MERMAID

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Risk Analysis

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1 Introduction and scope of the deliverable

This deliverable presents the risk analysis results of the application of the Methodology for Integrated Socio-Economic Assessment (MISEA) which was developed in MERMAID (MERMAID D.8.1) to socio-economically assess the different proposed designs of novel Multi-Use Offshore Platforms (MUOPs). MISEA assists on identifying, not only the potential range of impacts of a proposed investment such as the construction of MUOPs, but also the likely responses of those impacted by the investment project. Since it is anticipated that these novel designs of platforms will have considerable socioeconomic and environmental impacts, MISEA provides an analytical framework that lies in agreement with the sustainability conditions. MISEA assists on designing appropriate mitigation strategies to minimize negative and maximize positive socio-economic and environmental impacts. In this context, this methodology extends the standard process of financial analysis into an assessment that incorporates socio-economic, legal, technological environmental parameters.

In particular, the methodology allows a stepwise approach of integrating information produced in the previous work packages (WPs) of the project towards the socio-economic assessment of different designs (being built by the engineers of MERMAID in previous WPs) of MUOPs. The multi-disciplinary information, allows a direct comparison between different MUOP designs, including comparison between multi-use and single-use alternatives. Under MERMAID, the information produced by the different WPs was used for the socio-economic assessment in each selected site and platform design.

- Legal and policy analysis provided the policy and legal background required for the development of the particular platform designs. Stakeholders' analysis and more specifically the stakeholders' roundtables provided inputs to for the final design and the socio-economic assessment of the selected MUOPs with regards to social acceptance and potential conflicts between stakeholders (MERMAID D2.1, MERMAID D2.4 and MERMAID Repository[1]: Regional Profiling Datasets).

- The identification of innovative platform designs formed the background required for the collection of the financial data, as well as the socio-economic analysis and monetization of environmental externalities. (MERMAID D7.1, MERMAID D7.2, MERMAID D7.3, and MERMAID Repository[2]: Regional Profiling Datasets).

- The case-study specific environmental assessments (MERMAID Repository[3]: Regional Profiling Datasets) identified the environmental effects in relation to the suggested designs. MUOPs are related to a stream of new social/environmental goods and services (e.g., increase of employment, increase food and energy security, potential interactions with

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[1] http://mermaid.madgik.di.uoa.gr/
[2] http://mermaid.madgik.di.uoa.gr/
[3] http://mermaid.madgik.di.uoa.gr/

marine environment etc.) with no values readily observed in existing markets. Hence, it was required to follow non-market economic valuation methods to estimate these values (Economic Valuation Methods are explained in D8.1). Although the information was limited and based on experts' opinions and stakeholder's views, the economic values of the main environmental externalities were estimated successfully.

- The case-study specific financial feasibility assessment was crucial for the comparison between different offshore platforms. The data used in the financial assessment were the investment costs with regards to equipment, construction, labor and other costs, as well as operation data for the costs and revenues according to different functions used in the final design of each study site (e.g. energy/aquaculture production output, price, raw materials, energy used, maintenance costs, operating costs).

This methodology provided useful information on which economic activities should be implemented on the different sites, with the scope to avoid developments that would have negative socio-economic and environmental consequences, considering legal and technical aspects. This load of information assists on identifying challenges and opportunities towards the implementation of suggested MUOPs.

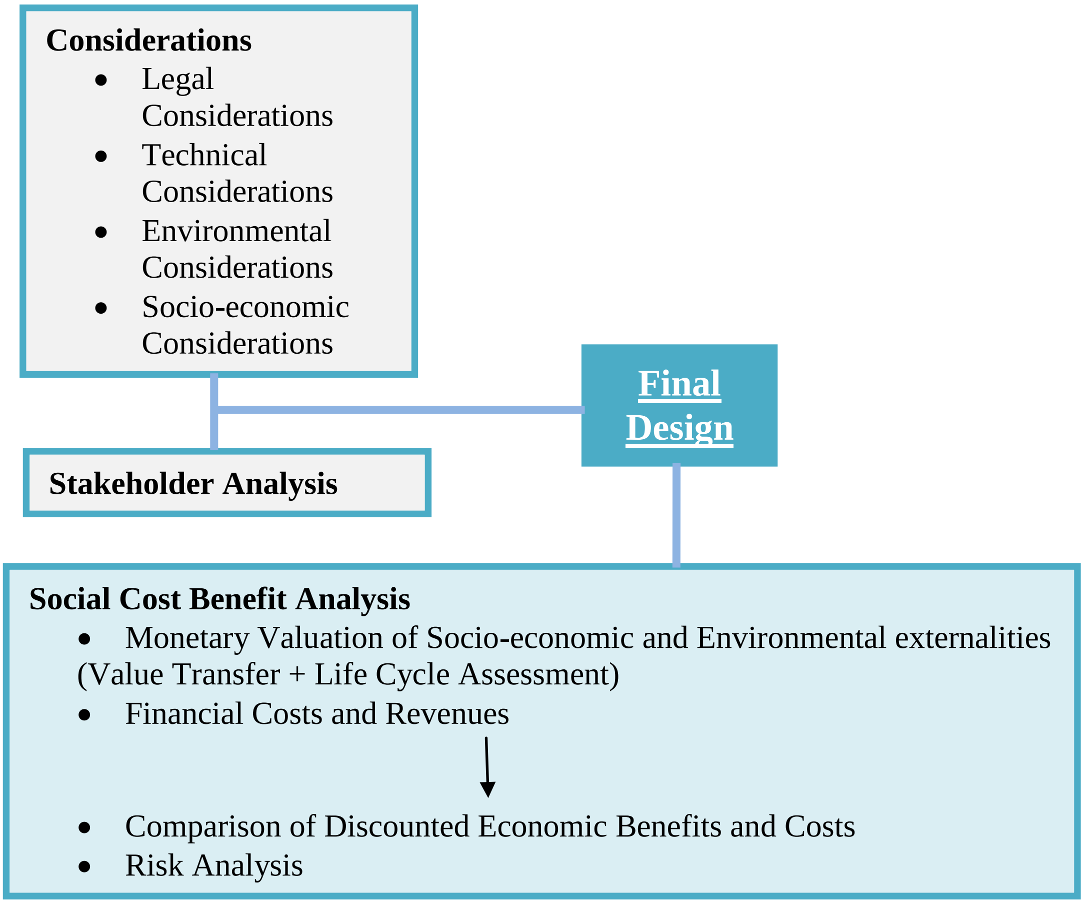

Figure 1 MERMAID Stepwise approach of integrating information

2 Outline for the reader

The document is divided into **6** different sections. **Section 2**introduces the risk analysis. **Section 3** describes the risk analysis produced for the Atlantic site. **Section 4** describes the risk analysis produced for the Baltic site. **Section 5**describes the risk analysis produced for the Mediterranean site. **Section 6**describes the risk analysis produced for the North Sea site. **Section 7** presents final conclusions and recommendations for the implementation of MUOPs based on the four examined European case studies.

3 Introduction of Risk Analysis

Risk analysis or risk assessment in cost benefit analysis aims at addressing **uncertainty associated with the future cash flows of a project**. In risk analysis the ‘stand alone’ risk for the project is analyzed. This type of risk represents measurable uncertainty which is the case where a known probability measure is associated with stochastic variables. Accounting for risk requires therefore an assessment of probability distributions indicating the likelihood of the realized value of a variable falling within stated limits.[4]

Risk assessment implies the estimation of the sensitivity of the project performance to stochastic effects and potentially the probability that a project will achieve a satisfactory performance, where performance is measured in terms of some threshold value of the *Net Present Value* (NPV) or the *Internal Rate of Return* (IRR). Probability should here be understood as an index that takes the value 1 under full certainty that a prediction will be confirmed, a zero value for certainty that the prediction will not be confirmed, and intermediate values for anything in between the two extremes. In this context, risk assessment can be used to make inference and test hypothesis in the statistical sense. Thus with an appropriate risk assessment an analyst can estimate the probability that the NPV or the IRR of a project will be between pre-specified limits (confidence interval estimation), or that will be above or below some acceptable cut-off level.

Uncertainty of future cash flows is a natural consequence of the fact that these cash flows represent forecasts based on current knowledge and future expectations. Similarly, the capital outlays associated with a new product are generally obtained from the engineering and product development staffs, while operating costs are estimated by cost accountants, production experts, personnel specialists, purchasing agents, and so forth.

For the specific project that performs Cost Benefit Analysis (CBA) of Multi-Use Offshore Platforms, costs and benefits associated with offshore wind/wave farms and aquaculture are expected to embody considerable uncertainties. These uncertainties affect not just the economic part of the project, that is prices and unit costs, but also the natural and the technological part that affect quantities of inputs and outputs and environmental impacts. In particular, variables associated withpower production (wind and wave), aquaculture(mussels, seaweed and fish), revenues and

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[4] In contrast in the case of pure uncertainty specific probabilities cannot be assigned to random events.

costs, under the proposed multi-functional structures determine the future cash flows of the Multi-Use Offshore Platforms. These cash flows are affected by strong stochastic factors. Furthermore, the project addresses different natural environments from deep water, to shallow water with high morphological activity, and further to inner waters like the inner Danish/Baltic areas and the Adriatic Sea. This spatial differentiation implies strong and spatially non homogeneous physical and environmental risks.

Risk assessment can be carried out at two different but interconnected levels: (i) Sensitivity analysis, and (ii) Monte Carlo Simulations.

Sensitivity Analysis

Sensitivity analysis is a technique that indicates how much the NPV will change in response to a given change in variables that affects the cash flow of the project, other things held constant.
Sensitivity analysis involves the following steps:

1. Define a **base-case or benchmark** estimation of the NPV, which is developed using the ***expected values*** for each variable involved in the cash flow.
2. Define a **maximum and minimum** value for each of the variables relative to the benchmark estimation. Calculate the NPV for the range of values from maximum to minimum by a predetermined step (10% in our case), for each variable of step 1 by keeping the rest of the variables fixed.
3. Identify **sensitive or critical variables**. These are cash flow variables (e.g. equipment, wind power, costs) with the property that small deviations of their values from the benchmark value will change the NPV or the IRR a lot.
4. Construct a **sensitivity diagram or spider graph** that relates proportional changes in the critical variable to proportional changes in the NPV or IRR. A variable is sensitive or critical if it has a steep slope on the spider graph.
5. Identify **switching values** for important cash flow variables. A switching value is the value of the variable at which the NPV switches from positive to negative.

Sensitivity analysis can be regarded as analyzing specific scenarios for the evolution of variables affecting the NPV of the project. In fact, the base-case, the minimum and the maximum can be regarded as three alternative scenarios. However, although sensitivity analysis provides very useful descriptive results about the sensitivity of NPV to changes that affect cash flows, it does not allow for statistical inference and hypothesis testing with respect to the NPV of the project. This can be obtained by using Monte Carlo simulations.

Monte Carlo

The **Monte Carlo method** is a computational algorithm which is based on random sampling. To use the method specific subjective probability distributions (e.g. uniform, triangular, normal) to important cash flow variables should be assigned. The method proceeds in the following steps:

1. A value for a variable affecting the cash flow is selected from its predetermined distribution function using a random number generator.
2. A vector of specific values is defined (e.g. equipment, wind output, costs).
3. These values are used to calculate an NPV and an IRR which are stored for this replication.
4. After a large number of replications (1000 in our case) a frequency distribution is estimated for the NPV and/or the IRR.
5. Making the normality assumption the estimated distribution can be used to construct confidence intervals and perform hypothesis testing.

4 Risk Analysisof the Atlantic Site

For the Atlantic site the financial costs and revenues, together with the benefits derived by the reduction of CO_2 emissions and research and education were included in the SCBA. For the case of CO_2 emissions both comparisons were used in the analysis (i.e. reduction of CO_2 emissions compared to coal energy production and ENTSO-E production). Since the baseline for the Atlantic site was considered to be “nothing”, the presented results are concentrated on the Wind & Wave scenario of multi-use platform.

4.1 Sensitivity Analysis

With regards to the sensitivity analysis, the scenarios refer to the Wind & Wave platform. We consider the variables presented on the table below.

Table 1 Variables examined in the sensitivity analysis

	min	**base***	**max**
Equipment cost	0,90	1,00	1,10
Energy output (wind)	0,80	1,00	1,20
Energy output (wave)	0,80	1,00	1,20

*Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

The results suggest that the critical variables are **wind energy output** and **equipment cost**. There is one switching value for wind output in the case where the discount rate is 4% and total cost reduction in terms of CO_2 refer to the ENTSO-E network which is around 17% below the base case (83% in the spider graph).

In the following we present spider graphs for the combined Wind & Wave platform for 3% and 4% discount rate. Spider graphs for the single use scenarios, Wind or Wave project can be provided under request.

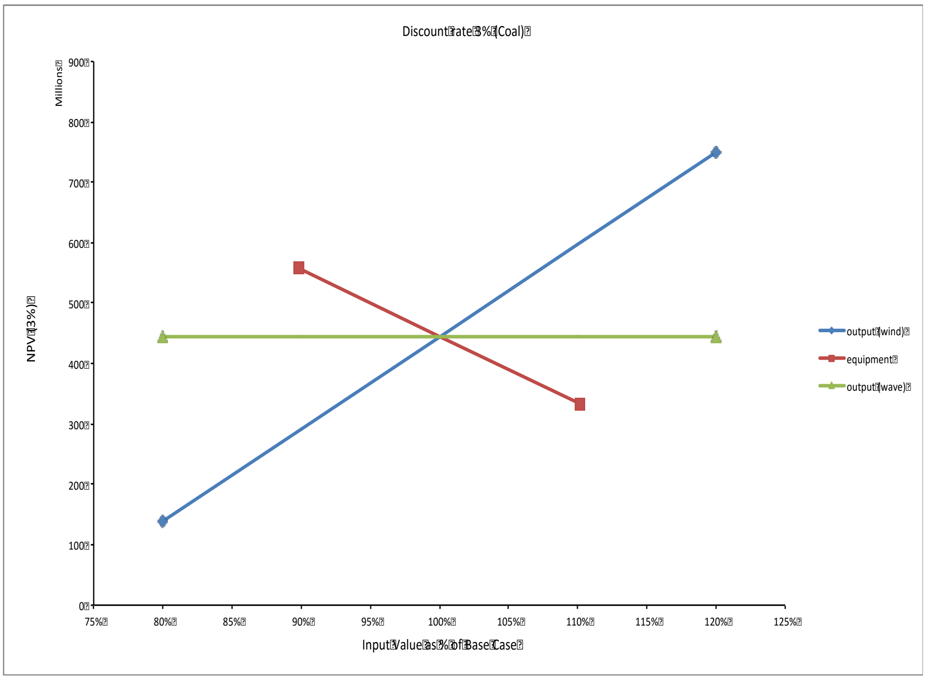


Figure 2 Sensitivity Analysis on SCBA (3% discount rate, compared to coal energy production)

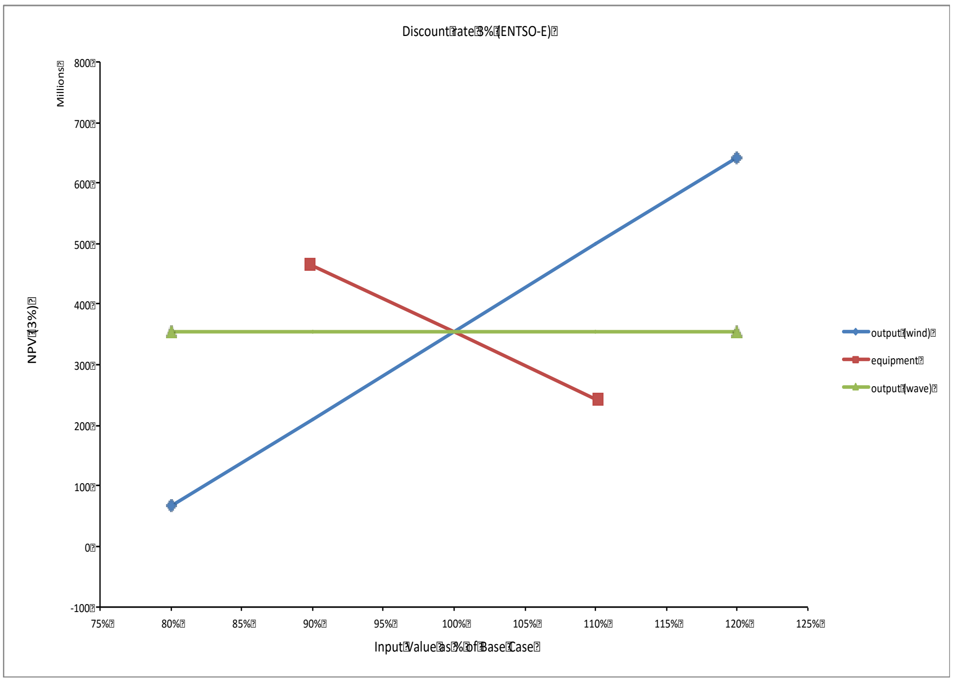


Figure 3 Sensitivity Analysis on SCBA (3% discount rate, compared to ENTSO-E energy production)

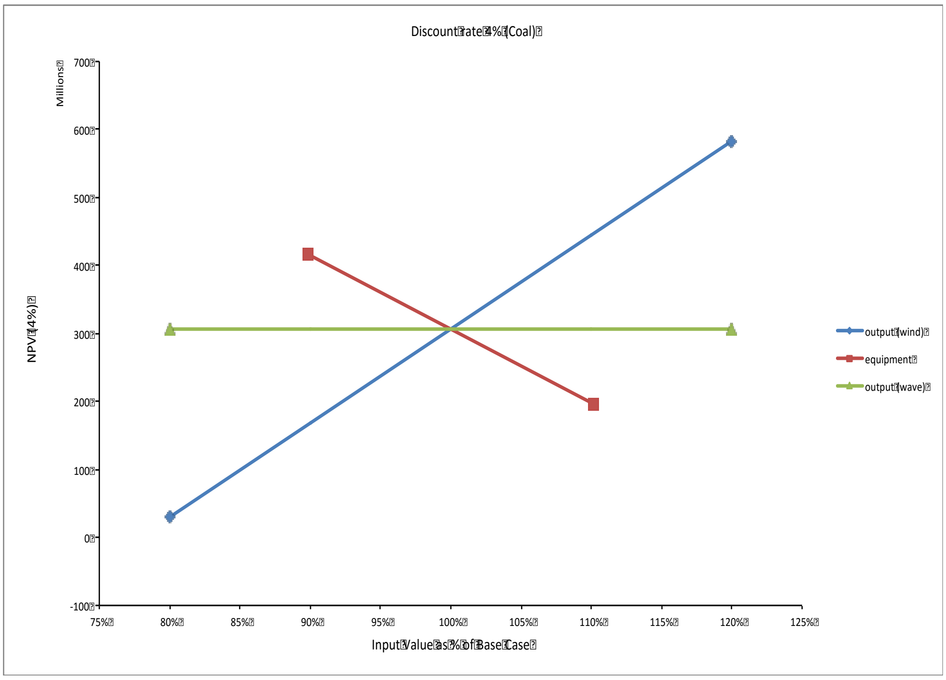


Figure 4 Sensitivity Analysis on SCBA (4% discount rate, compared to coal energy production)

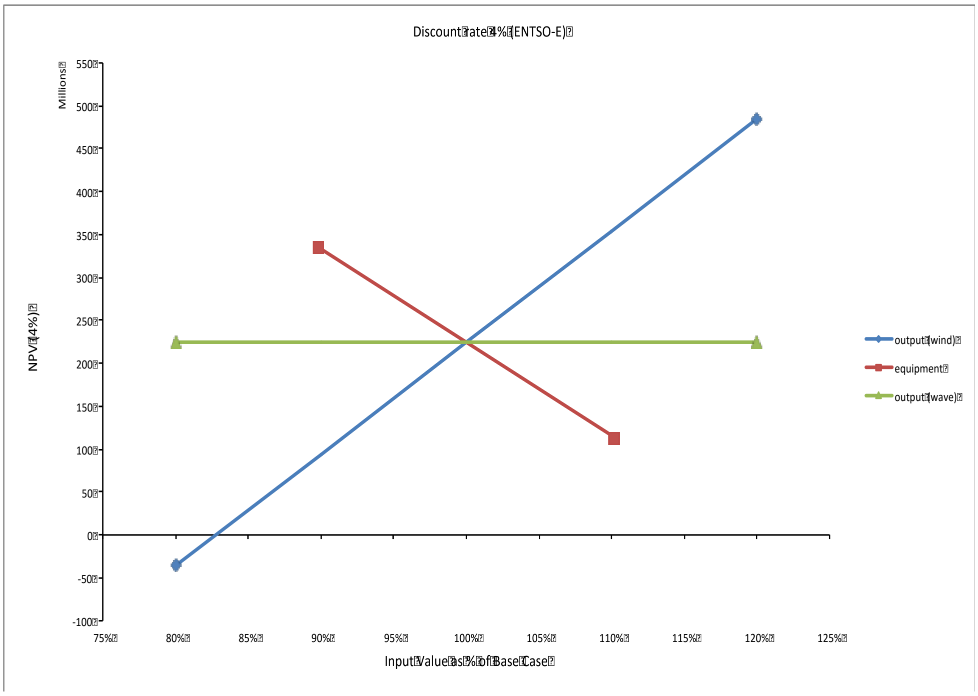


Figure 5 Sensitivity Analysis on SCBA (4% discount rate, compared to ENSTSO-E energy production)

4.2 Monte Carlo Simulations

Wind & Wave, 3% discount rate, compared to coal energy production

Based on the results from the Monte Carlo Simulations for the Atlantic MUOP and considering discount rate to be 3%, the 95% confidence interval for the NPV is 442.3±1.96*58.3. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 450 million is approximately 55%.

Table 2“Wind & Wave”compared to coal energy production (NPV, 3% discount rate)

Mean	442,343,771.94
St. Dev.	58,288,143.94
Mean St. Error	1,843,232.95
Minimum	275,148,899.85
First Quartile	401,167,456.76
Median	442,375,607.15
Third Quartile	482,805,388.36
Maximum	619,791,081.58
Skewness	-0.0057

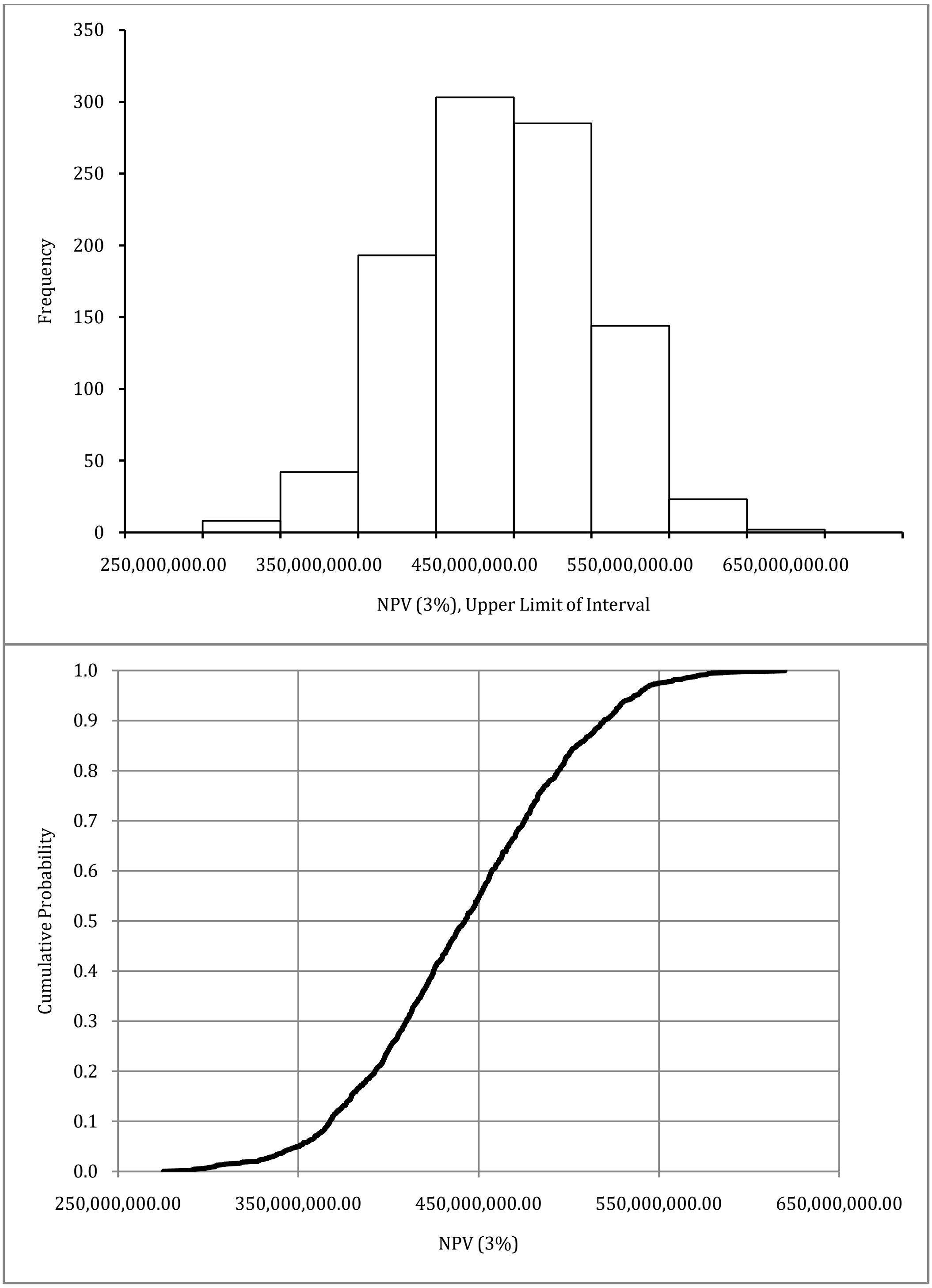


Figure 6 Monte Carlo Simulation for “Wind & Wave” compared to coal energy production (NPV, 3% discount rate)

Wind & Wave, 3% discount rate, compared to ENTSO-E energy production

Based on the results from the Monte Carlo Simulations for the Atlantic MUOP and considering discount rate to be 3%, the 95% confidence interval for the NPV is 355.4±1.96*56. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 358 million is approximately 50%.

Table 3 “Wind & Wave” compared to ENTSO-E energy production (NPV, 3% discount rate)

Mean	355,399,160.92
St. Dev.	56,008,811.17
Mean St. Error	1,771,154.12
Minimum	211,566,642.09
First Quartile	314,870,681.01
Median	357,464,014.39
Third Quartile	396,439,358.27
Maximum	503,039,011.29
Skewness	-0.0836

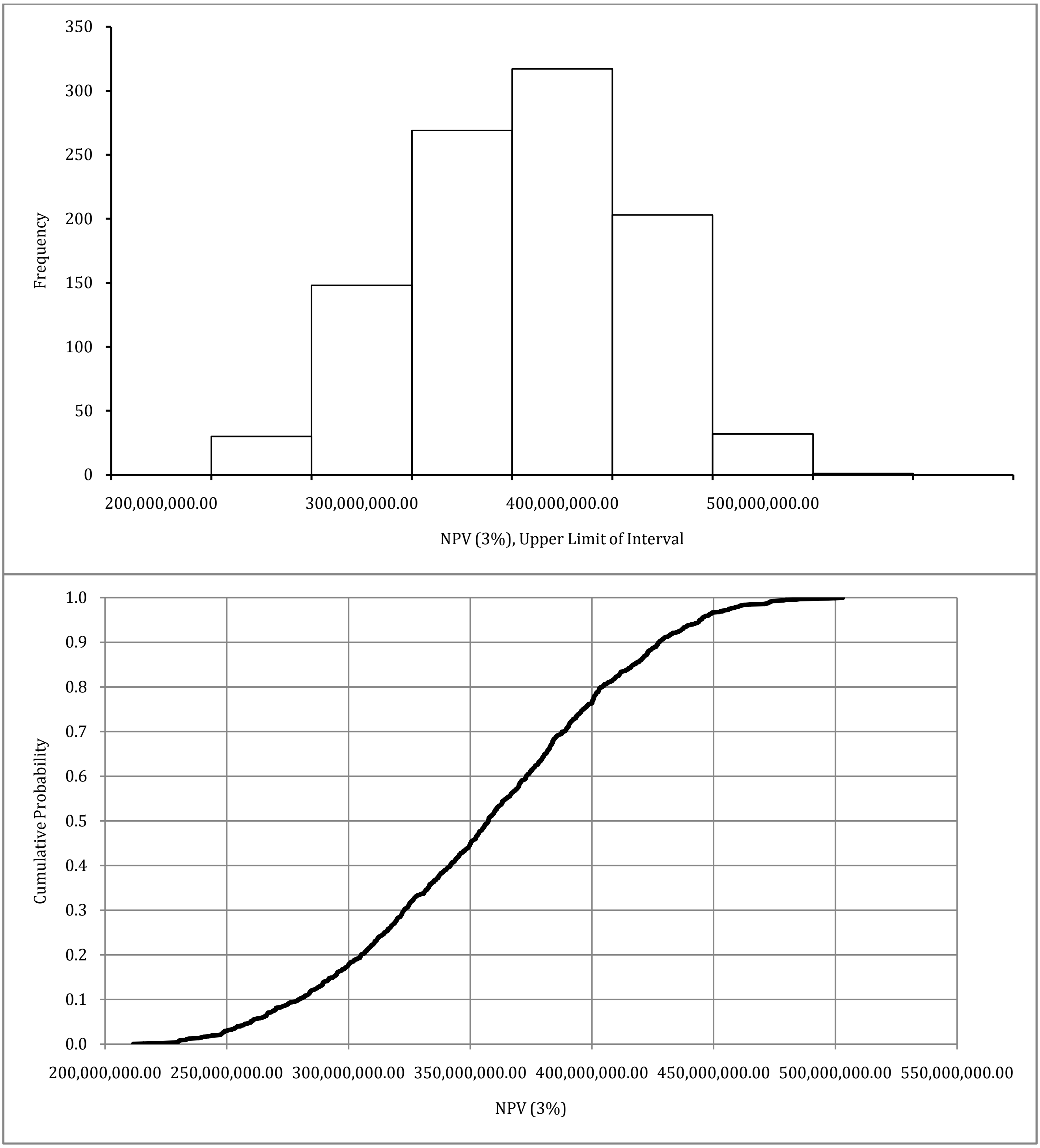


Figure 7 Monte Carlo Simulation for “Wind & Wave” compared to ENTSO-E energy production (NPV, 3% discount rate)

Wind & Wave, 4% discount rate, compared to coal energy production

Based on the results from the Monte Carlo Simulations for the Atlantic MUOP and considering discount rate to be 4%, the 95% confidence interval for the NPV is 305.7±1.96*55.2. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 308 million is approximately 50%.

Table 4 “Wind & Wave” compared to coal energy production (NPV, 4% discount rate)

Mean	305,730,883.29
St. Dev.	55,184,066.20
Mean St. Error	1,745,073.40
Minimum	138,090,091.64
First Quartile	265,816,667.65
Median	306,618,557.11
Third Quartile	345,318,445.43
Maximum	442,005,485.77
Skewness	-0.0763

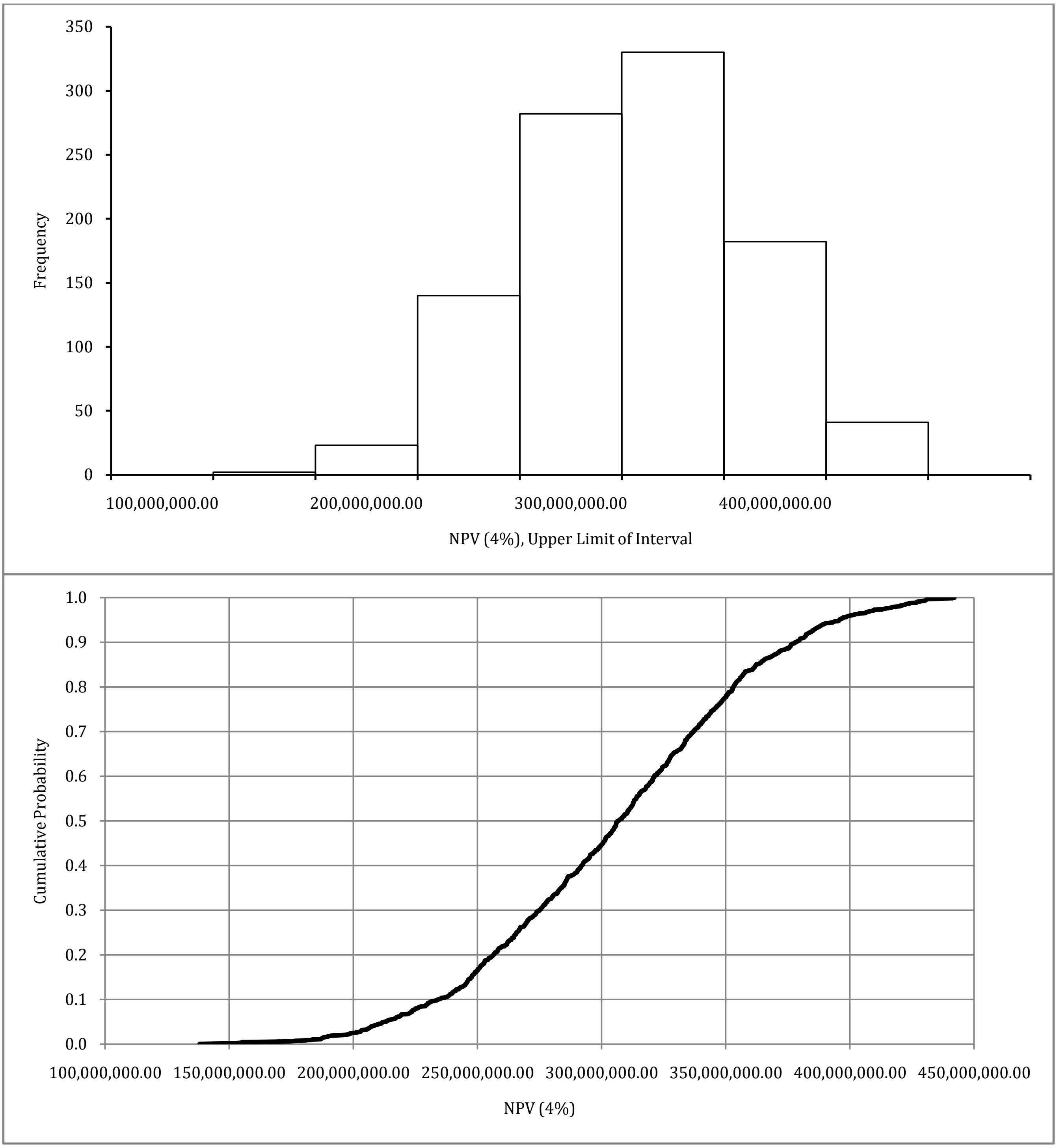


Figure 8 Monte Carlo Simulation for “Wind & Wave” compared to coal energy production (NPV, 4% discount rate)

Wind&Wave, 4% discount rate, compared to ENTSO-E energy production

Based on the results from the Monte Carlo Simulations for the Atlantic MUOP and considering discount rate to be 4%, the 95% confidence interval for the NPV is 225.9±1.96*54.9. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 300 million is approximately 90%.

Table 5“Wind & Wave” compared to ENTSO-E (NPV, 4% discount rate)

Mean NPV	225.915.262,55
St. Dev.	54.937.265,13
Mean St. Error	1.737.268,86
Minimum	43.041.973,37
First Quartile	187.856.542,51
Median	226.909.141,10
Third Quartile	263.717.964,18
Maximum	371.746.326,63
Skewness	-0,0418

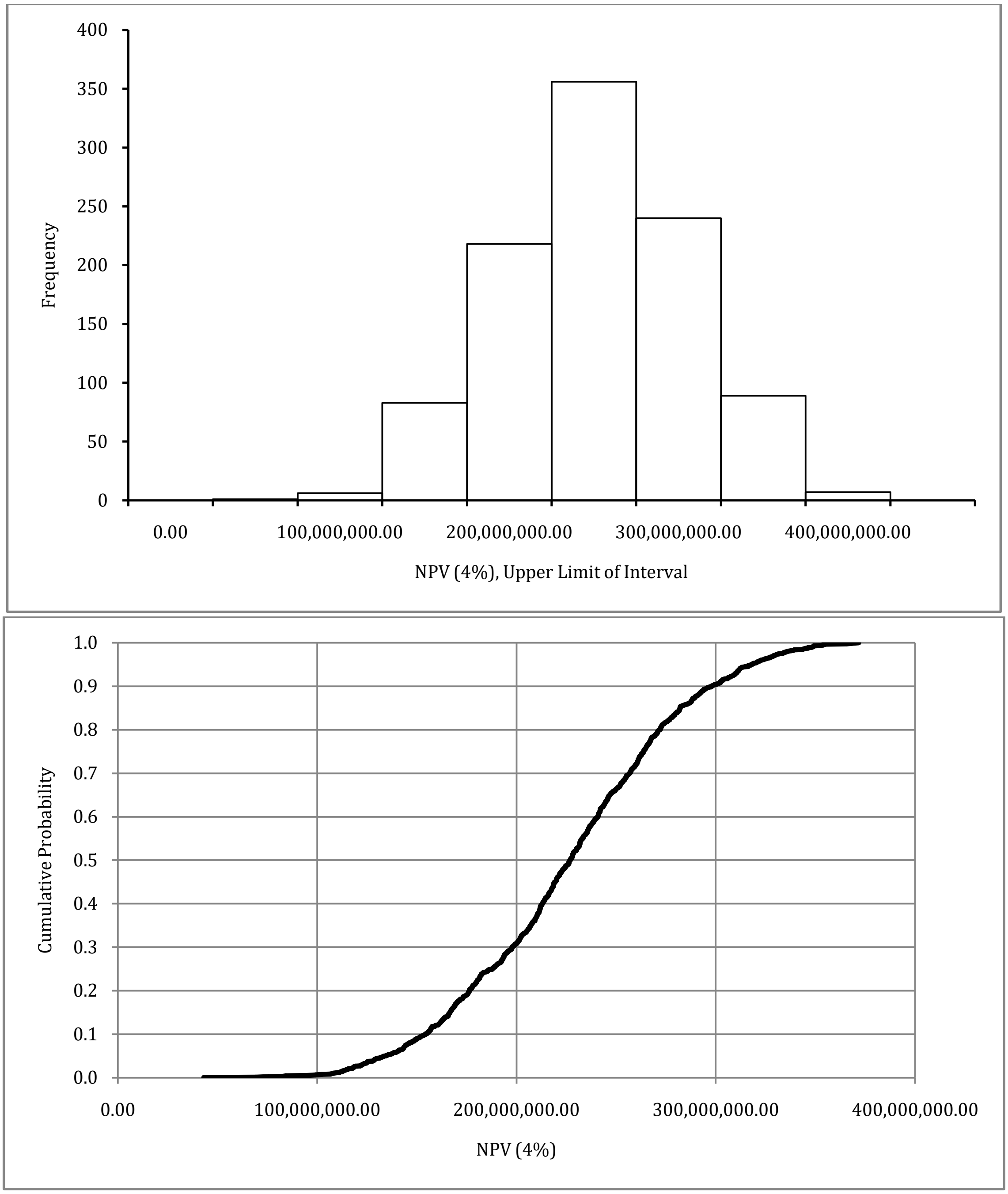


Figure 9 Monte Carlo Simulation for “Wind & Wave” (NPV, 4% discount rate)

Similar output for the IRR is presented below.

From the results we can conclude that the 95% confidence interval for the IRR is 7%±1.96*1%. This confidence interval is strictly above the cut-off rate of 4%; therefore, we can conclude that at 95% confidence interval this project passes the IRR test. From the cumulative chart we can conclude that the probability of having an IRR less than 7% is approximately 60%.

Table 6 “Wind & Wave” compared to coal energy production (IRR)

Mean	7%
St. Dev.	1%
Mean St. Error	0%
Minimum	5%
First Quartile	6%
Median	7%
Third Quartile	7%
Maximum	9%
Skewness	0.2072

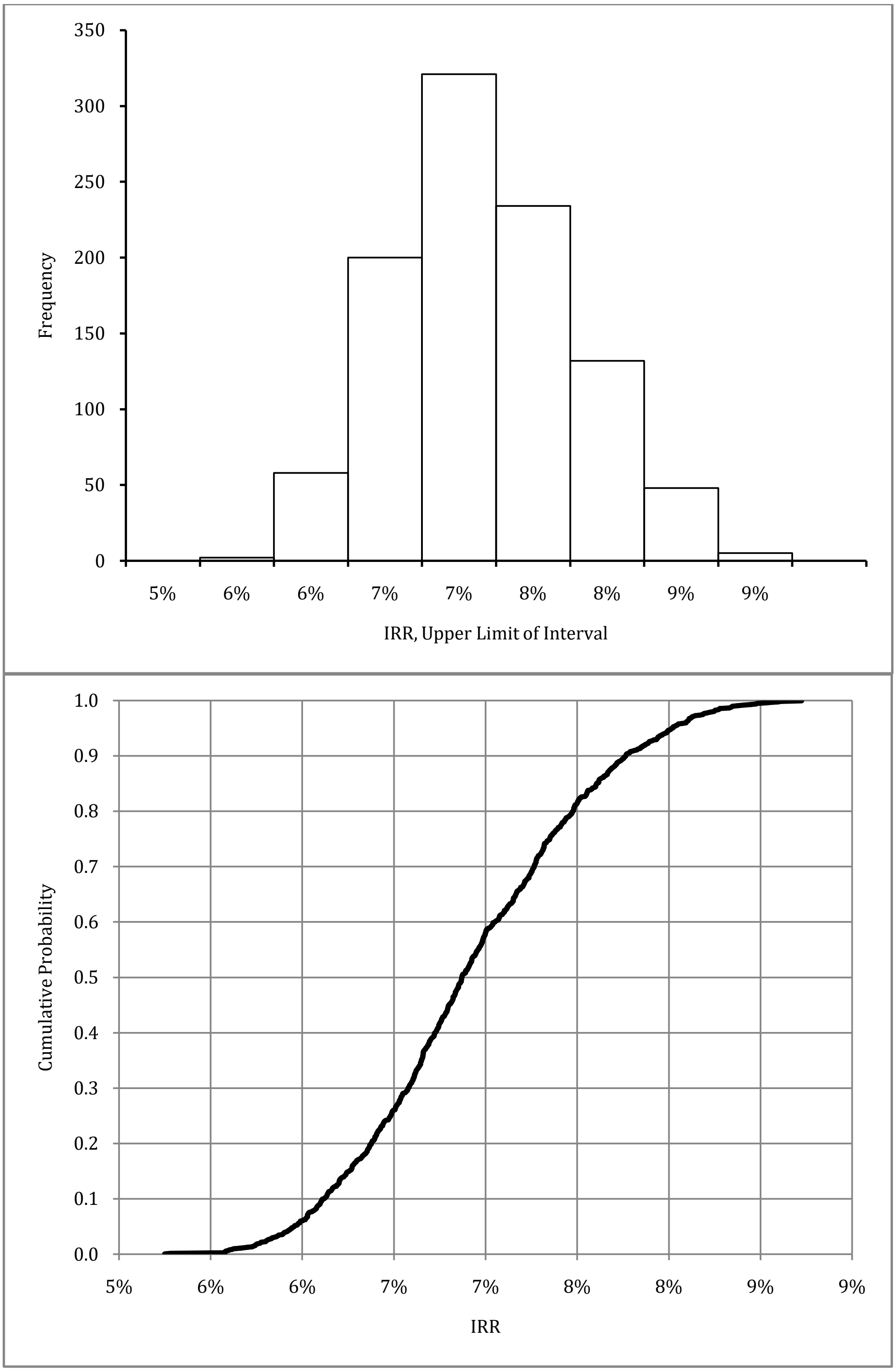


Figure 10 Monte Carlo Simulation for “Wind & Wave” compared to coal energy production (IRR)

From the results we can conclude that the 95% confidence interval for the IRR is 6.17±1.96*0.56. This confidence interval is strictly above the cut-off rate of4%; therefore, we can conclude that at 95% confidence interval this project passes the IRR test. From the cumulative chart we can conclude that the probability of having an IRR less than 6.5% is approximately 73%.

Table 7“Wind & Wave” compared to ENTSO-E energy production (IRR)

Mean IRR	6.17%
St. Dev.	0.56%
Mean St. Error	0%
Minimum	5%
First Quartile	6%
Median	6%
Third Quartile	7%
Maximum	8%
Skewness	0,1570

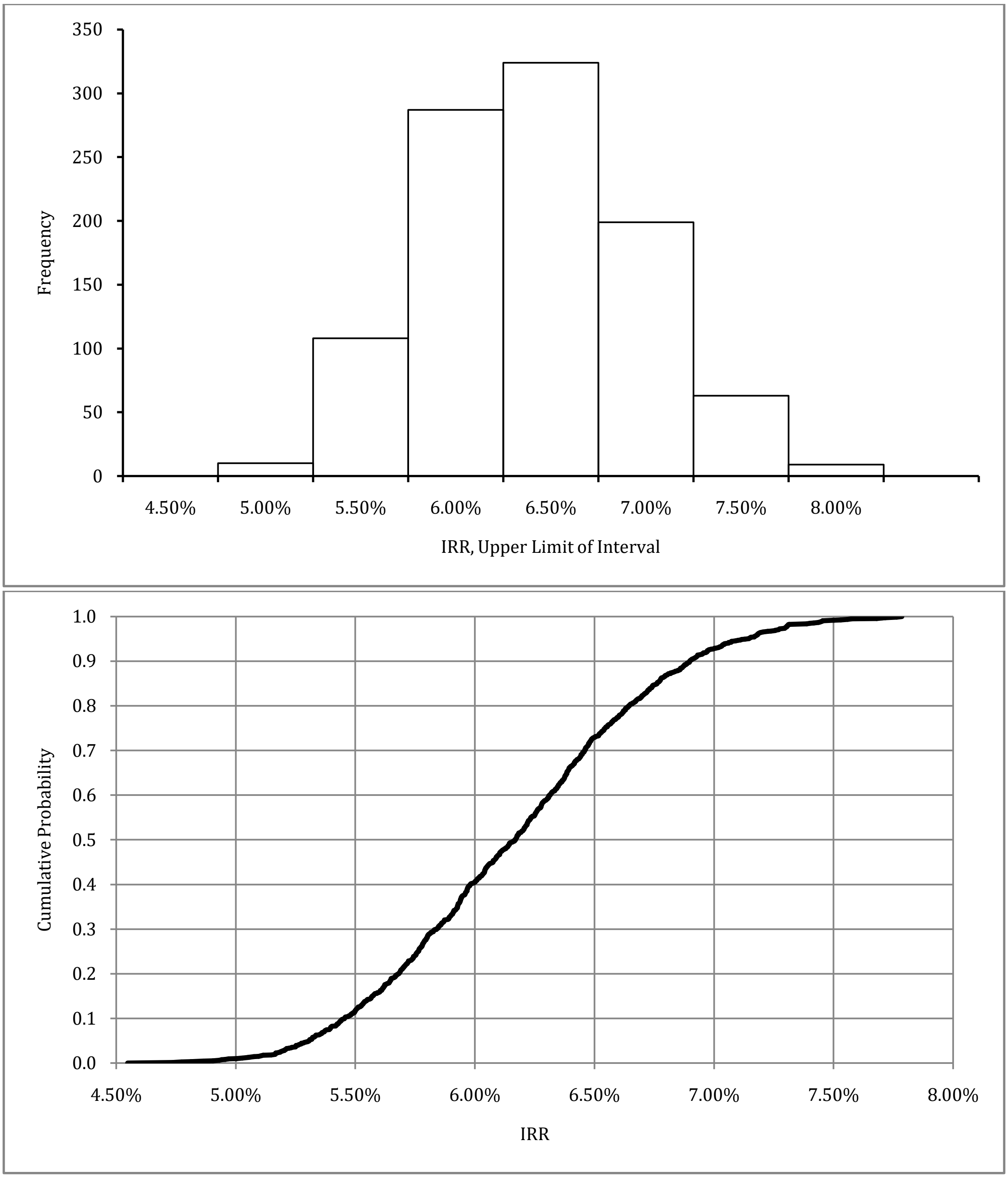


Figure 11 Monte Carlo Simulation for “Wind & Wave” compared to ENTSO-E energy production (IRR)

4.3 Comparison between Monte Carlo and Sensitivity Analysis

Comparing the sensitivity analysis and the Monte Carlo analysis we see that the results are consistent since the base-case NPV for the sensitivity analysis is around 225 million while the expected NPV resulting from Monte Carlo analysis is 225.9 million. We can thus conclude with a high degree of confidence that the project passes the CBA test at a 4% discount rate (comparing with ENTSO-E energy production). Similar conclusions we have when comparing with coal energy production.

Similarly, for the CBA test at a 3% discount rate and compared to coal energy production, the results of the two methods are consistent (i.e. NPV equal to 442 million estimated using Monte Carlo and around 440 million derived from the sensitivity analysis).Similar conclusions we have when comparing with ENTSO-E energy production.

5 Risk Analysisof the Baltic Site

For the Atlantic site the financial costs and revenues, together with the benefits derived by the CO_2 emissions reduction and artificial reefs effect due to wind energy production were included in the SCBA. Costs derived from the production of CO_2 emissions due to salmon harvesting were not included in the SCBA, since due to lack of information only the single-use scenario of energy production was examined. Although the baseline for the Baltic site was considered to be “nothing”, the results present the risk analysis undertaken for the wind energy function.

5.1 Sensitivity Analysis

With regards to the sensitivity analysis,the scenarios refer only to the energy project. Note that due to lack of data the NPV calculations do not include operating costs, thus the sensitivity analysis refers to the NPV defined in terms of construction cost, maintenance cost and revenues due to energy output and artificial reefs effect. In the Monte Carlo analysis, we have calculated the maximum annual equivalent operating cost which would result in a positive NPV.

Table 8 Variables examined in the sensitivity analysis

	min	**base***	**max**
Construction cost	0,8	1	1,2
Energy output	0,8	1	1,2
Maintenance cost	0,85	1	1,15
Artificial Reefs effect	0,75	1	1,25

*Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

The results suggest that the critical variables are the **energy output** and **construction cost**. There are no switching values.The spider graphs for the 3% and 4% discount rate are shown below.

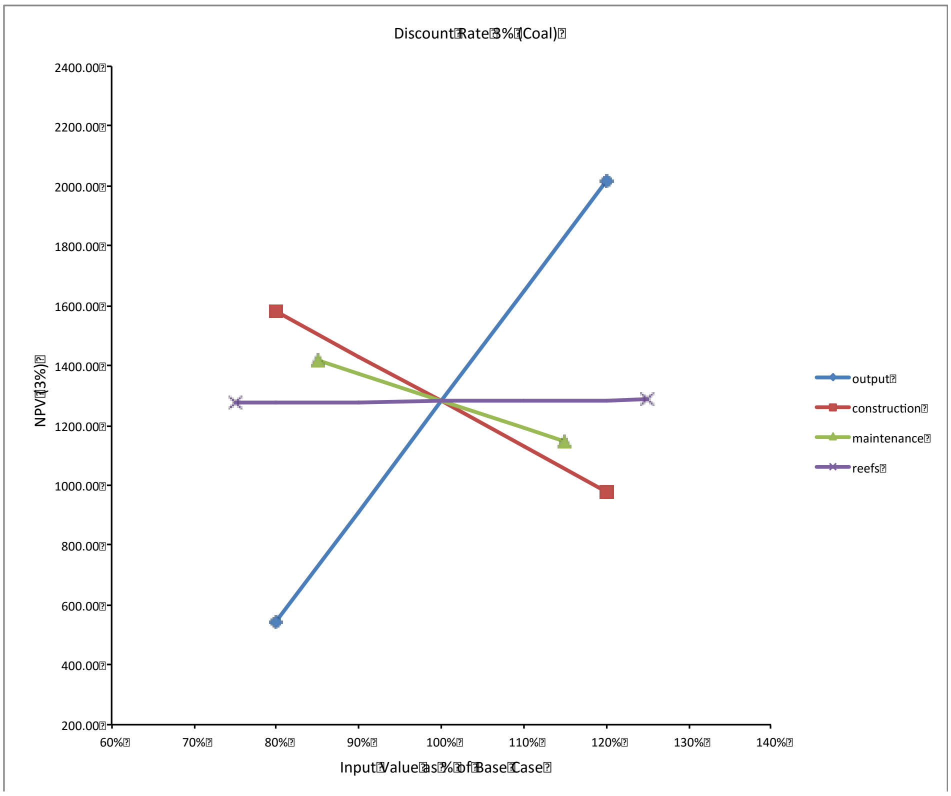


Figure 12 Sensitivity Analysis on SCBA (3% discount rate, compared to coal energy production)

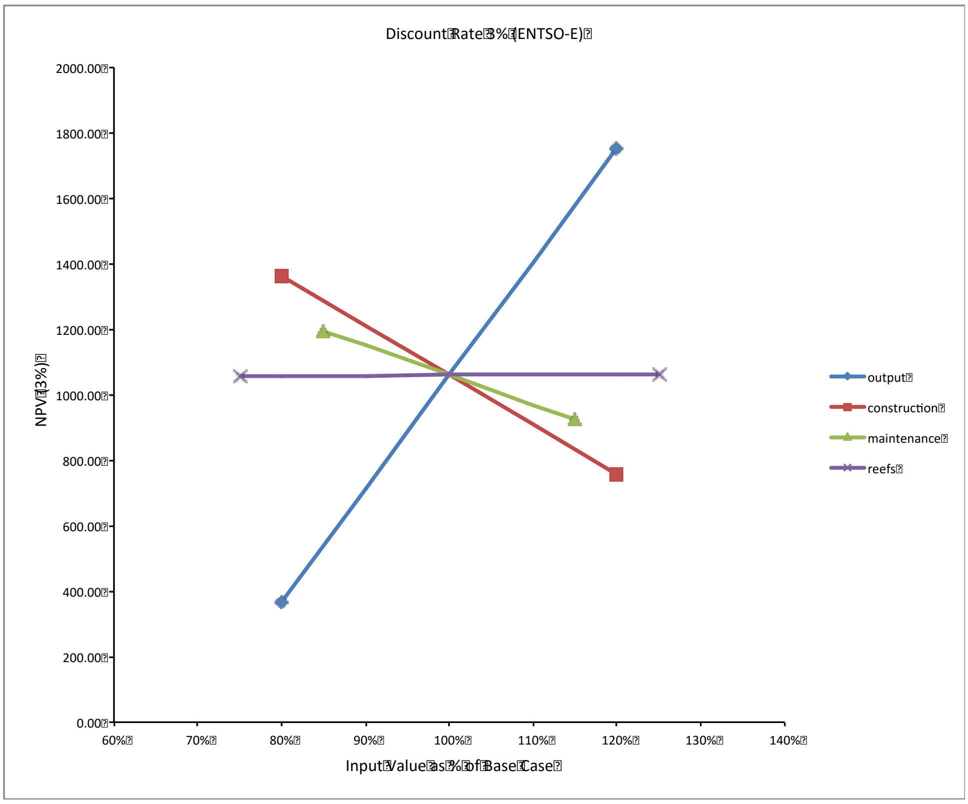


Figure 13 Sensitivity Analysis on SCBA (3% discount rate, compared to ENTSO-E energy production)

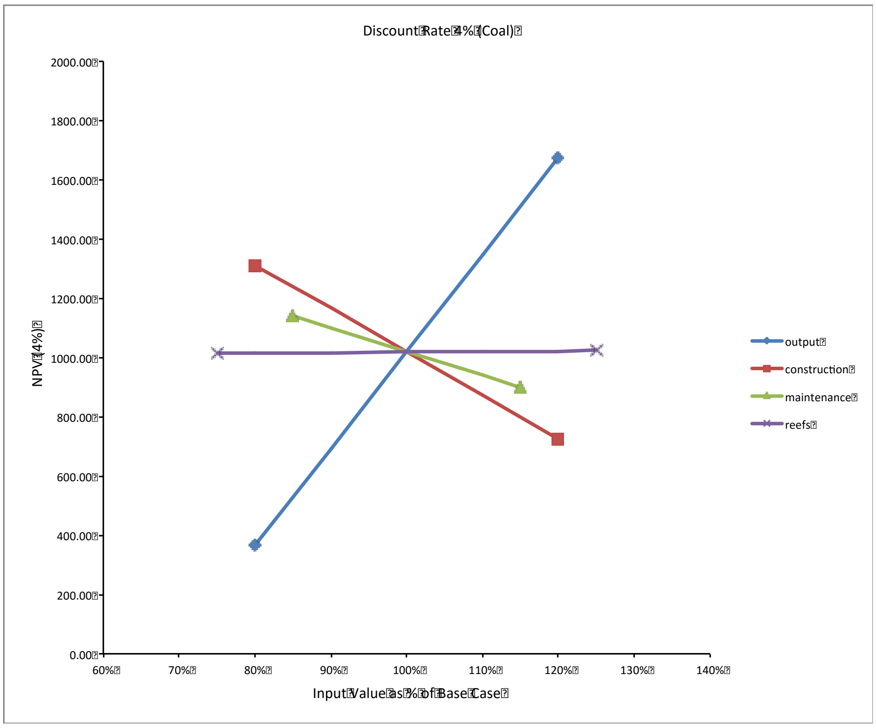


Figure 14 Sensitivity Analysis on SCBA (4% discount rate, compared to coal energy production)

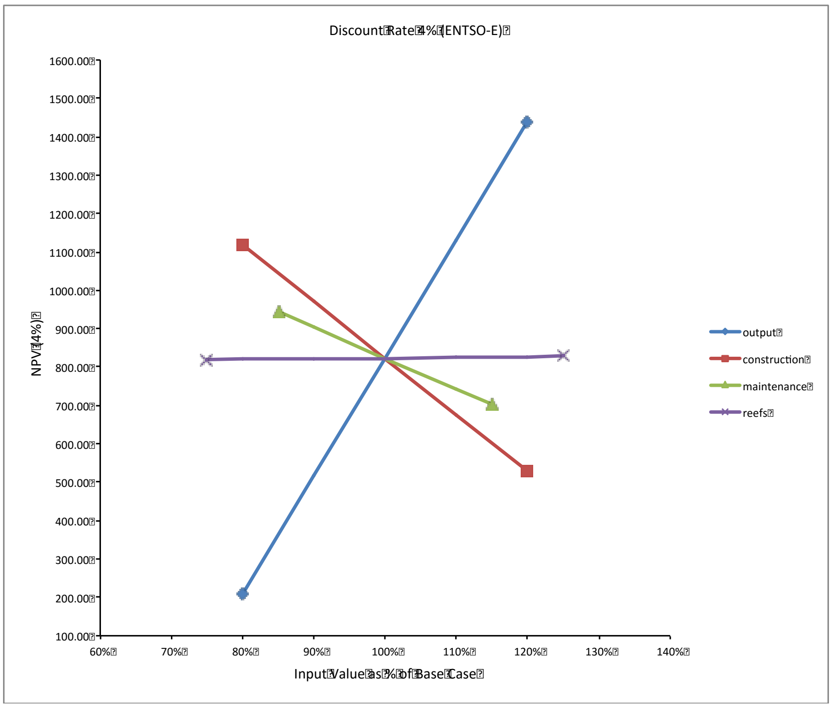


Figure 15 Sensitivity Analysis on SCBA (4% discount rate, compared to ENTSO-E energy production)

5.2 Monte Carlo Simulations

Wind, 3% discount rate, compared to coal energy production

Based on the results from the Monte Carlo Simulation for the Baltic offshore platform and considering discount rate to be 3%, the 95% confidence interval for the NPV is 1283.97±1.96*115.22. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 1300 million is approximately 57%.

Table 9 “Wind” compared to coal energy production (NPV, 3%)

Mean	1283,97
St. Dev.	115,22
Mean St. Error	3,64
Minimum	955,45
First Quartile	1200,18
Median	1285,15
Third Quartile	1366,96
Maximum	1585,49
Skewness	-0,0684

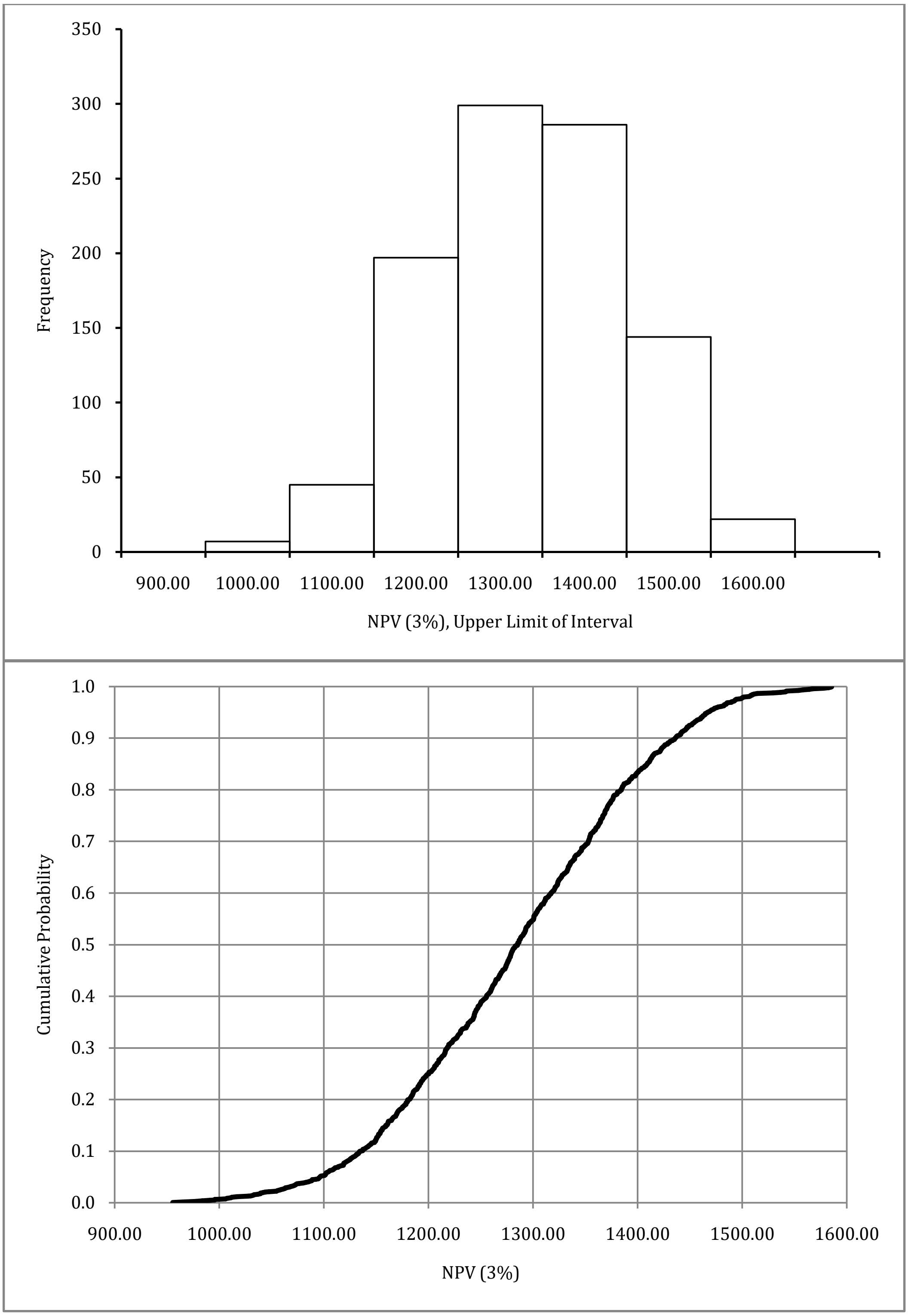


Figure 16 Monte Carlo Simulation for “Wind” compared to coal energy production (NPV, 3%)

Wind, 3% discount rate, compared toENTSO-E energy production

Based on the results from the Monte Carlo Simulation for the Baltic offshore platform and considering discount rate to be 3%, the 95% confidence interval for the NPV is 1062.2±1.96*112.29. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 1068 million is approximately 40%.

Table 10 “Wind” compared to ENTSO-E energy production (NPV, 3%)

Mean	1062.20
St. Dev.	112.29
Mean St. Error	3.55
Minimum	702.77
First Quartile	983.51
Median	1065.93
Third Quartile	1142.12
Maximum	1373.72
Skewness	-0.0964

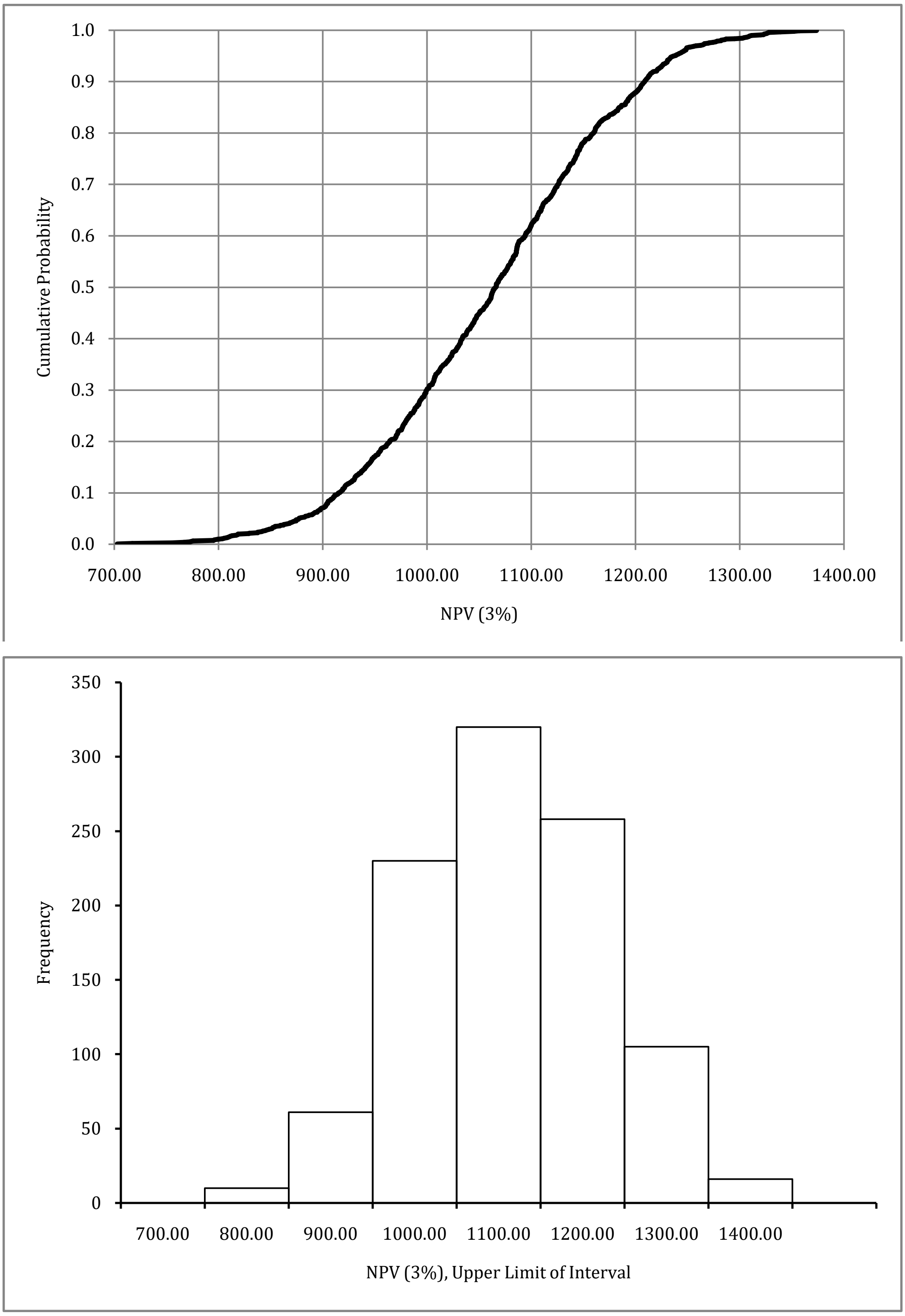


Figure 17 Monte Carlo Simulation for “Wind” compared to ENTSO-E energy production (NPV, 3%)

Wind, 4% discount rate, compared to coal energy production

Based on the results from the Monte Carlo Simulation for the Baltic offshore platform and considering discount rate to be 4%, the 95% confidence interval for the NPV is 1018.85±1.96*110.61. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 1026 million is approximately 50%.

Table 11 “Wind” compared to coal energy production (NPV, 4%)

Mean	1018.85
St. Dev.	110.61
Mean St. Error	3.50
Minimum	664.59
First Quartile	946.38
Median	1023.05
Third Quartile	1097.00
Maximum	1316.98
Skewness	-0.1685

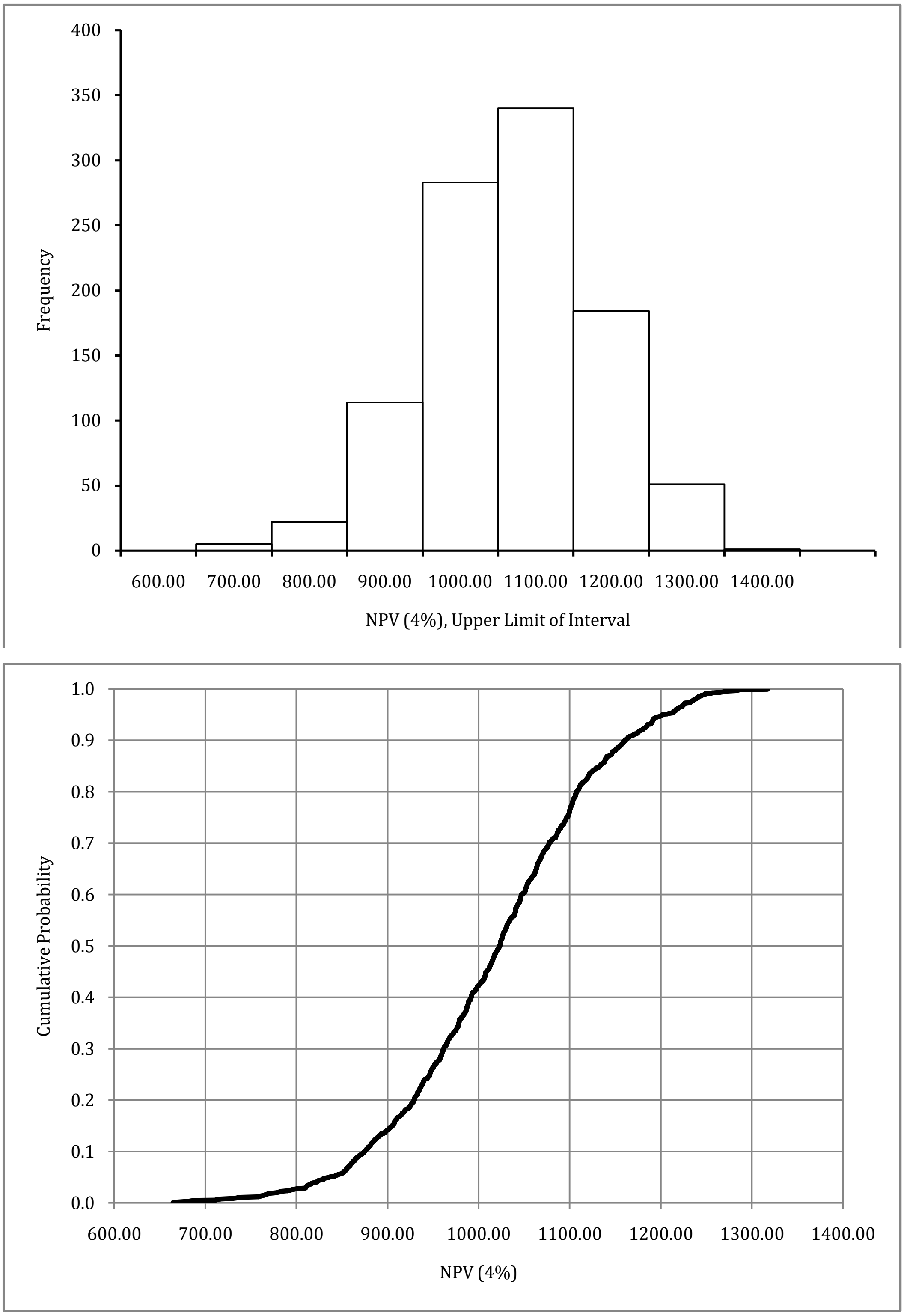


Figure 18 Monte Carlo Simulation for “Wind” compared to coal energy production (NPV, 4%)

Wind, 4% discount rate, compared to ENTSO-E energy production

Based on the results from the Monte Carlo Simulation for the Baltic offshore platform and considering discount rate to be 4%, the 95% confidence interval for the NPV is 823.60±1.96*107.31. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 830 million is approximately 50%.

Table 12”Wind” compared to coal energy production (NPV, 4%)

Mean	823,60
St. Dev.	107,31
Mean St. Error	3,39
Minimum	481,26
First Quartile	752,65
Median	826,59
Third Quartile	898,33
Maximum	1113,31
Skewness	-0,1675

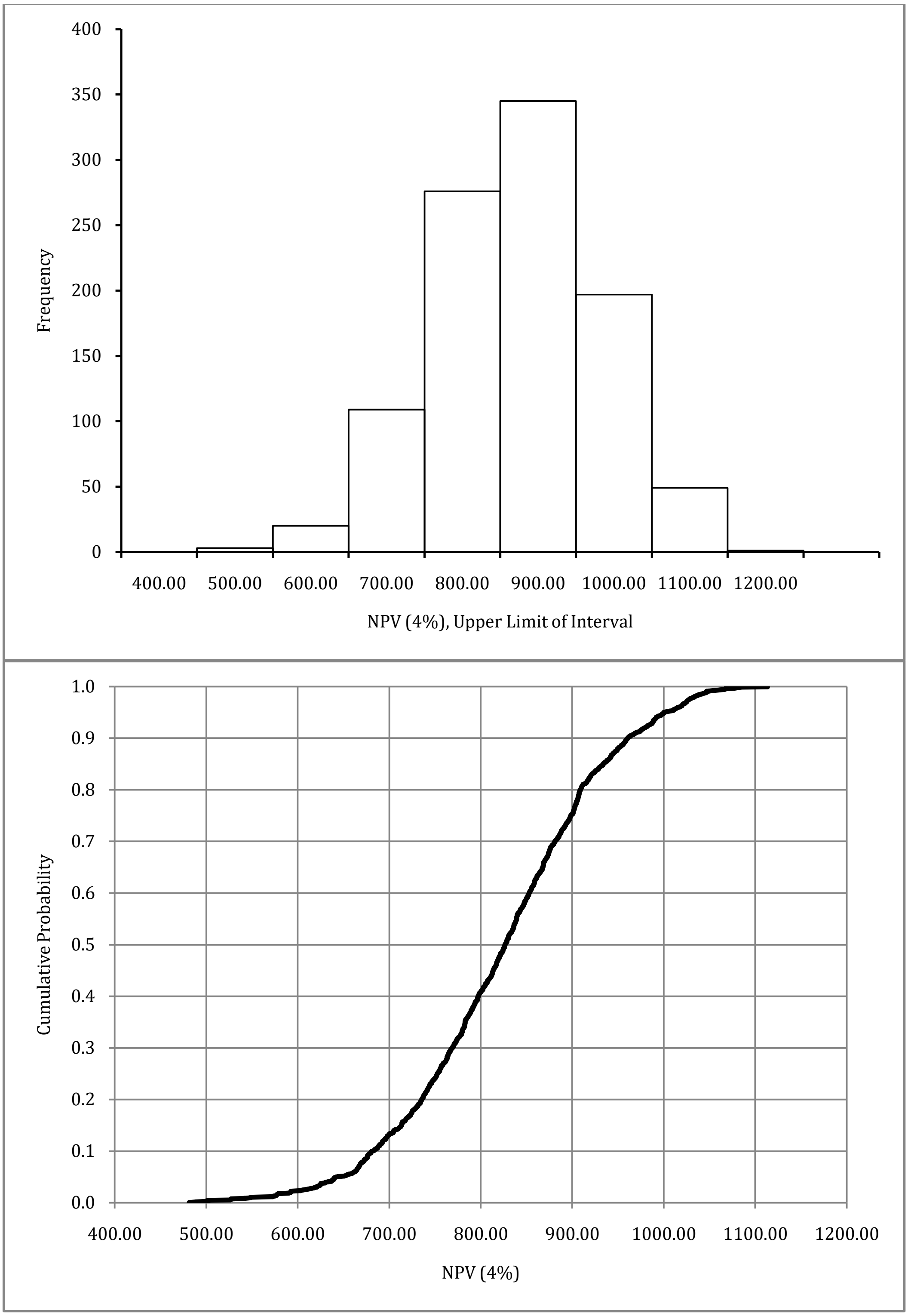


Figure 19 Monte Carlo Simulation for "Wind" compared to ENTSO-E energy production (NPV, 4%)

5.3 Comparison between Monte Carlo and Sensitivity Analysis

Comparing the sensitivity analysis and the Monte Carlo analysis we see that the results are consistent since the base-case NPV for the sensitivity analysis is around 823 million while the expected NPV resulting from Monte Carlo analysis is 823.60 million. We can thus conclude with a high degree of confidence that the project passes the CBA test at a 4% discount rate comparing with ENTSO-E energy production. Similar conclusions we have when comparing with coal energy production.

Similarly, for the CBA test at a 3% discount rate, the results of the two methods are consistent (i.e. NPV equal to 1283.97million estimated using Monte Carlo and around 1280 million derived from the sensitivity analysis).Similar conclusions we have when comparing with ENTSO-E energy production.

6 Risk Analysis: Sensitivity analysis for the Mediterranean Site

For the Mediterranean site the financial costs and revenues, together with the costs derived by the CO_2 emissions produced due to fishing operation were included in the SCBA. Benefits derived from the reduction of CO_2 emissions were not included in the SCBA, since due to lack of information only the single-use “Aquaculture” scenario was examined. Although the baseline for the Mediterranean site was considered to be “nothing”, the results present the risk analysis undertaken for the aquaculture function due to lack of information.

6.1 Sensitivity Analysis

We consider the following scenarios for the purposes of sensitivity analysis. The scenarios refer only to the single-use of fish production.

Table 13 Variables examined in the sensitivity analysis

	min	**base***	**max**
equipment cost (fish)	0,85	1,00	1,15
revenue (fish)	0,75	1,00	1,25
labor (fish)	0,75	1,00	1,25
raw material cost (fish)	0,75	1,00	1,25
other costs (fish)	0,75	1,00	1,25
maintenance cost(fish)	0,75	1,00	1,25
operating costs (fish)	0,75	1,00	1,25

*Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

The results suggest that the critical variables are **raw materials** and **fish revenue**. There is a switching value for raw materials which is around 10%-11% above the base case (110%-111% in the spider graph), and a switching value for fish revenue which is around 6%-7% below the base case (93%-94% in the spider graph).

The spider graphs for the 3% and 4% discount rate are shown below.

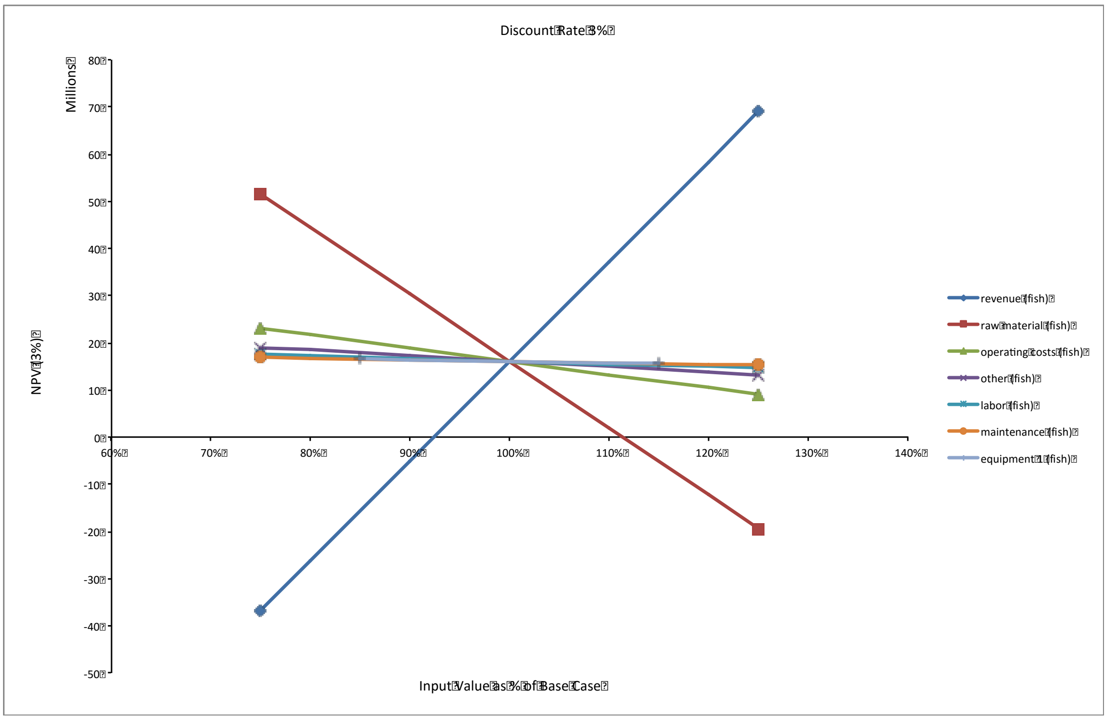


Figure 20 Sensitivity Analysis on SCBA (3% discount rate)

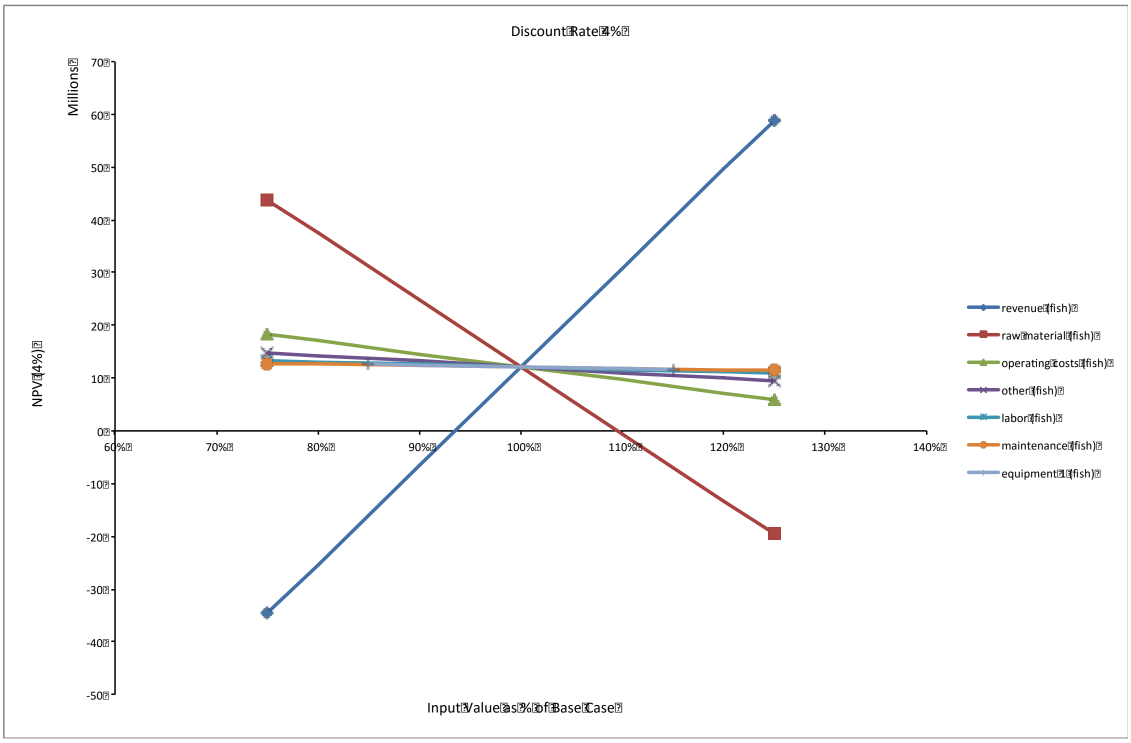


Figure 21 Sensitivity Analysis on SCBA (4% discount rate)

6.2 Monte Carlo Simulations

Aquaculture, 3% discount rate

Based on the results from the Monte Carlo Simulation for the Mediterranean offshore platform and considering discount rate to be 3%, the 95% confidence interval for the NPV is 16.05±1.96*6.18. This confidence interval is not strictly positive; therefore, we cannot conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 16.1 million is approximately 50%. However, the probability of having a negative NPV is less than 1%.

Table 14"Aquaculture" (NPV, 3%)

Mean	16.052.583,76
St. Dev.	6.179.906,34
Mean St. Error	195.425,80
Minimum	-2.108.360,84
First Quartile	11.860.864,75
Median	16.051.626,22
Third Quartile	20.095.165,88
Maximum	34.711.943,79
Skewness	0,0088

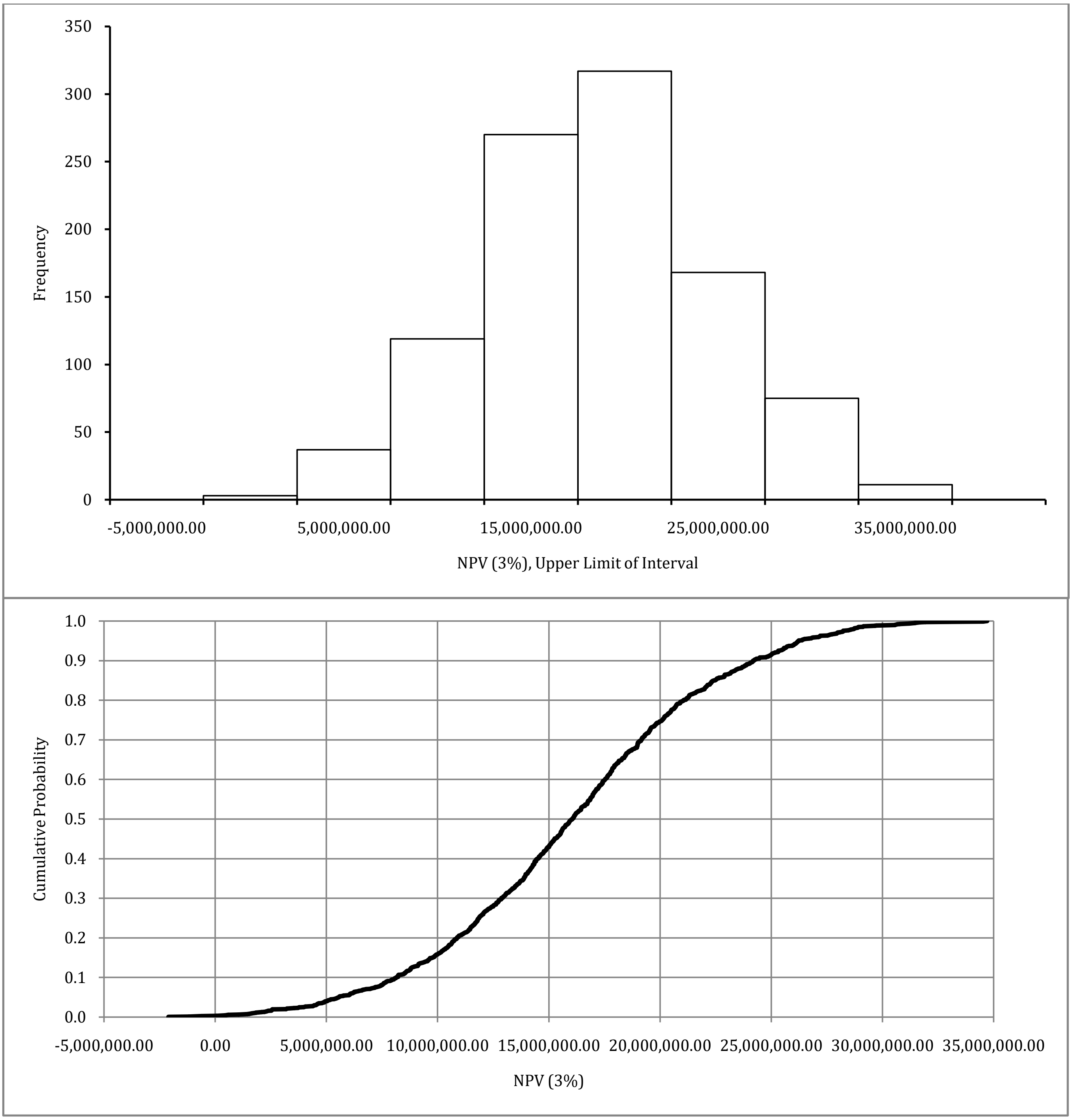


Figure 22 Monte Carlo Simulation for “Aquaculture” (NPV, 3%)

Aquaculture, 4% discount rate

Based on the results from the Monte Carlo Simulation for the Mediterranean offshore platform and considering discount rate to be 4%, the 95% confidence interval for the NPV is 12.14±1.96*5.59. This confidence interval is not strictly positive; therefore, we cannot conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 16.1 million is approximately 50%. However, the probability of having a negative NPV is less than 2%.

Table 15"Aquaculture" (NPV, 4%)

Mean	12.140.351,31
St. Dev.	5.589.853,89
Mean St. Error	176.766,70
Minimum	-5.234.981,20
First Quartile	8.546.981,10
Median	12.307.186,42
Third Quartile	15.797.696,43
Maximum	34.681.235,59
Skewness	-0,0497

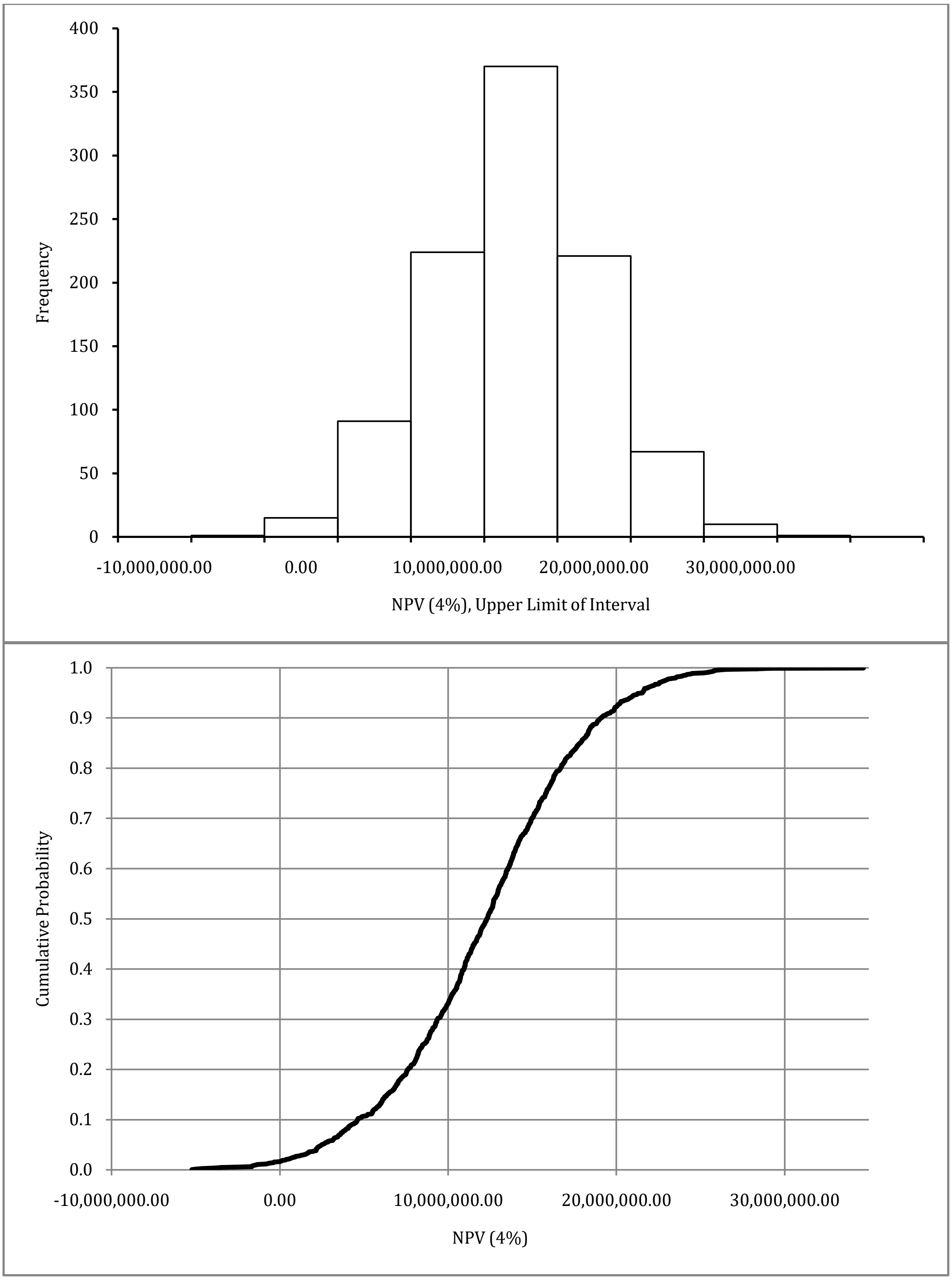


Figure 23 Monte Carlo Simulationfor “Aquaculture” (NPV, 4%)

Similar output for the IRR is presented below.

From the results we can conclude that the 95% confidence interval for the IRR is 9%±1.96*2%. This confidence interval is not strictly above the cut-off rate of 4%; therefore, we cannot conclude that at 95% confidence interval this project passes the IRR test. From the cumulative chart we can conclude that the probability of having an IRR less than 9% is approximately 50%. However, the probability of having an IRR less than 3% is around 1%.

Table 16 "Aquaculture" (IRR)

Mean	9%
St. Dev.	2%
Mean St. Error	0%
Minimum	1%
First Quartile	7%
Median	9%
Third Quartile	11%
Maximum	15%
Skewness	-0,1276

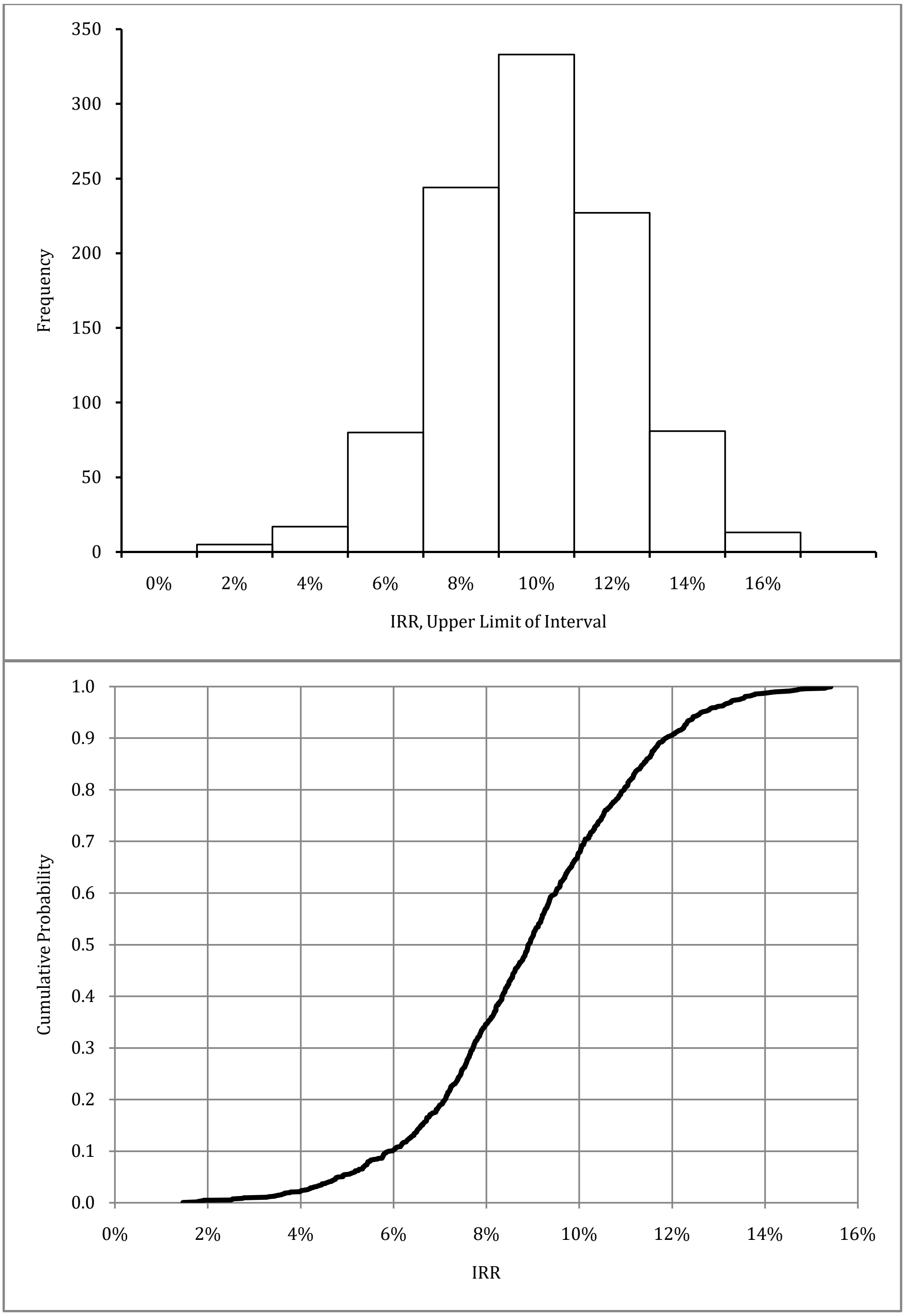


Figure 24 Monte Carlo Simulation for “Aquaculture” (IRR)

6.3 Comparison between Monte Carlo and Sensitivity Analysis

Comparing the sensitivity analysis and the Monte Carlo analysis we see that the results are consistent since the base-case NPV for the sensitivity analysis is around 12 million while the expected NPV resulting from Monte Carlo analysis is 12.14 million. We can thus conclude with a high degree of confidence that the project passes the CBA test at a 4% discount rate.

Similarly, for the CBA test at a 3% discount rate, the results of the two methods are consistent (i.e. NPV equal to 16.05 million estimated using Monte Carlo and around 16 million derived from the sensitivity analysis).

7 Risk Analysis: Sensitivity Analysis for the North Sea Site

For the North Sea site the financial costs and revenues, together with the benefits derived by the reduction of CO_2 emissions were included in the SCBA. For the case on CO_2 emissions due to wind energy production both comparisons were used in the analysis (i.e. reduction of CO_2 emissions compared to coal energy production and ENTSO-E production).Since the baseline for the North Sea site was considered to be the wind energy function, the presented results are concentrated on the Seaweed & Mussels functions of the multi-use platform.

7.1 Sensitivity Analysis

We consider the following scenarios for the purposes of sensitivity analysis. The scenarios refer to the **Seaweed &Mussels** functions.

Table 17 Variables examined in the sensitivity analysis

	min	**base***	**max**
mussels operation costs	1.74	1.00	0.26
seaweed price	0.52	1.00	1.48
seaweed operation costs	1.19	1.00	0.81
mussels output	0.94	1.00	1.06
seaweed investment	1.48	1.00	0.53
seaweed output	0.96	1.00	1.04
mussels price	0.98	1.00	1.02
mussels investment	1.22	1.00	0.78
energy output	0.89	1.00	1.12
energy operation costs	0.59	1.00	1.41

*Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

The results suggest that the critical variables are **seaweed and mussels operation costs, seaweed price and seaweed and mussels output**. All values seem to be *below the base case*. There is a switching value for mussels' operation costs, which is around 30% in the graph for both cases of 3% and 4%.

In the following, we present spider graphs for the combined Seaweed & Mussels functions for 3% and 4% discount rate. Spider graphs for the stand-alone energy, seaweed, mussels and all their rest of possible pairs can be provided under request.

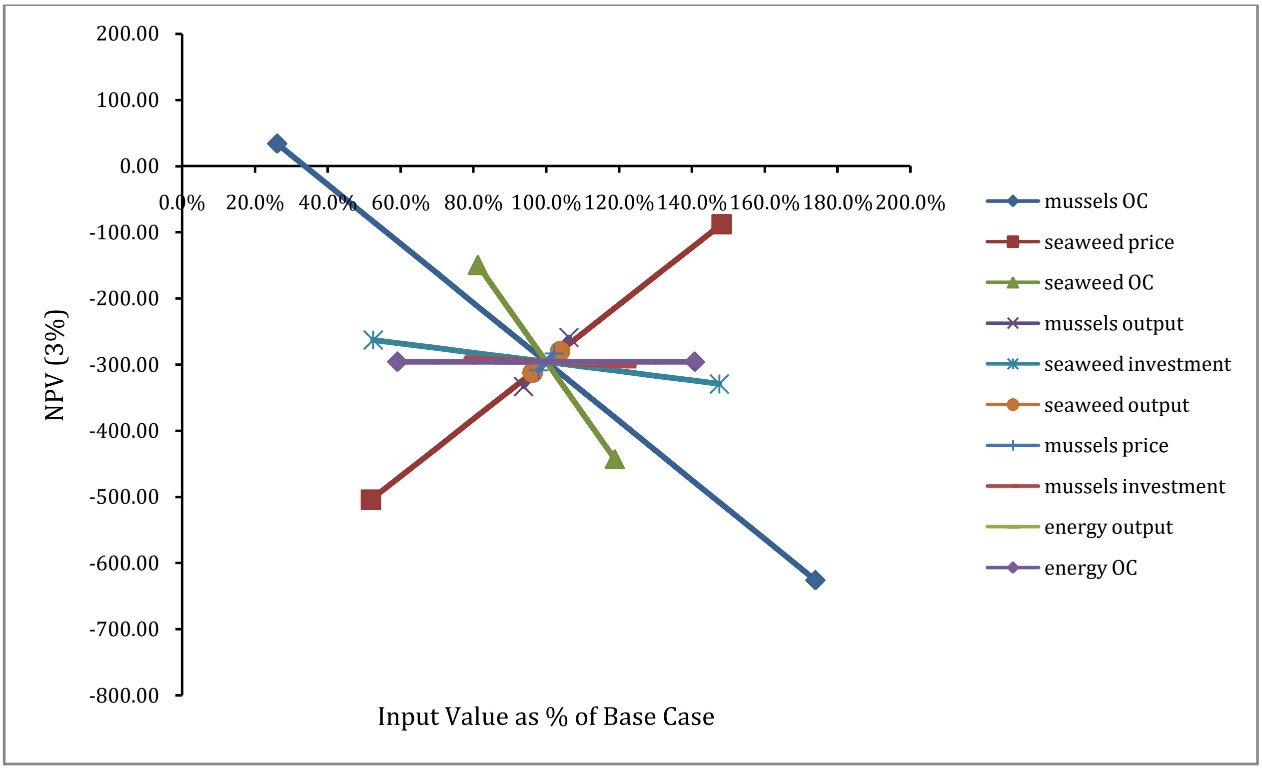


Figure 25 Sensitivity Analysis on SCBA (3% discount rate)

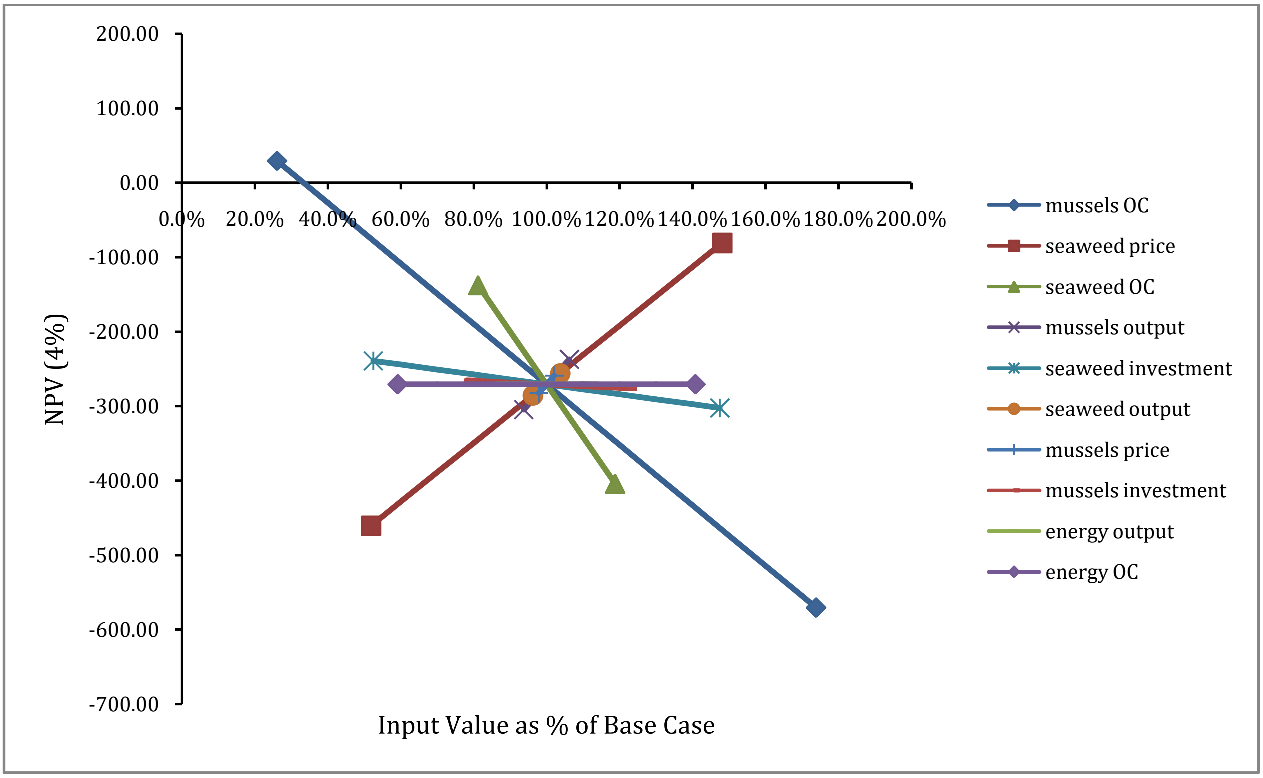


Figure 26 Sensitivity Analysis on SCBA (4% discount rate)

Furthermore we present the results for the scenarios referring to the **Seaweed & Mussels & Wind MUOP.**

Table 18 Variables examined in the sensitivity analysis

	min	**base***	**max**
mussels investment cost	0.7805	1.00	1.2195
seaweed investment cost	0.8	1.00	1.2
energy output	0.885	1.00	1.115
energy operation costs	0.5919	1.00	1.4081
mussels output	0.9375	1.00	1.0625
mussels price	0.9787	1.00	1.0213
Mussels operation costs	0.261	1.00	1.739
seaweed output	0.9625	1.00	1.0375
seaweed price	0.5185	1.00	1.4815
seaweed operation costs	0.812	1.00	1.188

*Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

The results suggest that the critical variables are **energy operating cost** and **energy output**. There are no switching values.

In the following we present spider graphs for the combined energy, seaweed and mussels project for 3% and 4% discount rate. Spider graphs for the stand-alone energy, seaweed, mussels and the rest of possible pairs can be provided under request.

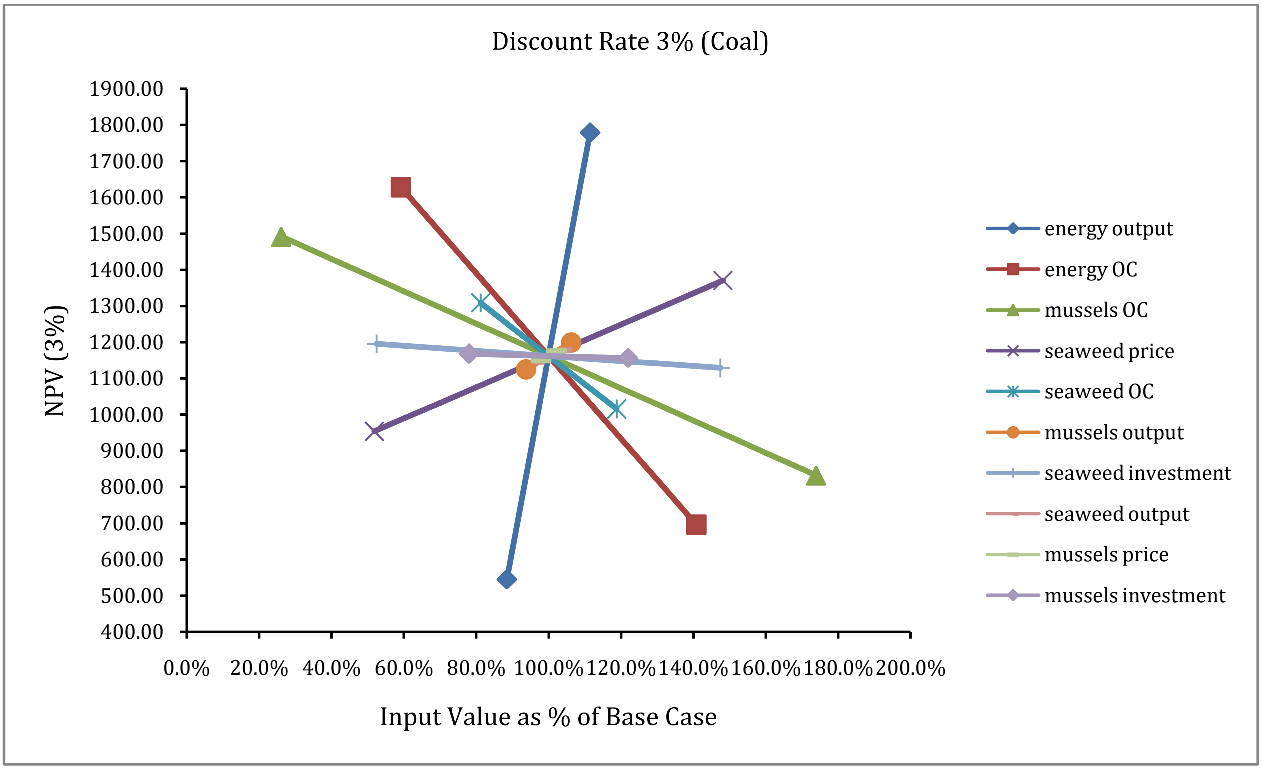


Figure 27 Sensitivity Analysis on SCBA (3% discount rate, compared to coal energy production)

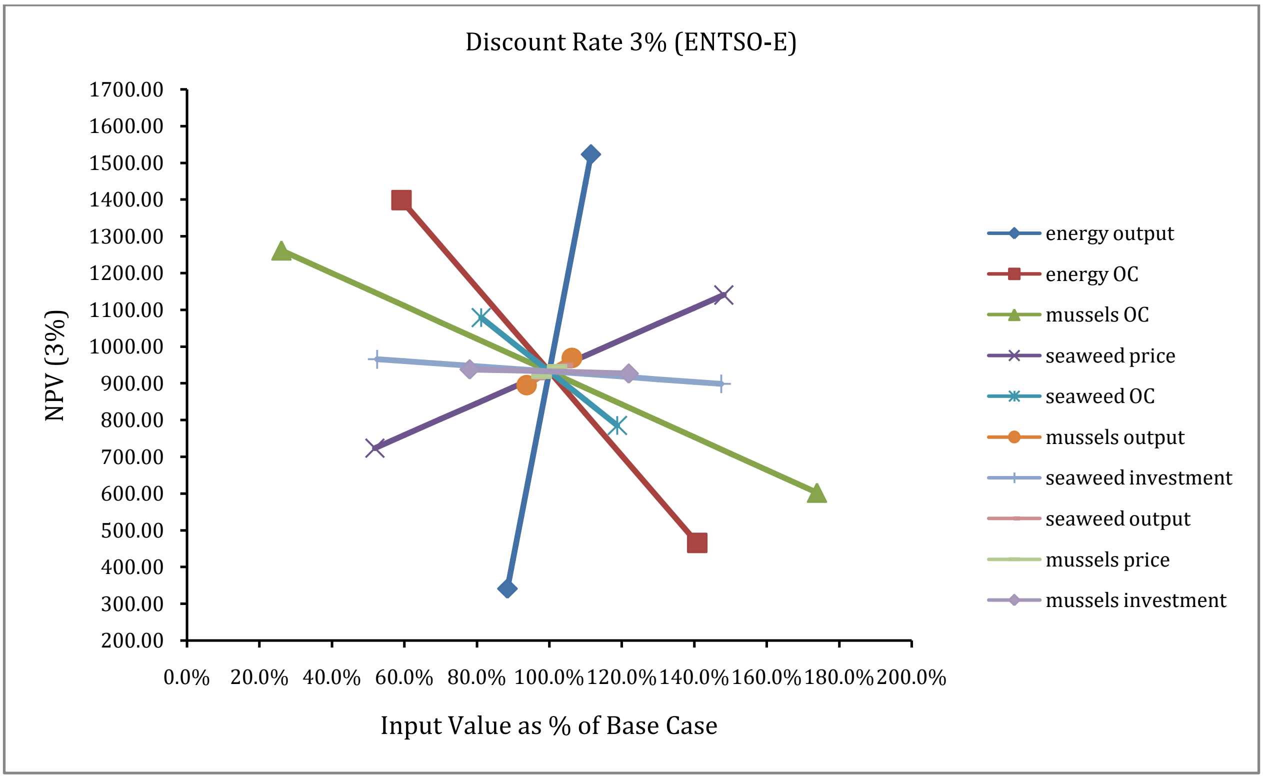


Figure 28 Sensitivity Analysis on SCBA (3% discount rate, compared to ENTSO-E energy production)

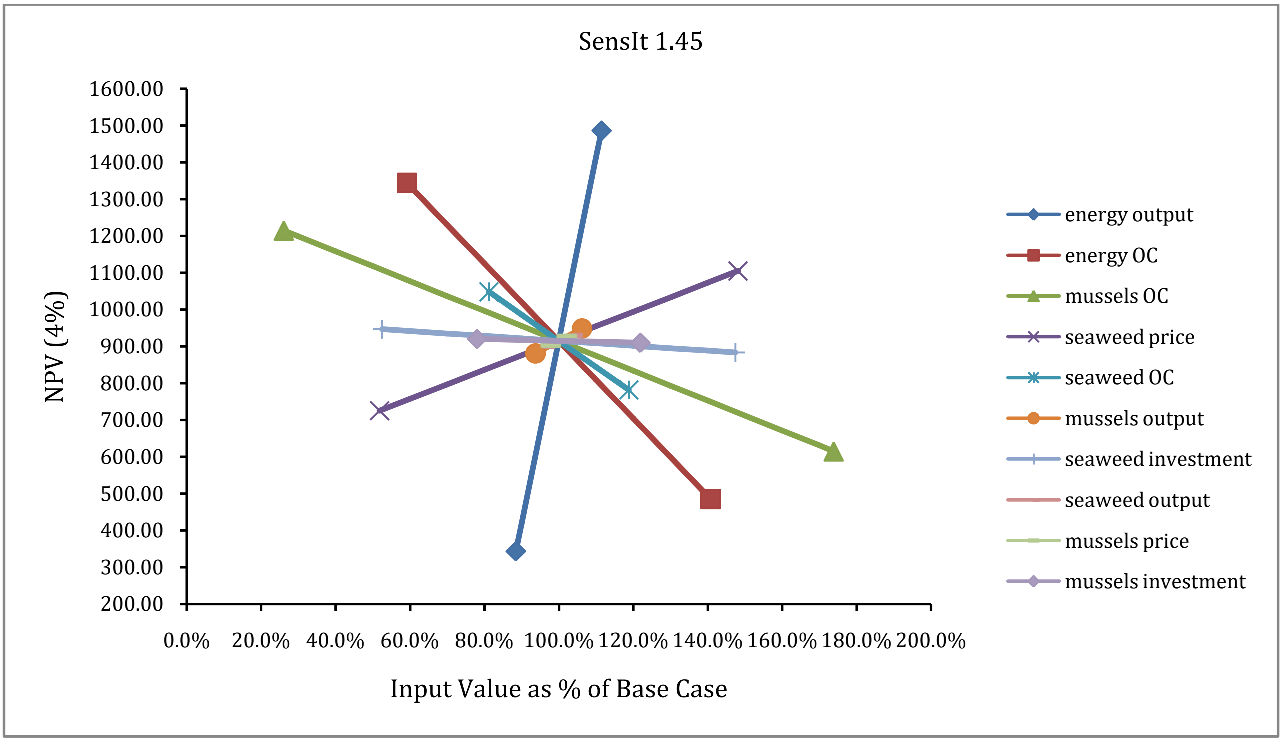


Figure 29 Sensitivity Analysis on SCBA (4% discount rate, compared to coal energy production)

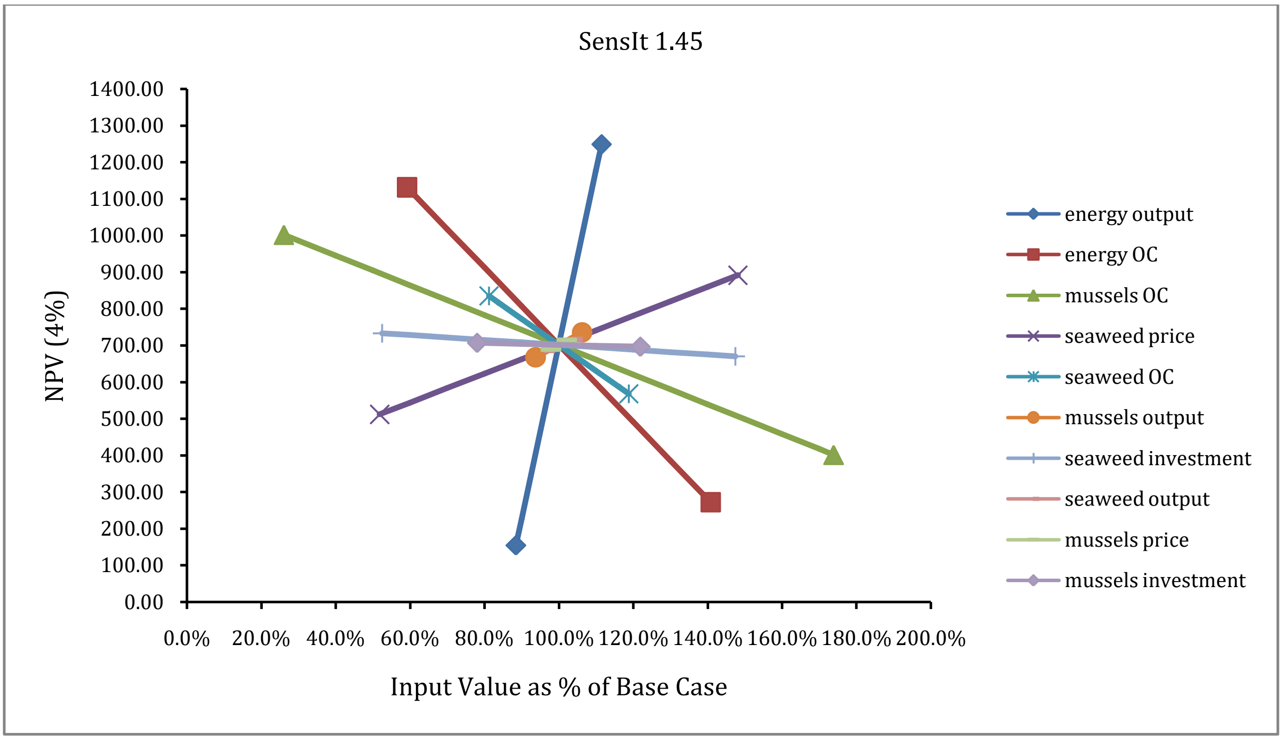


Figure 30 Sensitivity Analysis on SCBA (4% discount rate, compared to ENTSO-E energy production)

Furthermore for the purpose of comparison, we present the results for the scenarios referring to the base line for the North Sea, which is the single use of **Wind energy production.**

Table 19 Variables examined in the sensitivity analysis

Input Variable	Low Output	Base Case	High Output
energy output	0.89	1.00	1.12
energyoperation cost	1.41	1.00	0.59
mussels investment cost	0.78	1.00	1.22
seaweed investment cost	0.53	1.00	1.48
mussels output	0.94	1.00	1.06
mussels price	0.98	1.00	1.02
musselsoperation cost	0.26	1.00	1.74
seaweed output	0.96	1.00	1.04
seaweed price	0.52	1.00	1.48
seaweedoperation cost	0.81	1.00	1.19

*Base refers to 100% of the central value for the corresponding variable. Min and max refer to the corresponding percentages of the base case.

The results suggest that the critical variables are **energy operating cost** and **energy output**. There are no switching values.

In the following we present spider graphs for the combined energy, seaweed and mussels project for 3% and 4% discount rate. Spider graphs for the stand-alone energy, seaweed, mussels and the rest of possible pairs can be provided under request.

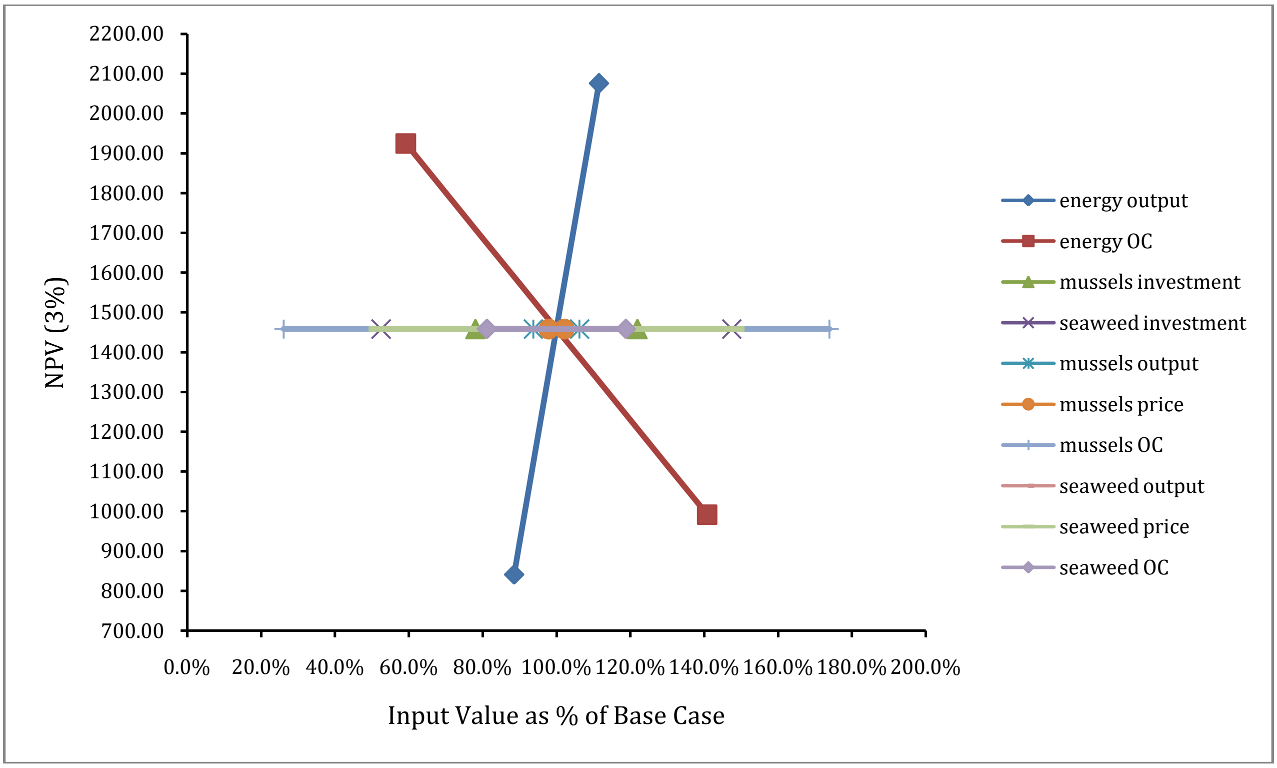


Figure 31 Sensitivity Analysis on SCBA (3% discount rate, compared to coal energy production)

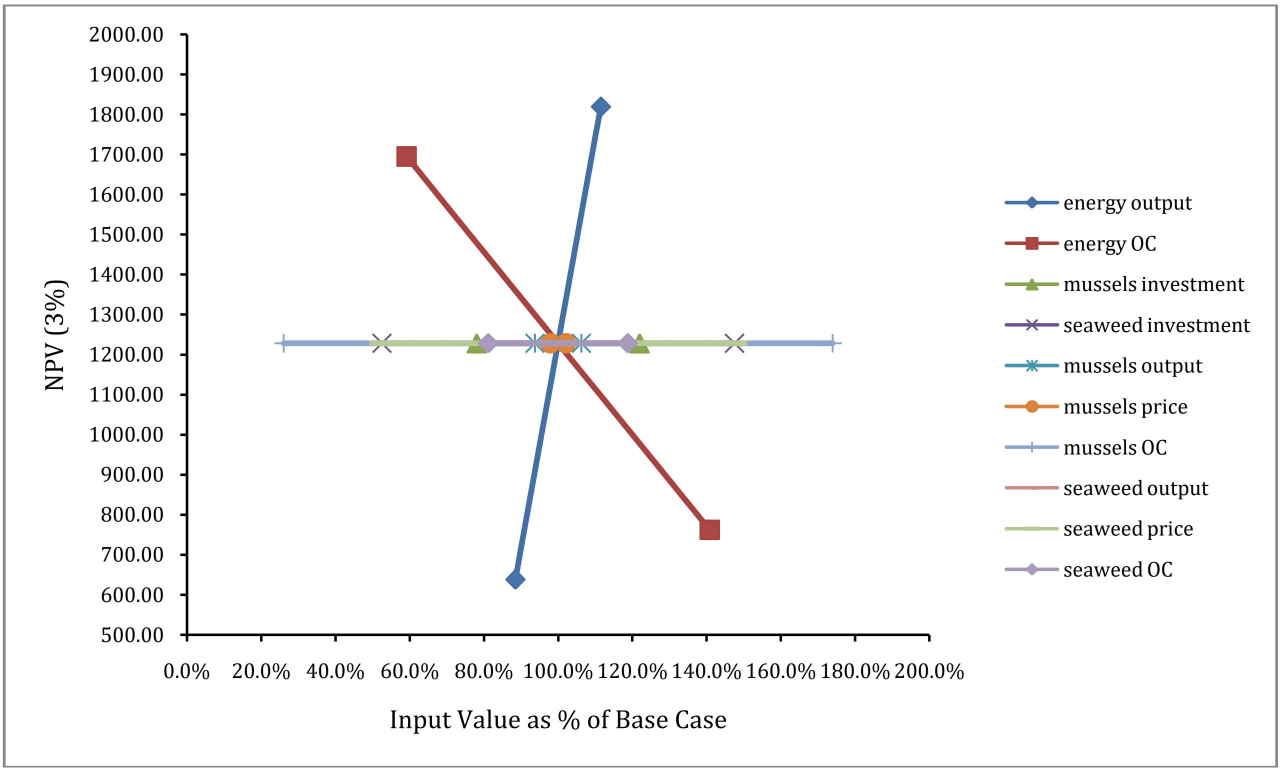


Figure 32 Sensitivity Analysis on SCBA (3% discount rate, compared to ENTSO-E energy production)

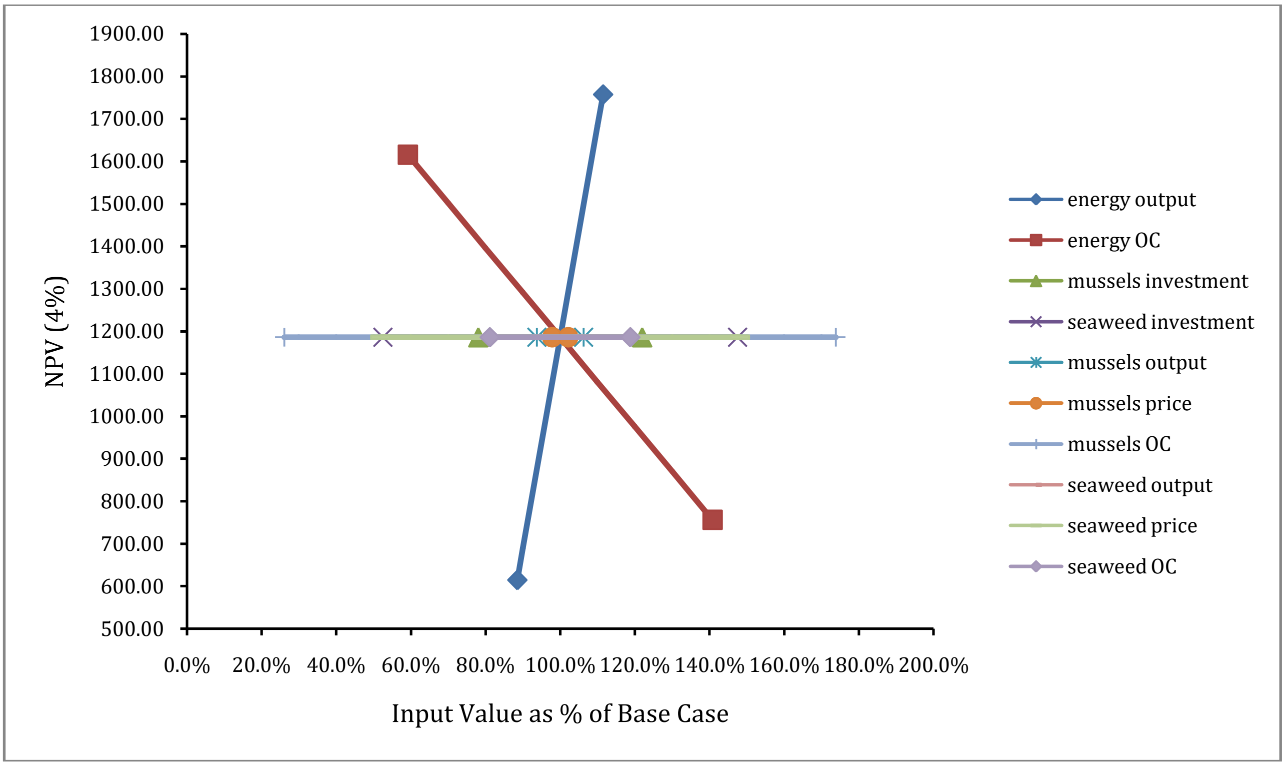


Figure 33 Sensitivity Analysis on SCBA (4% discount rate, compared to coal energy production)

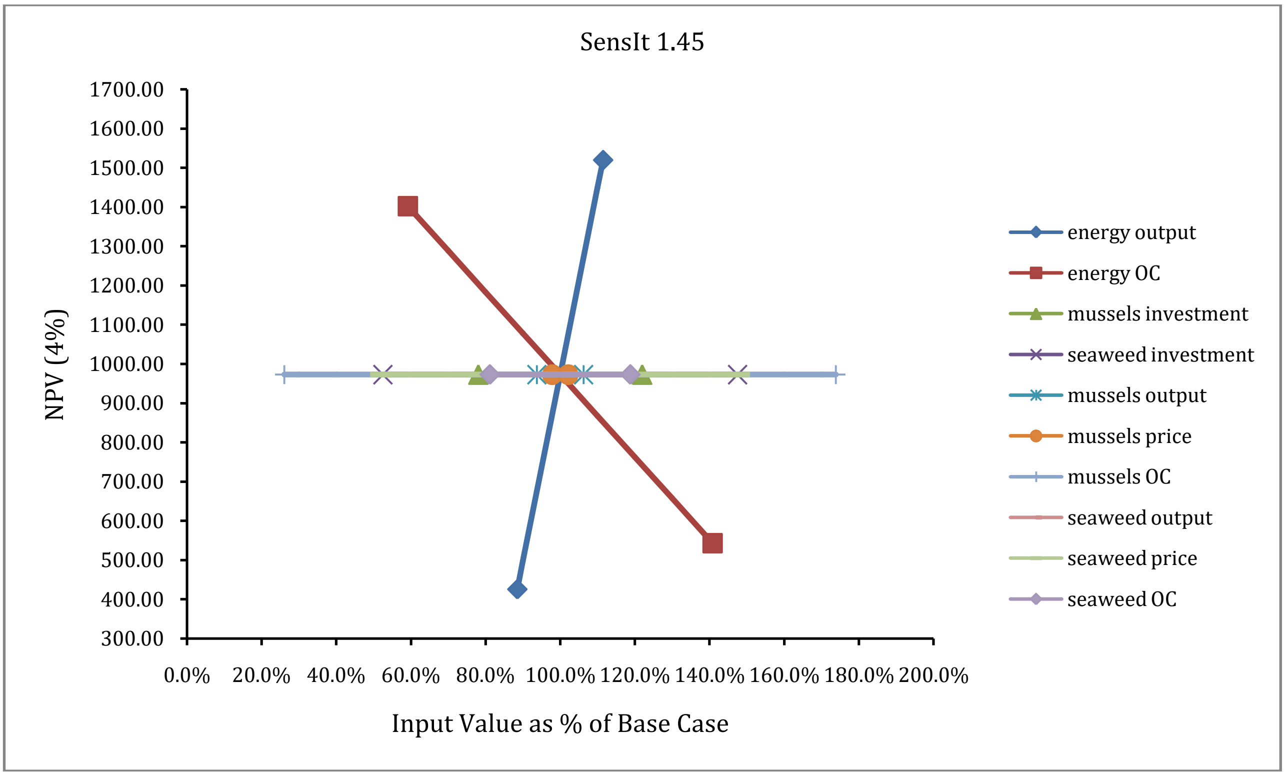


Figure 34 Sensitivity Analysis on SCBA (4% discount rate, compared to ENTSO-E energy production)

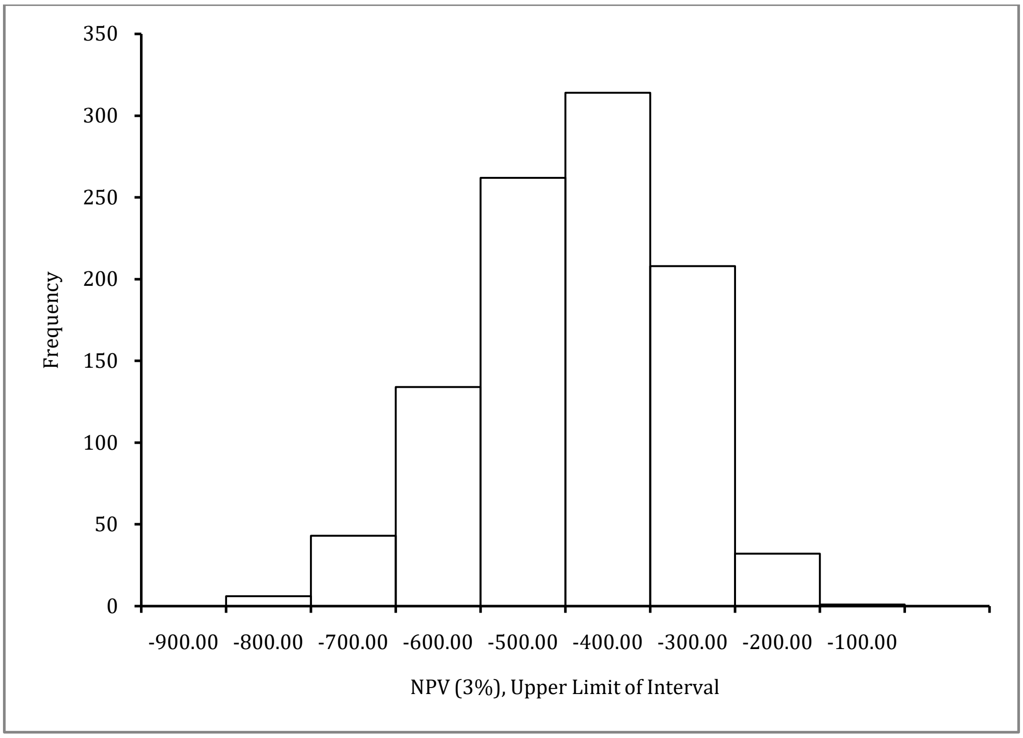
7.2 Monte Carlo Simulations

Mussels & Seaweed, 3% Discount rate

Based on the results from the Monte Carlo Simulations for the North Sea site MUOP and considering discount rate to be 3%, the 95% confidence interval for the NPV is -490.53±1.96*116.32. This confidence interval is strictly negative; therefore, we can conclude that at 95% confidence interval this project has a negative NPV.

Table 20 “Mussels & Seaweed”(NPV, 3%)

Mean	-490,53
St. Dev.	116,32
Mean St. Error	3,68
Minimum	-836,28
First Quartile	-568,98
Median	-481,54
Third Quartile	-403,27
Maximum	-193,66
Skewness	-0,3500



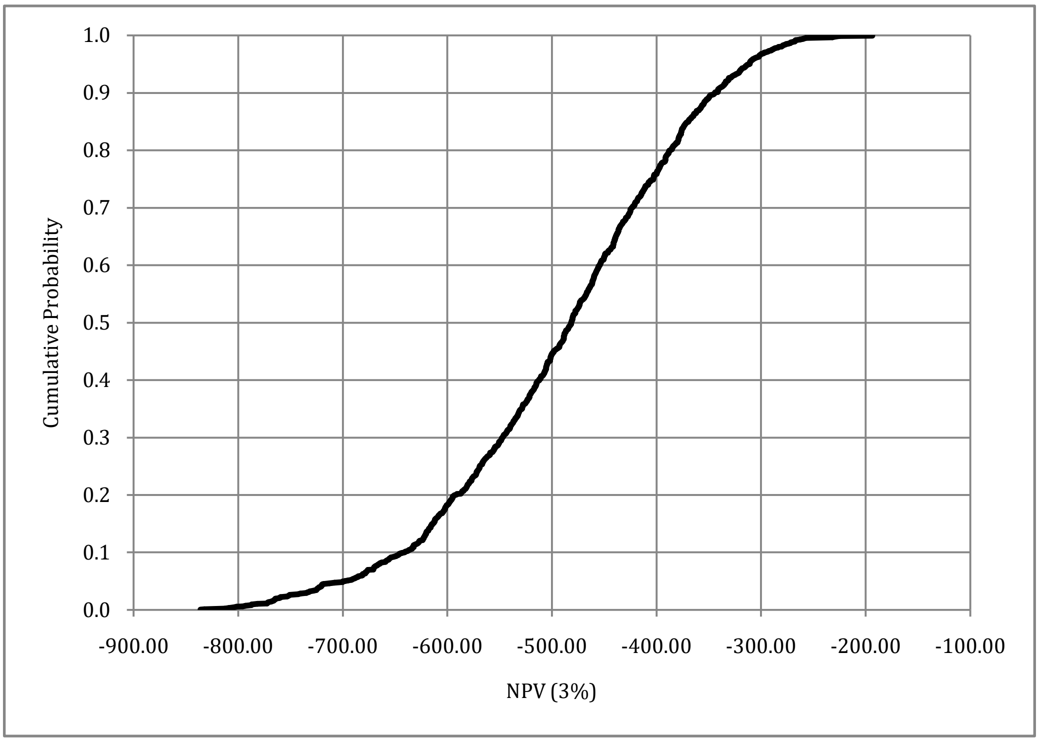


Figure 35 Monte Carlo Simulation for “Mussels & Seaweed” (NPV, 3%)

Mussels & Seaweed, 4% Discount rate

Based on the results from the Monte Carlo Simulations for the North Sea site MUOP and considering discount rate to be 4%, the 95% confidence interval for the NPV is -459.3±1.96*108.17. This confidence interval is strictly negative; therefore, we can conclude that at 95% confidence interval this project has a negative NPV.

Table 21 “Mussels & Seaweed”(NPV, 4%)

Mean	-459,30
St. Dev.	108,17
Mean St. Error	3,42
Minimum	-791,03
First Quartile	-527,18
Median	-448,91
Third Quartile	-380,37
Maximum	-201,35
Skewness	-0,3826

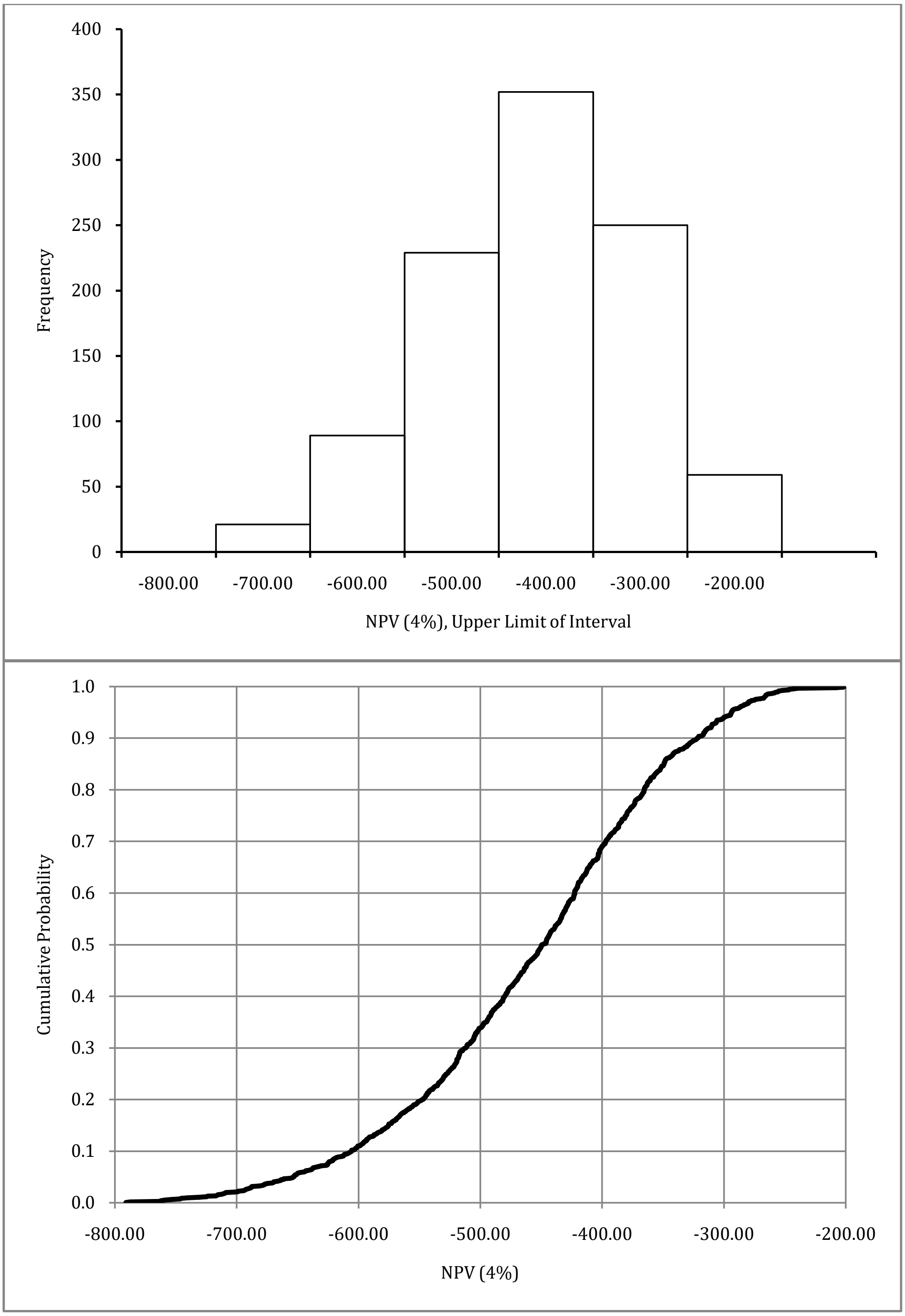


Figure 36 Monte Carlo Simulation for “Mussels & Seaweed” (NPV, 4%)

Wind &Seaweed & Mussels, 3% discount rate, compared to coal energy production

Based on the results from the Monte Carlo Simulation for the North Sea site MUOP and considering discount rate to be 3%, the 95% confidence interval for the NPV is 755.70±1.96*156.77. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 760 million is approximately 50%.

Table 22 “Mussels & Seaweed & Wind”compared to coal energy production(NPV, 3%)

Mean	755,70
St. Dev.	156,77
Mean St. Error	4,96
Minimum	158,42
First Quartile	644,70
Median	764,69
Third Quartile	876,25
Maximum	1178,85
Skewness	-0,2475

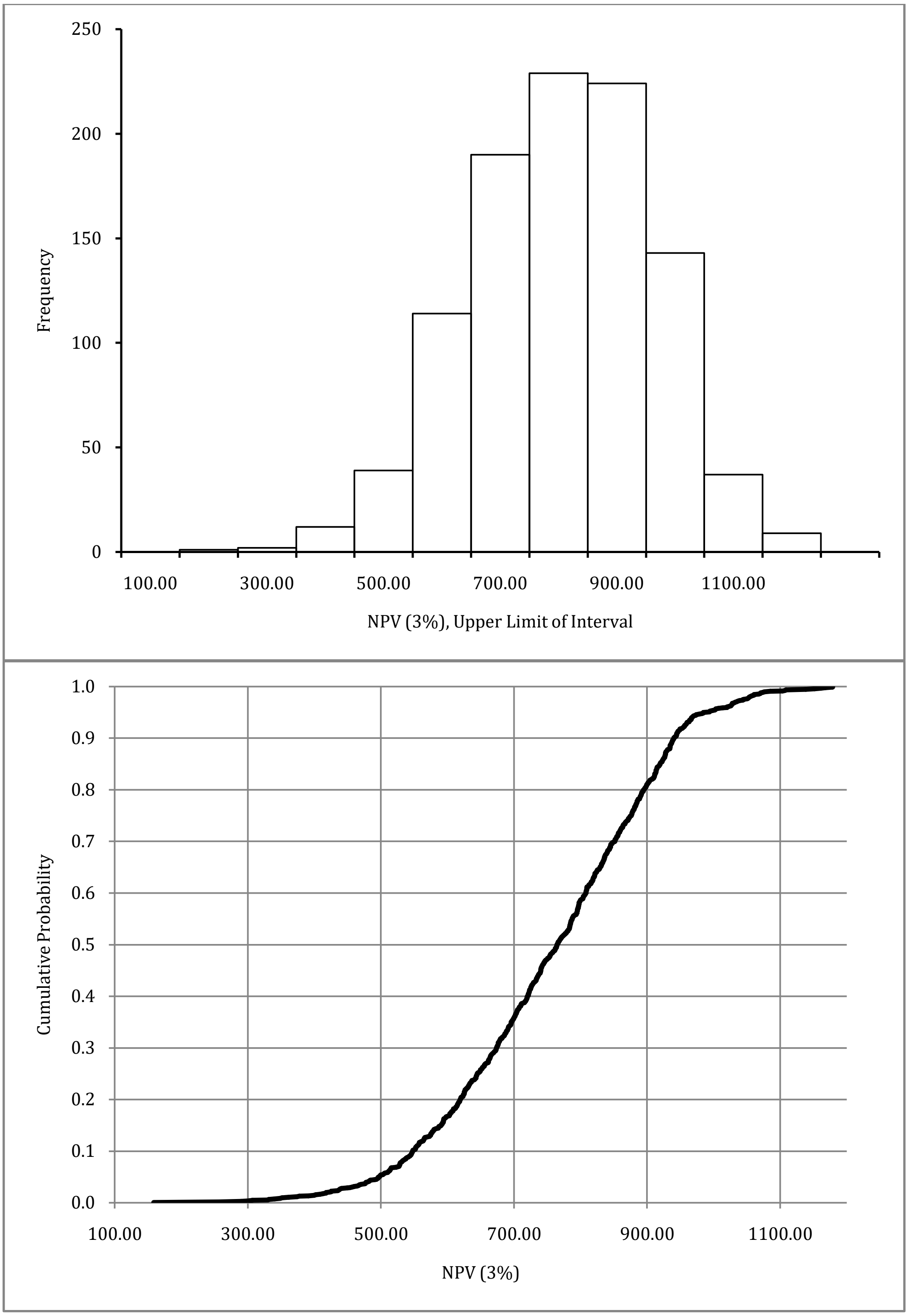


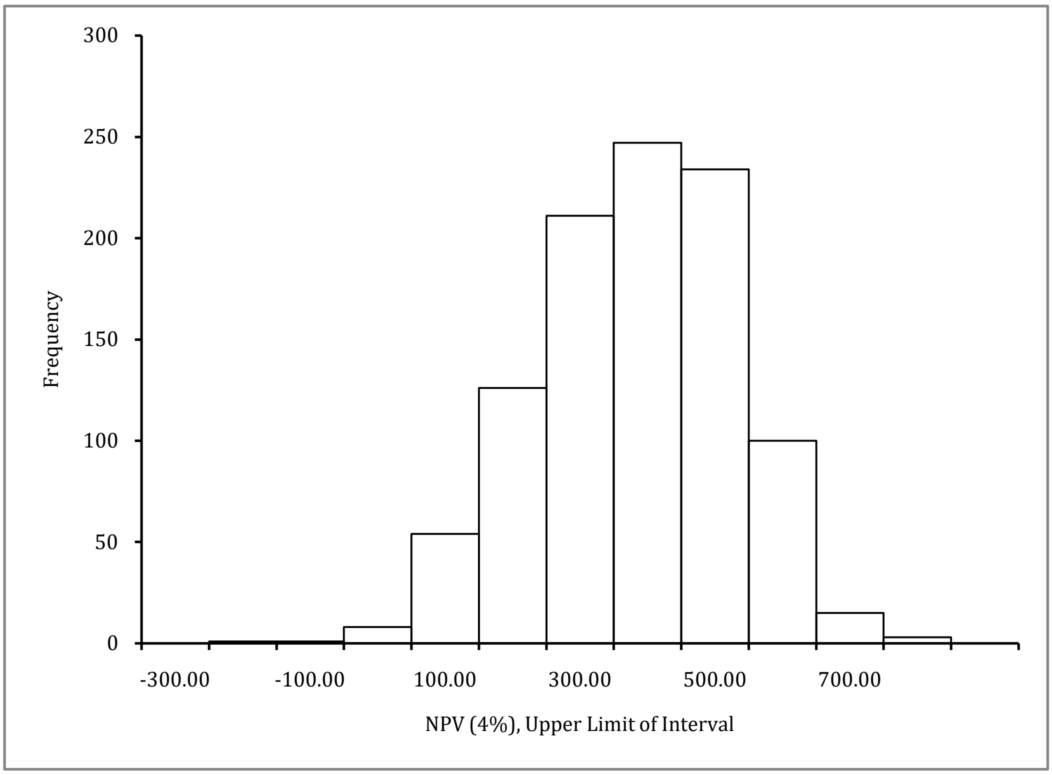
Figure 37 Monte Carlo Simulation for “Mussels & Seaweed & Wind” compared to coal energy production (NPV, 3%)

Wind & Seaweed & Mussels, 4% discount rate, compared to ENTSO-E energy production

Based on the results from the Monte Carlo Simulation for the North Sea site MUOP and considering discount rate to be 4%, the 95% confidence interval for the NPV is 332.75±1.96*144.37. This confidence interval is not strictly positive; therefore, we cannot conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 335 million is approximately 50%. However, the probability of having a negative NPV is less than 1%.

Table 23 “Mussels & Seaweed & Wind” compared to ENTSO-E energy production(NPV, 4%)

Mean	332,75
St. Dev.	144,37
Mean St. Error	4,57
Minimum	-287,86
First Quartile	229,44
Median	341,42
Third Quartile	437,23
Maximum	722,95
Skewness	-0,2786



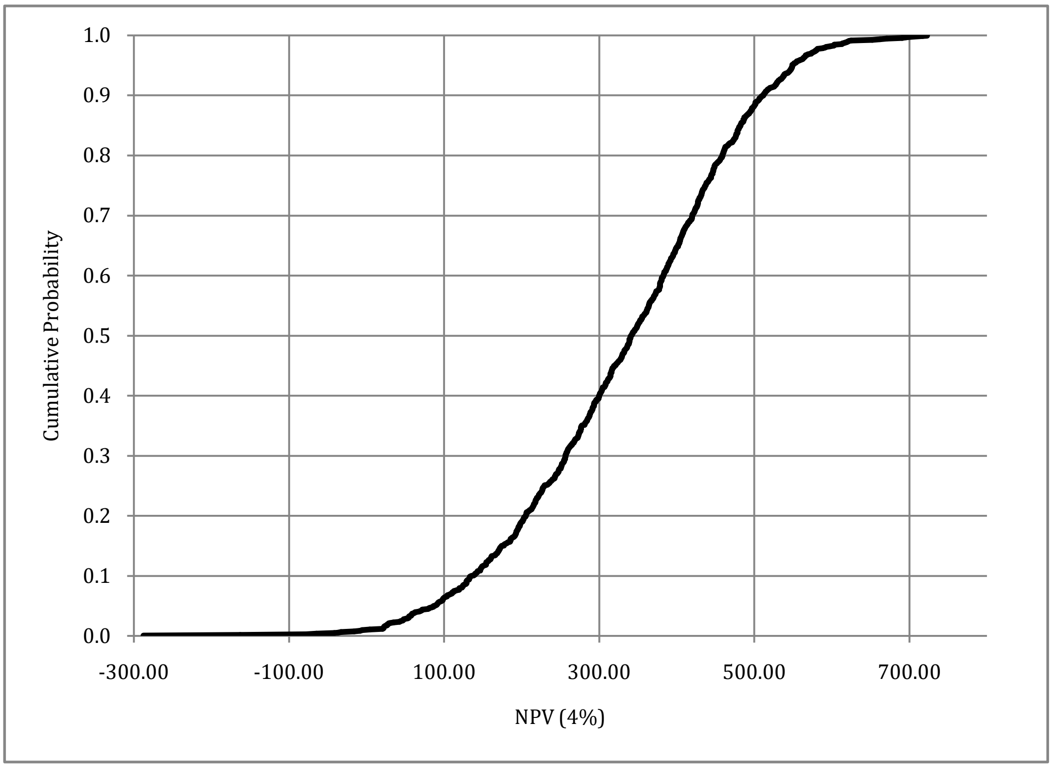


Figure 38 Monte Carlo Simulation for “Mussels & Seaweed & Wind” compared to ENTSO-E energy production (NPV, 3%)

”Wind”, 3% discount rate, compared to coal energy production

Based on the results from the Monte Carlo Simulation for the North Sea site MUOP and considering discount rate to be 3%, the 95% confidence interval for the NPV is 1225.5±1.96*98.08. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 1256 million is approximately 52%.

Table 24 “Wind” compared to coal energy production(NPV, 3%)

Mean	1252,50
St. Dev.	98,08
Mean St. Error	3,10
Minimum	930,22
First Quartile	1188,34
Median	1251,44
Third Quartile	1320,74
Maximum	1670,25
Skewness	-0,0018

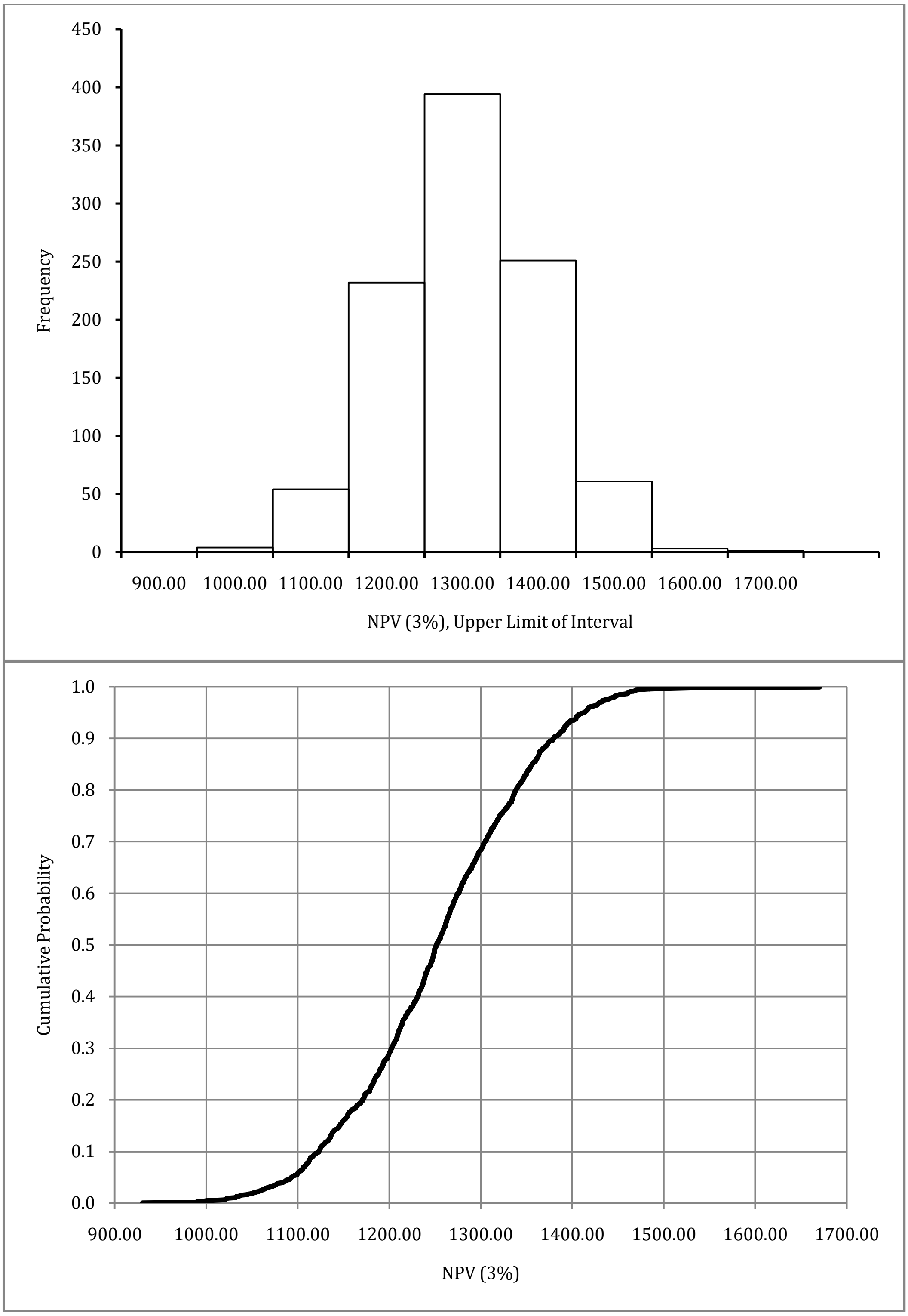


Figure 39 Monte Carlo Simulation for “Wind” compared to coal energy production (NPV, 3%)

”Wind”, 3% discount rate, compared to ENTSO-E energy production

Based on the results from the Monte Carlo Simulation for the North Sea site MUOP and considering discount rate to be 3%, the 95% confidence interval for the NPV is 1020.93±1.96*95.92. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 1026 million is approximately 52%.

Table 25 “Wind” compared to ENTSO-E energy production(NPV, 3%)

Mean	1020,93
St. Dev.	95,92
Mean St. Error	3,03
Minimum	693,03
First Quartile	954,31
Median	1021,31
Third Quartile	1090,93
Maximum	1358,82
Skewness	0,0104

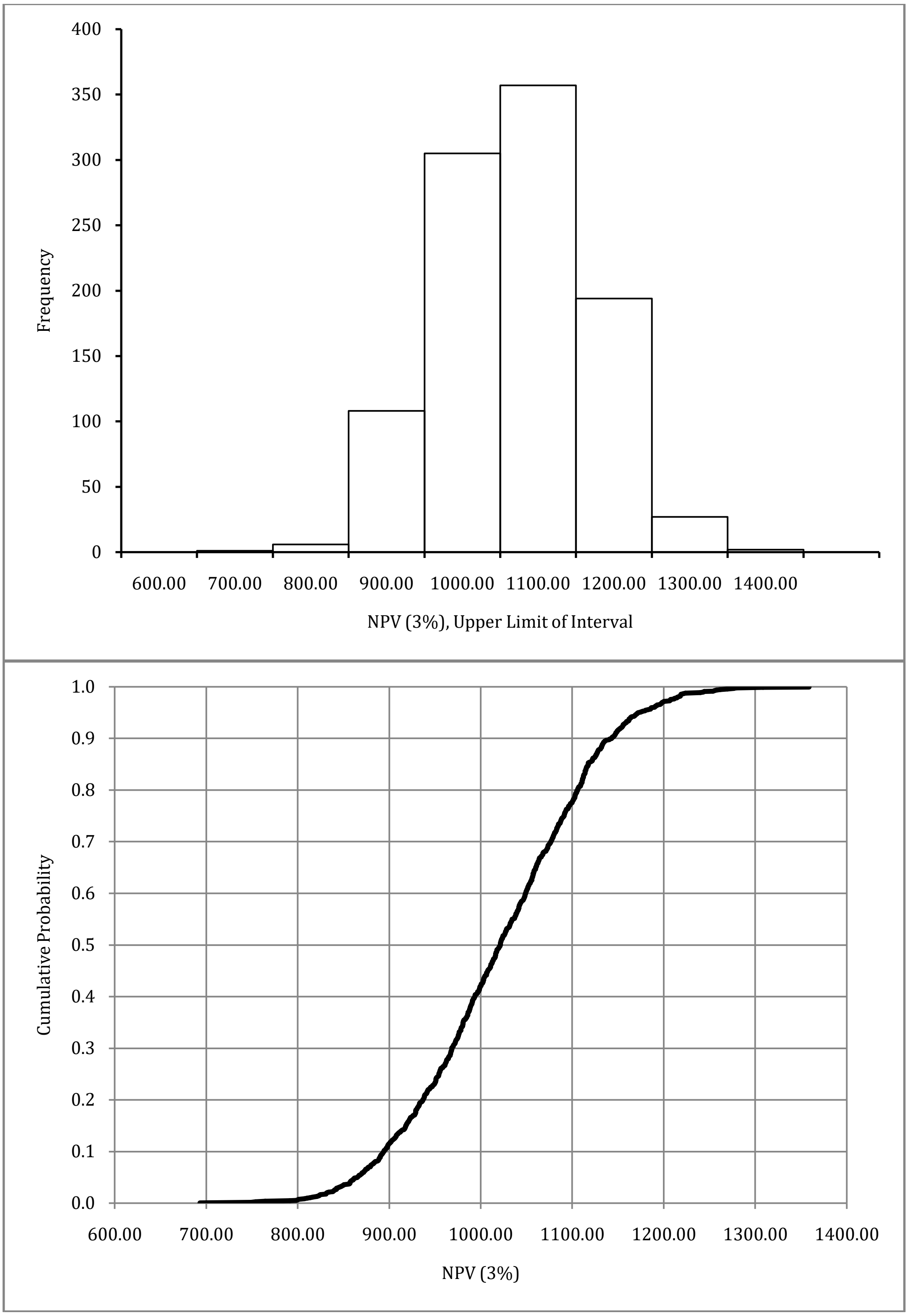


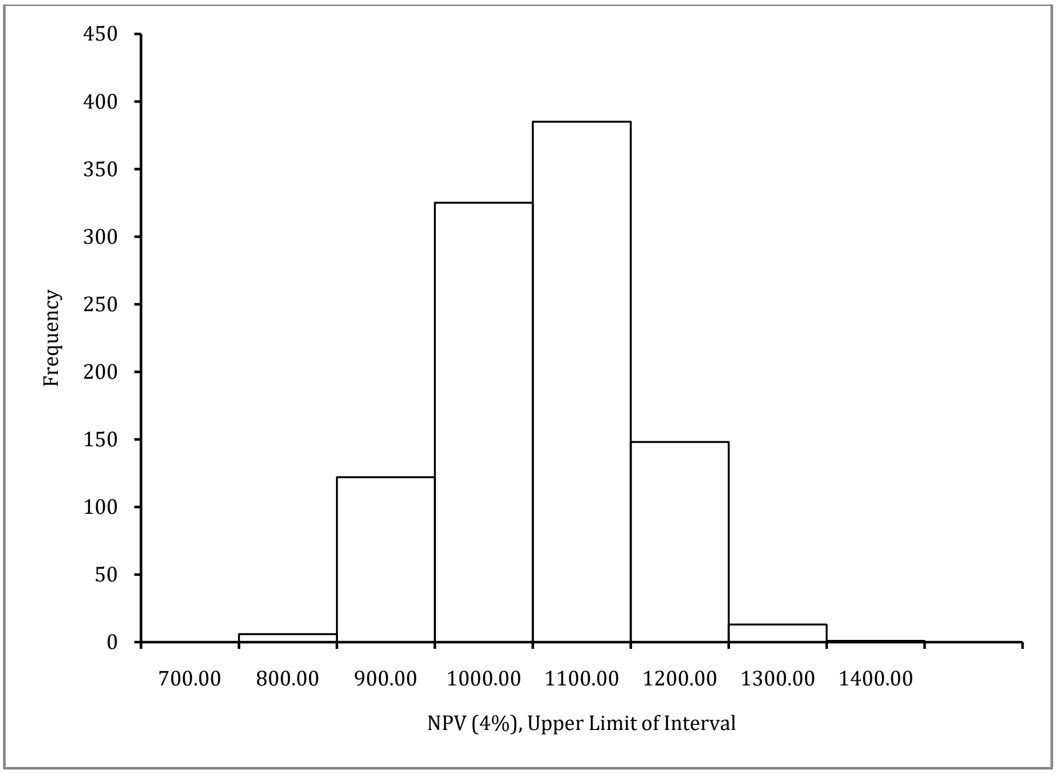
Figure 40 Monte Carlo Simulation for “Wind” compared to ENTSO-E energy production (NPV, 3%)

”Wind”, 4% discount rate, compared to coal energy production

Based on the results from the Monte Carlo Simulation for the North Sea site MUOP and considering discount rate to be 4%, the 95% confidence interval for the NPV is 1009.27±1.96*90.96. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 1014 million is approximately 52%.

Table 26 “Wind” compared to coal energy production(NPV, 4%)

Mean	1009,27
St. Dev.	90,96
Mean St. Error	2,88
Minimum	722,90
First Quartile	944,00
Median	1010,30
Third Quartile	1075,15
Maximum	1303,35
Skewness	0,0184



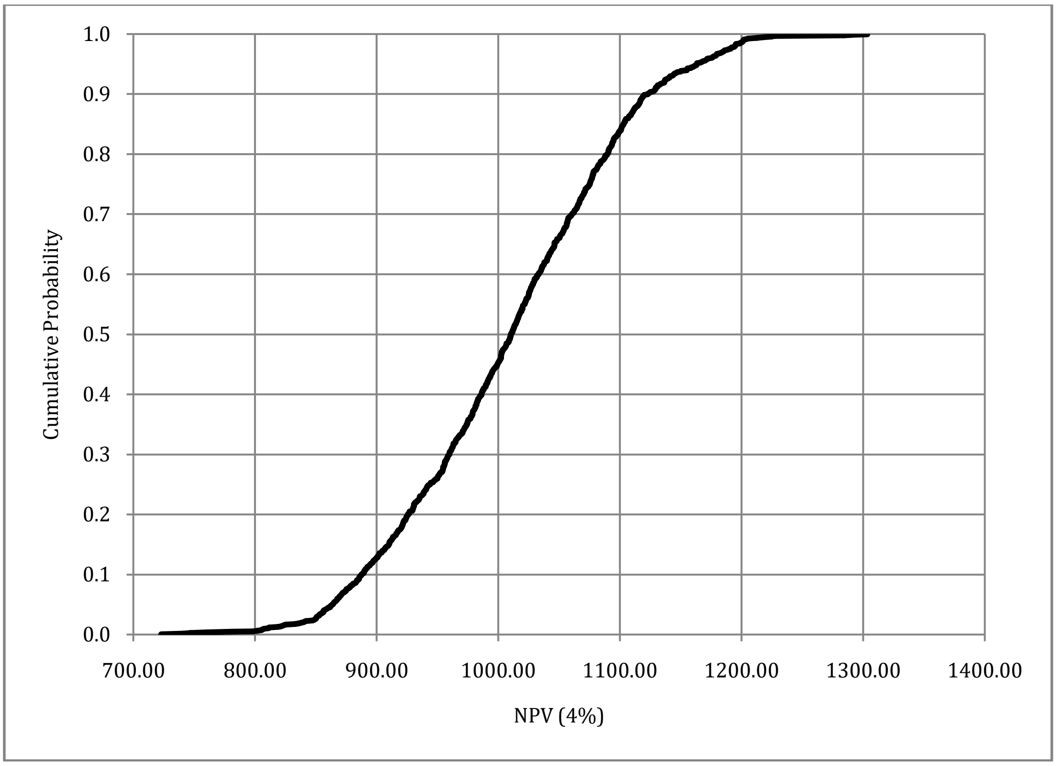


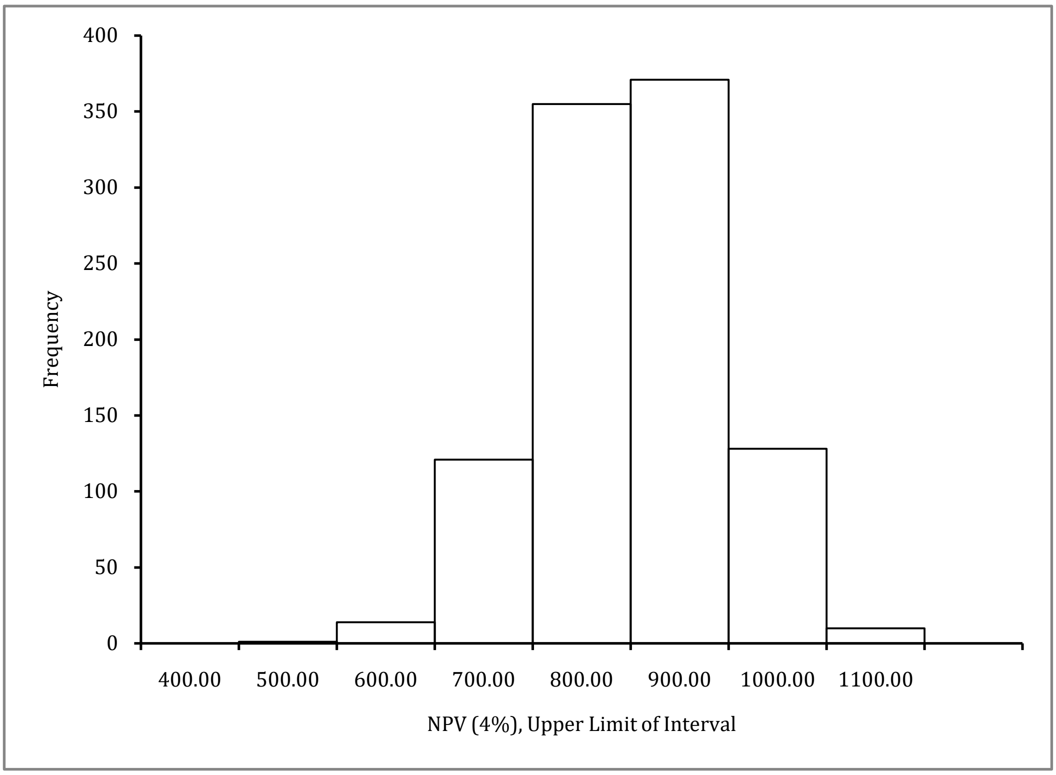
Figure 41 Monte Carlo Simulation for “Wind” compared to coal energy production (NPV, 4%)

”Wind”, 4% discount rate, compared to ENSTO-E energy production

Based on the results from the Monte Carlo Simulation for the North Sea site MUOP and considering discount rate to be 4%, the 95% confidence interval for the NPV is 799.64±1.96*91.46. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 800 million is approximately 50%.

Table 27 “Wind” compared to ENTSO-E energy production(NPV, 4%)

Mean	799,64
St. Dev.	91,46
Mean St. Error	2,89
Minimum	488,55
First Quartile	736,58
Median	801,57
Third Quartile	863,54
Maximum	1098,18
Skewness	-0,1516



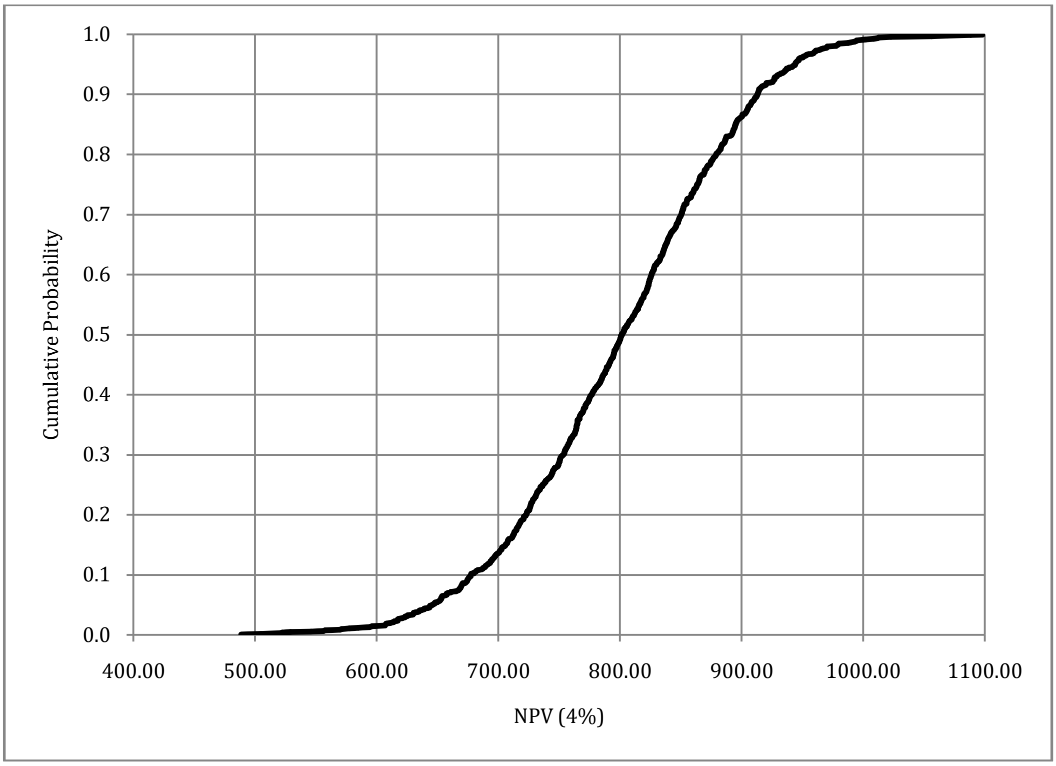


Figure 42 Monte Carlo Simulation for “Wind” compared to ENTSO-E energy production (NPV, 4%)

7.3 Comparison between Monte Carlo and Sensitivity Analysis

Similarly to the rest of the cases and alternatives, the results of Monte Carlo and Sensitivity Analysis are consistent. NPV mean value estimated under Monte Carlo are very close to the corresponding base values of sensitivity analysis.

8 Conclusions and Recommendations

Forecasts based on current knowledge and future expectations inevitably create uncertainty related to future cash flows of a project under development. This uncertainty stems from the uncertainties related to offshore wind/wave energy and aquaculture values (eg. output, costs, prices), related to economic, environmental and technological aspects due to spatial differentiation between the different MUOP projects (North Sea, Atlantic, Mediterranean, Baltic). Based on the risk analysis results the output and operation costs represent the most vulnerable to changes parameters for the projects. However, we should note that the results are based on limited information and time horizon (20-25 years) that does not allow for the inclusion of long-run effects (eg. environmental effects that take place after more than 40 years of platform operation). Hence, information risks could overestimate or underestimate the profitability and results of the analysis.

Main challenges for the assessment and implementation of the MUOPs are the lack of data (financial, environmental, socio-economic, technological) that made the monetization of externalities difficult, lack of institutional support and legal barriers, probable lack of coordination between countries at regional level, public unfamiliarity and distrust towards MUOPs. Location and stakeholders' views had played an important role for the final resign of the MUOPs.

Nevertheless, with regards to opportunities, MUOPs represent future opportunities for efficient marine space, which provides opportunities for regional development and higher cooperation between the different countries involved in the implementation of the MUOP. MUOPs provide R&D opportunities that could create new jobs for high skilled workers. Furthermore, technological synergies correspond to energy efficiency and less environmental effects i.e.less CO_2 emissions.

Based on the current results, the final designs for the Atlantic and North Sea site seem to be economically sustainable. However, stand alone functions of Wave energy production for the Atlantic site and Seaweed production for the North Sea site seems not economically sustainable. For the Mediterranean and the Baltic site, since financial data with regards to the multi-use scenario were not available, experts' opinions and initial financial analysis has suggested that Baltic site can be economically sustainable. However, the Mediterranean MUOP scenario could be economically sustainable in the long run when the ocean space will get limited. Nevertheless, these are conclusions based on specific assumptions that were taken into account (See MERMAID D8.2, D8.3, D8.4, D8.5). Results change when data assumptions, information gathered and long time horizon is examined.

Subsidies included in the SCBA can alleviate for negative profitability with respect to stand alone functions. One way to motivate subsidies for the MUOPs development is to point out that these subsidies are used to cover installation cost of the MUOPs different functions with the purpose of capturing the positive externalities not only in terms of environmental benefits such as CO_2 reductions, but also in terms of more general positive network externalities that promote technical change, support the transition to low carbon, support an energy independent economy, and improve food security due to more controlled aquaculture. Economic theory suggests that activities which generate positive externalities should be subsidized, because market equilibrium without subsidies will not provide the correct amount of the externality generating activity. This is the opposite of imposing taxes to restrict activities that generate negative externalities. If we do not subsidize the market economy will not install MUOPs and we will loose benefits. So subsidies are not a form of supporting the income of a pressure group but a means to secure the benefits accruing from positive externalities. However, it is advised to avoid subsidies in the long-term, as MUOPs should be economically viable in the long-term. Additionally, MUOPs should be able to compete with "conventional" producers if site conditions are good enough. Other mechanisms for financial support that create incentives for developers to explore possibilities of these type of investment and make them more attractive, need to be further examined. Apart from subsidies, taxes to conventional energy production uses could be applied or make sure that insurance to reduce risks is effectively addressed. Furthermore, the advantage of first mover and the benefit of pioneer with regards to investors, should not disregarded.

As suggested in the Deliverable D2.5, institutional and policy level, policy frameworks for the implementation of MUOPs need to be adjusted to reduce uncertainties with regards to licensing and operating this type of enterprise that usually contribute to complexity of decision making and implementation process. Clear and agile licensing procedures that are open to accept innovative solutions and co-existence of uses in offshore environment are advisable. The licensing procedure should be based on site-specific environmental studies that guarantee the implementation of an environmental monitoring system in the designated marine areas for multi-use platforms development. For example, an environmental monitoring program that considers environmental issues such as, the spreading of invasive species, biodiversity, underwater noise and electromagnetic radiation, and water pollution. Minimizing environmental impact and continued monitoring should not be seen as burden, instead, they contribute to the social license to operate for MUOPs.

With regards to the stakeholders participation, it is recommended to engage different stakeholders in spatial planning and when developing policy instruments for MUOPs. Diverse knowledge and competences, as well as different responsibilities are spread out by several stakeholders capable of affecting the policy making process that is required for planning and developing future MUOPs. Important stakeholders are business partners and the potential future developers, environmental authorities, local or regional administration, relevant professional associations, local NGOs, and research institutes. In formal procedures such as impact assessment of plans, programs (Strategic Environmental Assessment) and projects (Environmental Impact Assessment), consultation is already a given. Hence, it is important to take advantage of the knowledge from other scientific projects. This helps taking into account a variety of institutional, technical, environmental, financial and socio-economic aspects in maritime spatial planning and for developing policy instruments that can support the development, implementation and running of MUOPs (MERMAID D2.5, D2.7).

Finally, it is understood that MUOPs are able to generate public benefits private funding will be required in the future. For the initial state of MUOPs development, subsidies and other possible economic instruments are advised to be used to create incentives of investment. This requires that the benefits are visible to all relevant stakeholders and policy makers. Given the lack of data and the high research potential in this area, it is suggested to have pilot MUOPs project that could close the knowledge gaps and be used as examples to show the possible benefits to policy makers and potential investors.

9 References

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