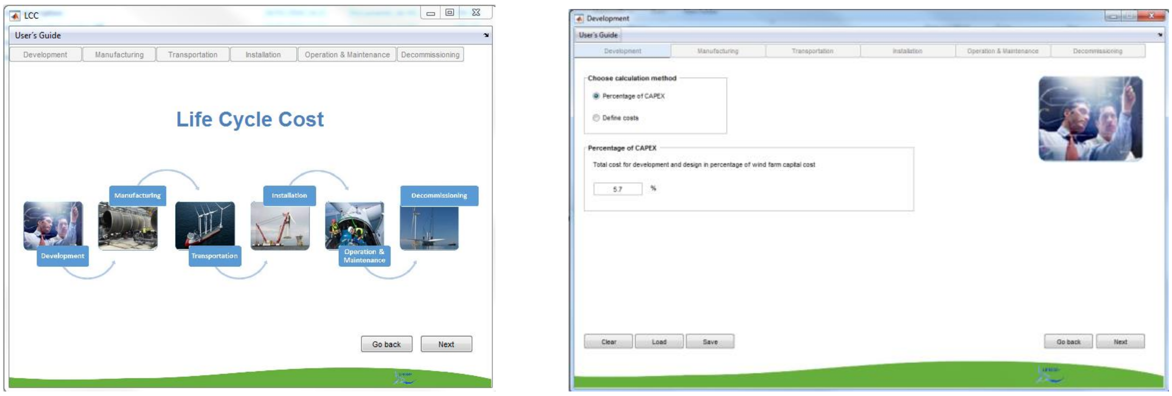

Figure 9: Life Cycle Cost and Development Cost

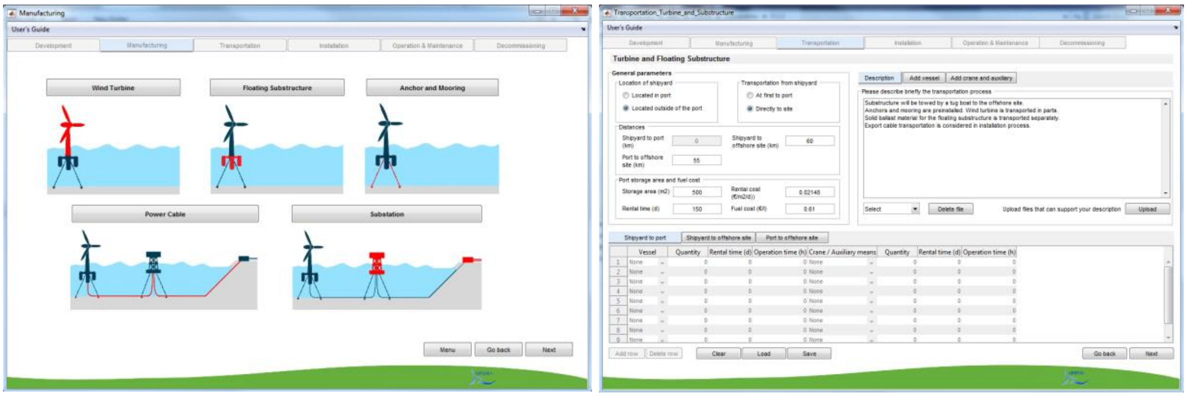

Figure 10: Manufacturing Overview and Substructure Transportation

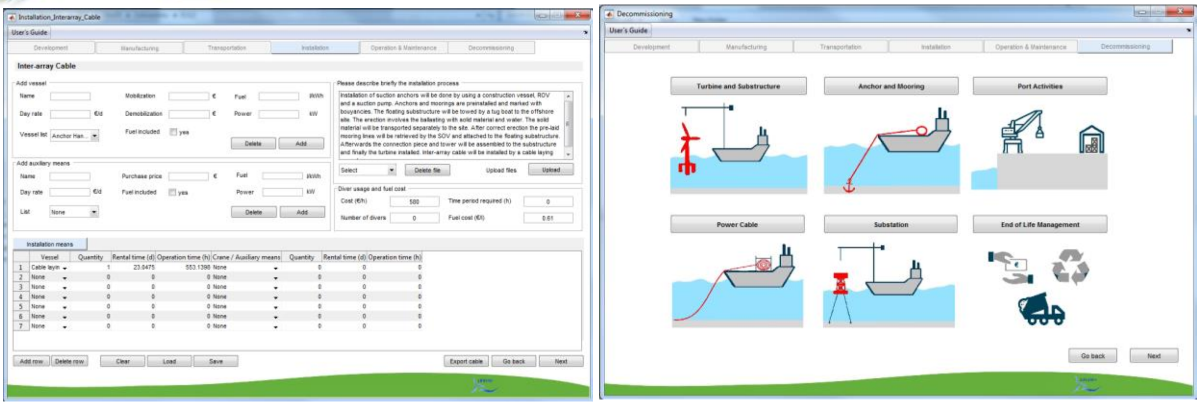

Figure 11: Power Cable Installation and Decommissioning Overview

The results section contains the calculated LCOE value as well as the total energy production and life cycle costs considering the entire lifetime of the wind farm. Besides that, figures are used to illustrate the energy losses in the system, as well as life cycle costs.

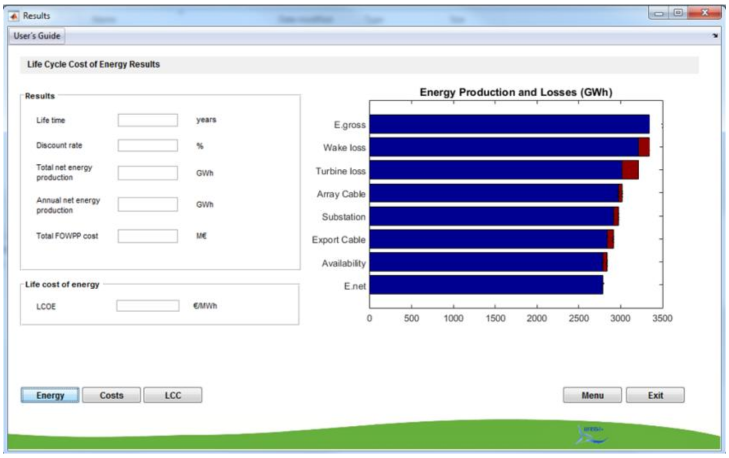

Figure 12: Results Section

The LCA Module calculates the parameters Global Warming Potential, Primary Energy, Abiotic Depletion Potential and Energy Payback Time for the defined floating offshore wind farm. The Risk module calculates the 4 commercial risk values for this case. The following figure shows both modules.

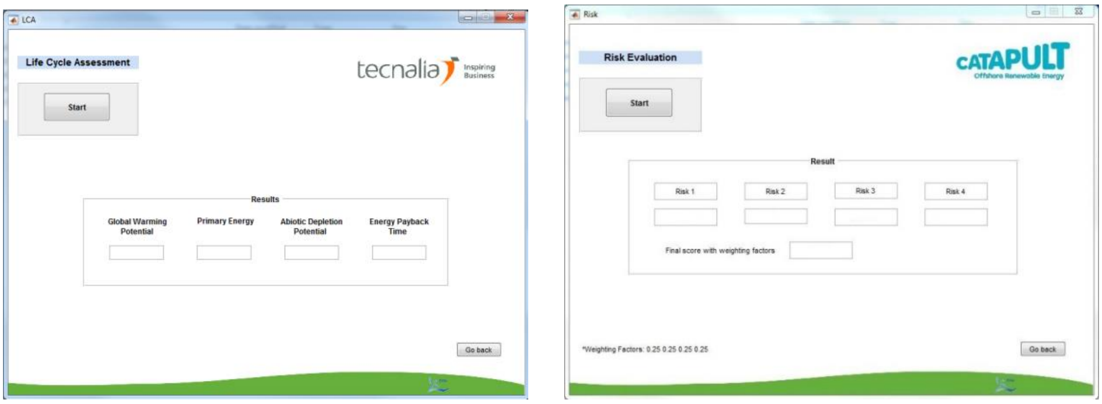

Figure 13: LCA and Risk Module

The KPI evaluation section is used to create a PDF containing all KPI parameters considered for this evaluation process. Figure 14 presents this section of the tool.

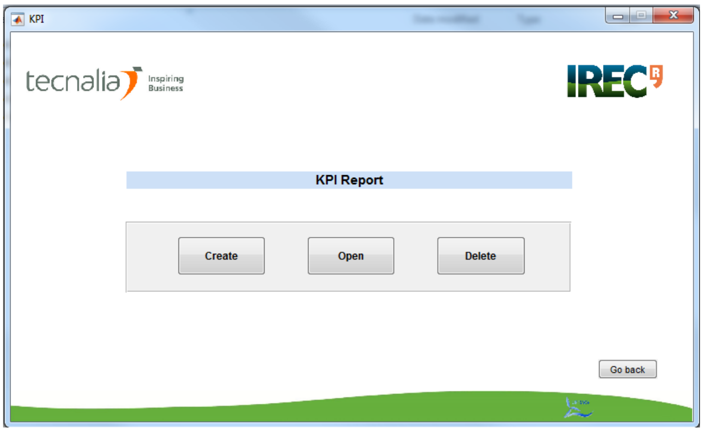

Figure 14: KPI Report Section

The Evaluation Mode in contrast to the Single Mode is used for the ranking of the different concepts and will be explained next.

After selection of this mode and the upload of all required data, the menu of this part of the tool is shown. The menu differs from the one of the Single Mode since in this part of the tool the Multi-Criteria Evaluation can be selected. Furthermore, the LCOE Module includes the uncertainty assessment. As shown in the following figure, the menu contains also the Definition Section. The user can therefore also select a specific wind farm and check the wind farm layout and wind conditions at the offshore site. However, a breakdown of the costs and energy losses is not available in this part of the tool since a distribution of LCOE values is computed.

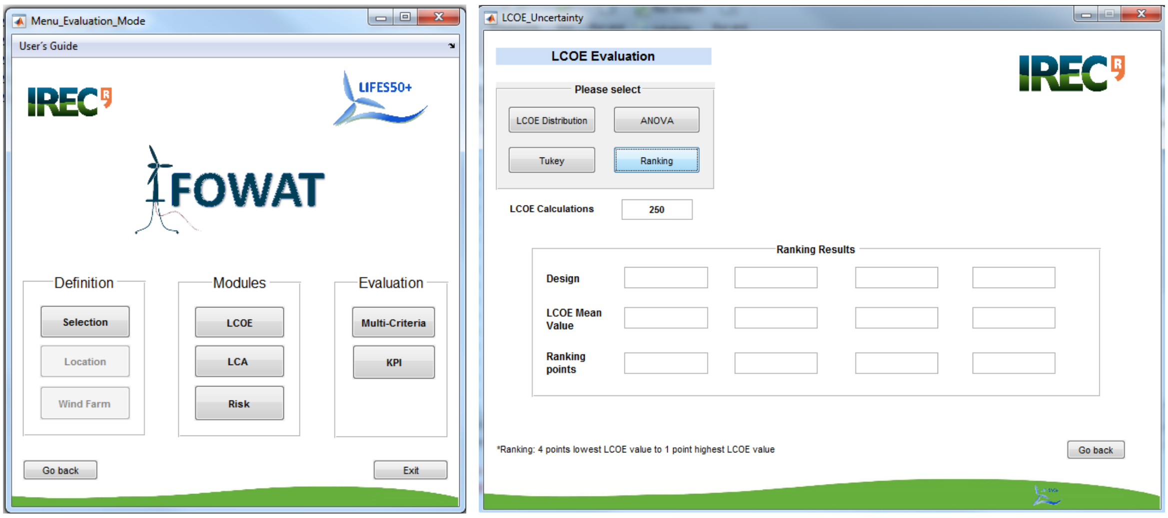

Figure 15: Menu Evaluation Mode and LCOE module

The LCOE Module is shown in Figure 16. It consists of the LCOE calculation considering the uncertainty parameters and the amount of calculations used for computing the LCOE distributions for each concept. This module is used to present graphically the LCOE distribution values and to rank the concepts according to the mean values of the distributions based on ANOVA and Tukey tests. The following figure presents exemplary the LCOE Tukey test distributions.

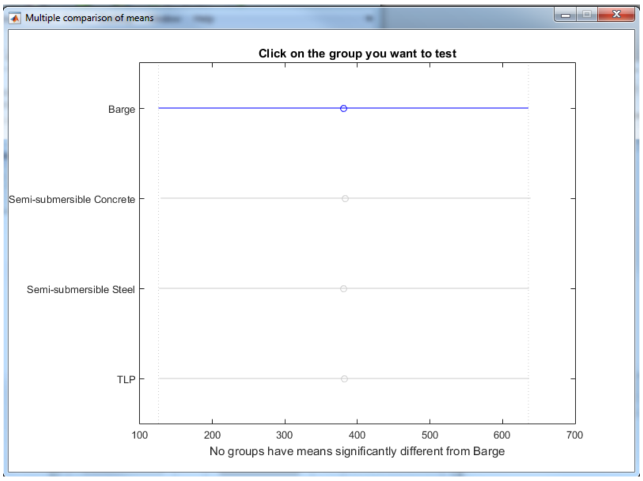

Figure 16: LCOE Distribution Figure

The LCA module is similar to the one of the Single Mode, but in this case shows the LCA parameters for all concepts and provides the ranking according to the LCA results. The same applies for the Risk module, which now computes the risks values for all concepts and provides the ranking.

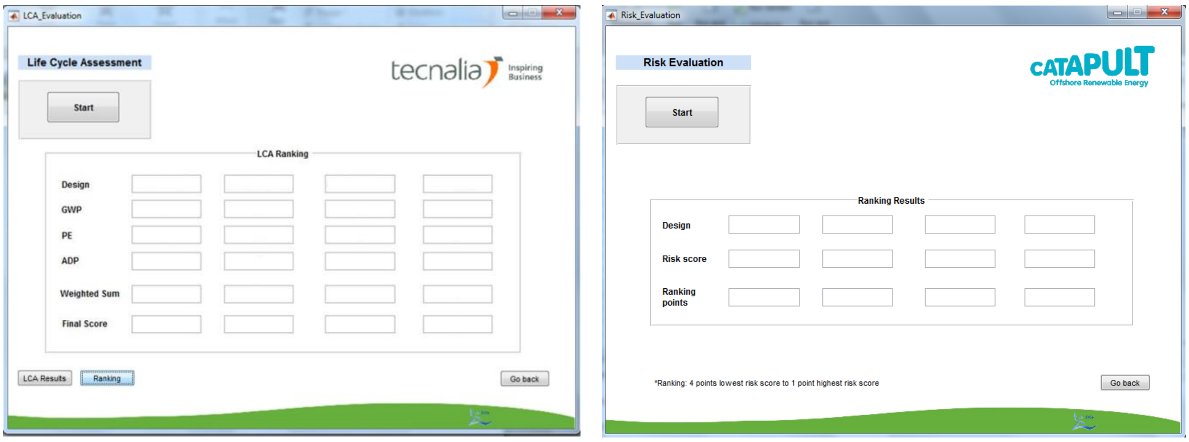

Figure 17: LCA Module and Risk Module

The KPI Section is also similar to the Single Mode and provides KPI reports according to each site and concept developer. The Multi-Criteria Evaluation section finally shows the rankings of the different FOWT concepts according to LCOE, LCA and Risk. In this section the final ranking is performed considering the weighting factors of each evaluation module. The next figure shows this section.

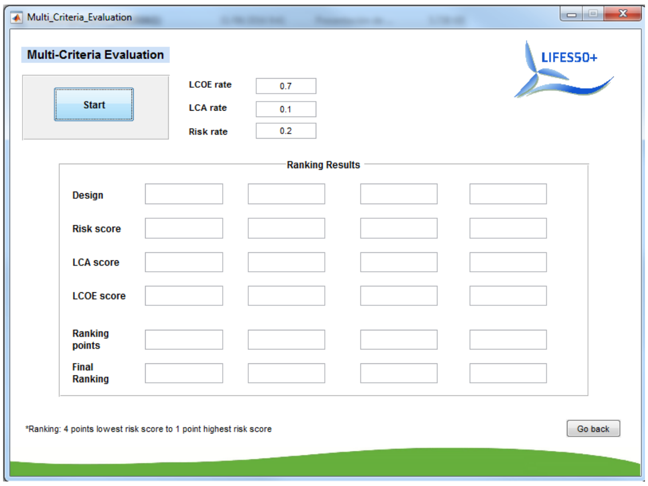

Figure 18: Multi-Criteria Evaluation

4.2 LCOE Uncertainty approach

LCOE calculation will be subjected to a certain degree of uncertainty due to the fact that some of the inputs that will be used for the CAPEX, OPEX and energy production assessment are given with a specific uncertainty range. Table 1 and Table 2 list the uncertainty drivers that have been considered within this project after a careful revision from concept developers, IREC and ORE Catapult. For easy reference same are reported in deliverable D2.2.

Table 1: LCOE selected uncertainty ranges for common components

Item Number	Description	Scope	Base	Low	High
1	Discount rate	Common	10%	8.00%	12.00%
2	Turbine supply cost	Common	EURO 1.3m/MW	1.2 M€/MW	1.5 M€/MW
3	Export Cable Installation vessel rate (inc. labour)	Common	Site-specific	-32.00%	58.00%
4	Export Cable Installation time	Common	Site-specific	-70.00%	100.00%
5	Export cable supply costs	Common	Design-specific	-12.50%	12.50%
6	Uncertainty in turbine availability	Common	Site-specific	-2.00%	2.00%
7	Gross capacity factor variation	Common	Site-specific	-5.00%	5.00%
8	Cost of turbine major repairs	Common	Site and design specific	-7.00%	7.00%
9	Cost of turbine minor repairs	Common	Site and design specific	-7.00%	7.00%
10	Potential variation in transmission fees	Common	Site and design specific	-6.00%	6.00%

Table 2: LCOE selected uncertainty ranges for design dependent components

Item Number	Description	Scope	Base	Low	High
1	Anchor and Mooring Installation vessel rate (inc. labour)	Developer	Design-specific		
2	Anchor and Mooring Installation time	Developer	Design-specific		
3	Substructure Installation vessel rate (inc. labour)	Developer	Design-specific		
4	Substructure Installation time	Developer	Design-specific		
5	Array Cable Installation vessel rate (inc. labour)	Developer	Design-specific		
6	Array Cable Installation time	Developer	Design-specific		
7	Array cable supply costs	Developer	Design-specific		
8	Substructure fabrication cost	Developer	Design-specific		
9	Substructure onshore assembly cost	Developer	Design-specific		
10	Cost of moorings	Developer	Design-specific		
11	Cost of substructure major repairs	Developer	Site and design specific		
12	Cost of substructure minor repairs	Developer	Site and design specific		
13	Total development costs	Developer	Site and design specific. Reference 5.7%		

The LCOE calculations using these uncertainty drivers add complexity to the original calculations and also imply that the ranking of the four different concepts becomes not a trivial issue. For this reason, different statistical approaches were evaluated. The first step to choose the approach is to identify to which distribution family the drivers belong to. The triangular distribution is often used when there is only limited sample data and especially in cases where the relationship between variables is known, but data is scarce. Therefore, this type of distribution is an excellent candidate for the uncertainty data given in Table 1. Finally, all uncertainty drivers which follow a triangular distribution must be combined to obtain the final LCOE value.

The assumptions considered to adopt the triangular distribution are:

1. It has been agreed that information regarding the most likely value (denoted as c), a minimum (denoted as “a”) and a maximum (denoted as “b”) possible value for the drivers, for all the inputs subjected to uncertainty used in the LCOE computation, would be provided by IREC for the common values and by concept developers for design driven values.
2. The uncertainty region must be considered and analysed to allow performance comparison among the concept designs. It is therefore not acceptable to simply compare mean values for the LCOE results for each concept design and site.

The LCOE distribution for each site and concept are calculated considering all uncertainty driver ranges represented as a central value (mode) and minimum and maximum values fit to a triangular distribution.

4.3 Multi-criteria and overall evaluation

The overall concept ranking will be based on the scoring results obtained by the LCOE, LCA and Risk evaluation.

The Multi-criteria module included in the Overall Evaluation tool has been developed in order to collect (read) the results obtained from the LCOE, LCA and Risk tools, combine them appropriately, and provide the final concept's design ranking. The role performed by the Multi-criteria tool serves to achieve the ultimate goal of obtaining a Global Evaluation of the proposed designs in an objective manner.

The Global Evaluation procedure for LCOE, LCA and risk ranking is explained in D2.5; in this document, a summary of the structure of the Multi-criteria module and the weighting factors to be applied to each of the criteria is provided.

A schematic of the proposed Global Evaluation procedure is shown below.

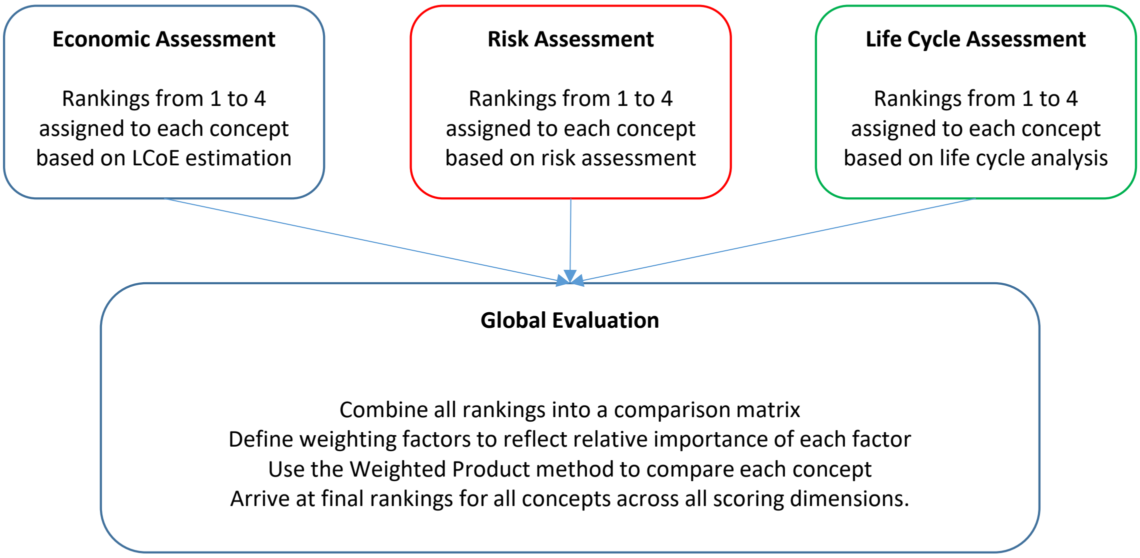

Figure 19: Illustration of Global Evaluation Procedure

A final score for each technology concept will be based on the three sets of rankings related to each of the three sets of evaluation criteria (LCOE, LCA, Risk).

The Multi-criteria module will store in different matrices results of the LCOE and the LCA calculations for each site and concept design. Each matrix will be treated in order to convert the absolute values (e.g. €/MWh for LCOE, or kg CO_2eq for LCA) into scores from 1 to 4 as explained in deliverable D2.5. There will be no need of further treatment of the outputs from the Risk module, as they will be expressed in the same dimensionless scoring system.

Each of these three sets of scores will be given a weighting factor, agreed by the concept developers and the Evaluation Committee as shown in Table 3.

Table 3: List of the weighting factors for each evaluation criteria set

Evaluation criteria	Weighting factor
Economic Assessment	0.7
Risk Assessment	0.2
Life Cycle Assessment	0.1

An example of this in practice is given in

Table 4.

Table 4: Example of evaluation matrix

Concept	Economic	Risk	LCA	Weighted sum	Final score
Concept 1	3	1	4	2.7	3
Concept 2	1	3	3	1.6	1
Concept 3	2	4	1	2.3	2
Concept 4	4	2	2	3.4	4
Weighting factor	0.7	0.2	0.1		

In the example above all concepts are ranked 1 – 4 in each dimension, with 4 being the highest ranking and 1 the lowest (e.g. Concept 3 is most highly ranked in terms of risk, Concept 4 is most highly ranked in terms of economics, etc.).

The result of running this through the Multi-criteria model would be the overall score as per the final column. In this case Concepts 1 and 4 would be the selected concepts (highest scores), which mimics the results of economic evaluation due to the high weighting factor (70%) associated with it.

5 D2.5 Global evaluation procedure including risks

The risk assessment of technology concepts for LIFES50+ will measure risk in terms of multiple criteria. At Phase I, only technology risk will be assessed. This will be expressed in terms of four types of consequence, namely:

– Cost

– Availability

– Health and Safety

– Environment

At phase II the technology risk assessment from Phase I will be complemented by the additional assessment of:

– Health, Safety and Environment (HSE) risks (in more detail)

– Operation and Maintenance (O&M) risks

– Commercialisation risks.

Risk will be evaluated as per the procedures outlined in D6.1, with the probability and consequence of each risk estimated relative to defined scales and placed on a risk matrix. Consequence scales for Phase I and Phase II are context-specific. At both Phase I and Phase II the average risk score (sum of risk scores for a given consequence category divided by the total number of risks) will be the overall indicator of risk for each consequence category. This approach will result in four measures of risk (four consequence categories) for each technology.

The decision as to the 'best' technology concept will therefore be based on four risk scores for four concepts combined to arrive at a ranking for each concept which characterises relative technology risk, i.e. technology choice is multi-dimensional. Various Multi-Criteria Decision Making (MCDM) methods were considered: it is important to achieve a balance between simplicity and fitness-for-purpose.

The criteria used in selecting a MCDM method were:

– Transparency (readily understood and easily implemented)

– Flexibility (applicable not just to the Risk Evaluation but to other multi-criteria decisions within LIFES50+ if necessary)

A Weighted-Sum method is recommended on this basis. The Risk Evaluation procedure for LIFES50+ will make use of this method to arrive at rankings for each technology concept in terms of relative risk.

The ranking for each technology from this risk assessment will be carried forward to the Global Evaluation procedure, and combined with other measures of suitability (Economic and LCA-related). For consistency, the Global Evaluation and the Risk Evaluation procedures will make use of the same MCDM approach.

6 D2.6 Economical, technical and environmental evaluation of Phase 1

The aim of deliverable D2.6 is to provide an overview of the process that has been followed during the Phase I Evaluation and the results obtained for the four concept designs in this phase.

The Phase I Evaluation Phase has taken place from November 2016 to March 2017. Within this period, data received from all the concept developers has been collected and reviewed in order to perform the evaluation. Concept developers have been asked to provide the required information in order to understand, check and validate the data provided. Data received has been introduced in the Overall Evaluation tool to perform single calculations (individual for each concept design and site) and combined evaluation, (using uncertainty ranges and combining LCOE, LCA and Risk results). The use of Two-way ANOVA and Tukey statistical test have shown that the LCOE distribution results provided by the tool are statistically different and therefore they can be scored using the methodology applied in WP2. The Overall Evaluation has determined that TLP and Semi-submersible concrete concepts have reached the highest scores and therefore they have been selected for Phase II. However, in phase 2 the semi-submersible steel concept has replaced the TLP concept due to the leaving of the project of the concept developer.

The outcomes of the first phase evaluation process have been subjected to the following disclaimers

- No independent numerical calculations have been performed to verify the information provided, except for basic sanity checks (hand calculations)
- Professionality and trust have been assumed as basis for the evaluation: each designer has been responsible to design at best of their ability and to transparently show the results
- All the designers have made efforts to reply to the EC comments with limits due to time and resources.
- Given the time/resources this review shall not be considered as a fully comprehensive review of the concept, i.e. if something was not spotted, it doesn't necessarily mean that it is considered correct.
- The EC evaluation does not constitute any form of approval, verification or certification of the technical feasibility of the design. EC partners request that no such claim or statement should be associated with the members (individuals, companies) of the EC in any form of communication.

7 D2.7 Evaluation Report Phase 2

The aim of this deliverable is to provide the results obtained by the LCOE calculation and LCA of the two FOWT concepts that have been selected during the evaluation workshop of phase 1 of the LIFES50+ project in Barcelona from 8th to 10th of March 2017. The selected FOWT concepts have been optimized in phase 2 of the project based on the experimental test campaigns and the numerical modelling of WP3 and WP4 and the industrialization study carried out in WP5. A detailed description of the concepts design optimization is provided in the deliverable D1.8. The concept developers have been asked to update the data collection questionnaires of phase 1 considering the performed optimization and the outcomes of the industrialization study.

The questionnaires have been introduced in the evaluation tool FOWAT to perform the LCOE and LCA calculations for both FOWT concepts and the three offshore locations Golfe de Fos, Gulf of Maine and West of Barra.

The results of the assessment given in this report are subject to the following disclaimers

- No independent numerical calculations have been performed to verify the information provided, except for basic sanity checks (hand calculations).

- Professionality and trust have been assumed as basis for the evaluation: each designer has been responsible to design and optimize at best of their ability and to transparently show the results.

- The LCOE and LCA results are based on the input data provided by the developers and the data used for the common costs, which were reviewed by the Evaluation Committee. Results do not necessarily represent the current state of FOWTs and are affected by the accuracy and uncertainty of the provided data.

8 D2.8 Expected LCOE for floating wind turbines 10MW+ for 50m+ water depth

The LCOE calculation is a method used to obtain the cost of one unit energy produced and is typically applied to compare the cost competitiveness of different power generation technologies and concepts. The method has been used in the LIFES50+ project to evaluate economically the FOWT concepts. The objective of this document is to present the LCOE results that were obtained in the project and the potential cost reductions based on optimization and industrialization studies.

The document introduces with a review on LCOE values of FOWTs obtained in the literature and then presents the results of the phase 1 concept evaluation of the LIFES50+ project. Furthermore, a sensitivity analysis outlines the parameters that most influence the LCOE in order to highlight potential components for cost reductions. In phase 2 of the project, the 2 selected FOWT concepts have been optimized based on the performed experimental test campaigns and numerical modeling. An evaluation at the end of the phase has resulted in a mean LCOE reduction of the optimized concepts by about 2%. Besides a mean decrease in manufacturing cost, a significant reduction in transport and installation costs could be achieved.

The document reports further an outline on potential cost reductions through industrialization and quantifies the LCOE reduction that can be achieved by economies of scale in substructure unit costs. As the sensitivity analysis has highlighted the discount rate to be one of the most influencing parameters on the LCOE, its impact on the concept evaluation is assessed. It has been found that a 3% lower discount rate can achieve a LCOE reduction of about 18% to 20% depending on the offshore site studied.

9 Presentation of the results at relevant conferences and scientific papers

The table below presents the dissemination activities (conferences attendance and scientific papers) developed within WP2.

Table 5: Dissemination activities within WP2

Conference/Premise	Date	Type of Action	Title
IRPWind Conference 2015	28-29 September 2015	Presentation	Wind integration – Cost of wind
		Presentation	Offshore wind - Introduction to LIFES50+
IEA Wind Task 26 meeting 2015WS	27 October 2015	Presentation	Cost of Wind IREC research activities: LIFES 50+ WP2 introduction
EERA DeepWind 2016	20-22 January 2016	Poster	Socio-economic evaluation of floating substructures within LIFES 50+ project
Spanish Wind Power Congress	28-29 June 2016	Presentation	Cualificación de subestructuras flotantes innovadoras para aerogeneradores de 10 MW y profundidades mayores de 50 metros: LIFES50+
Wind Europe conference 2016	26-29 September 2016	Presentation	Multi-criteria assessment tool for floating offshore wind power plant
WindEurope Summit 2016	27-29 September 2016	Paper	Multi-criteria Assessment Tool for Floating Offshore Wind Power Plant
WindFarms Conference 2017	31 May - 2 June 2017	Presentation	Comparative Assessment of Floating Foundations for Offshore Wind Power Plants
WindEurope Conference & Exhibition 2017	28 – 30 November 2017	Poster	Sensitivity Analysis of Floating Offshore Wind Power Plants
International Conference on Renewable Energies	25 – 27 April 2018	Presentation	A simplified model for the dynamic analysis and power generation of a floating offshore wind turbine
DeepWind Conference 2019	16 – 18 January 2019	Poster	Collection Grid Optimization of a Floating Offshore Wind Farm using Particle Swarm Theory
DeepWind Conference 2019	16 – 18 January 2019	Presentation	Summary of LIFES50+ project results: from the design basis to the floating concepts industrialization
Sustainable Energy Technologies and Assessments	2018	Scientific paper	Lerch, M., De-Prada-Gil, M., Molins, C. & Benveniste, G. (2018). Sensitivity analysis on the levelized cost of energy for floating offshore wind farms.

10 Conclusions

This deliverable has presented a summary of the deliverables produced in WP 2: Concept Evaluation. The report has also given an overview of the dissemination activities that have been carried out as part of the research, including publications and public presentations.

WP 2 had nine deliverables with each deliverable addressing a specific topic related to the evaluation of the FOWT concepts concerning economic aspects, environmental aspects, technical aspects and risk aspects.

The eight previous deliverables reported in this document are:

- D2.1: General consideration for evaluation procedures
- D2.2 LCOE Tool description, technical and environmental impact evaluation procedure
- D2.3 LCOE cost tool
- D2.4 Technical and environmental impact evaluation tool (software)
- D2.5 Global evaluation procedure including risk
- D2.6 Economical, technical and environmental evaluation of Phase I
- D2.7 Evaluation report Phase II
- D2.8 Expected LCOE for floating wind turbines 10MW+ for 50 m+ water depth