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Risk Analysis for the Selected MERMAID Final Designs

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Abstract This chapter presents the risk analysis results of the application of the Methodology for Integrated Socio-Economic Assessment (MISEA) which was developed in the MERMAID Project with regards to the different proposed designs of novel Multi-Use Offshore Platforms (MUOPs). For this purpose, sensitivity analysis of critical variables based on values given by experts and Monte Carlo simulation were undertaken to analyze the risk of developing these platforms. The approach integrates the results of the assessment discussed in the previous chapters. Both sensitivity analysis and Monte Carlo simulations approaches are compared.

Keywords Multi-use offshore platforms • Marine infrastructure • Risk analysis • Sensitivity analysis • Monte Carlo simulation

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7.1 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.[1]

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). Probability should here be understood as an index that takes the value of 1 under full certainty that a prediction will be confirmed, a 0 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 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 MUOPs, 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 with power production (wind and wave), aquaculture (mussels, seaweed and fish), revenues and costs, under the proposed multi-functional structures determine the future cash flows of the MUOPs. 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 namely (i) Sensitivity analysis, and (ii) Monte Carlo Simulations:

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

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 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.

Table 7.1 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.

7.2 Risk Analysis of 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.

7.2.1 Sensitivity Analysis

With regards to the sensitivity analysis, the scenarios refer to the wind & wave platform. We consider the variables presented in Table 7.1.

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 (Figs. 7.1, 7.2, 7.3 and 7.4). Spider graphs for the single use scenarios, wind or wave project can be provided under request.

7.2.2 Monte Carlo Simulations

7.2.2.1 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 $442.3 \pm 1.96 * 58.3$. This confidence interval is strictly positive; therefore, we can conclude that at 95% confidence interval this project has a positive NPV. From the

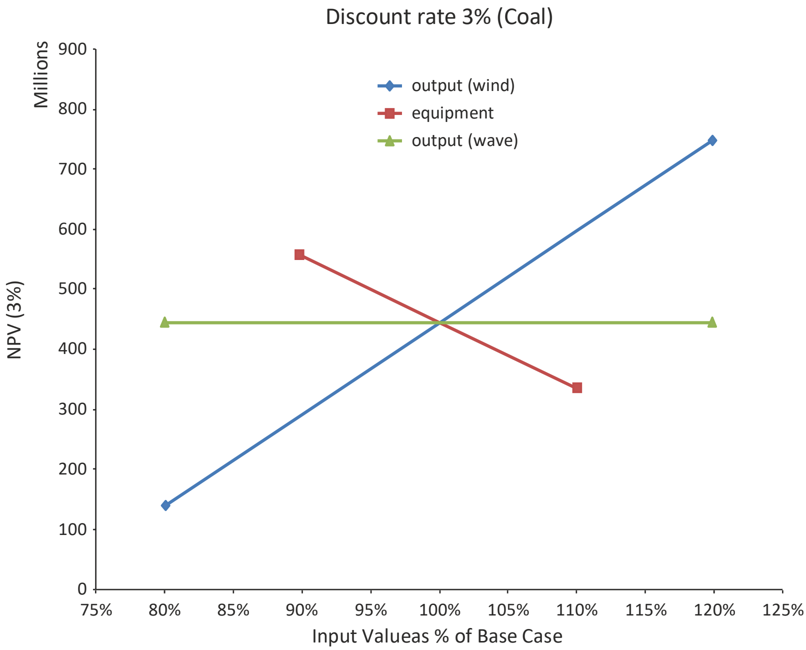


Fig. 7.1 Sensitivity analysis on SCBA (3% discount rate, compared to coal energy production)

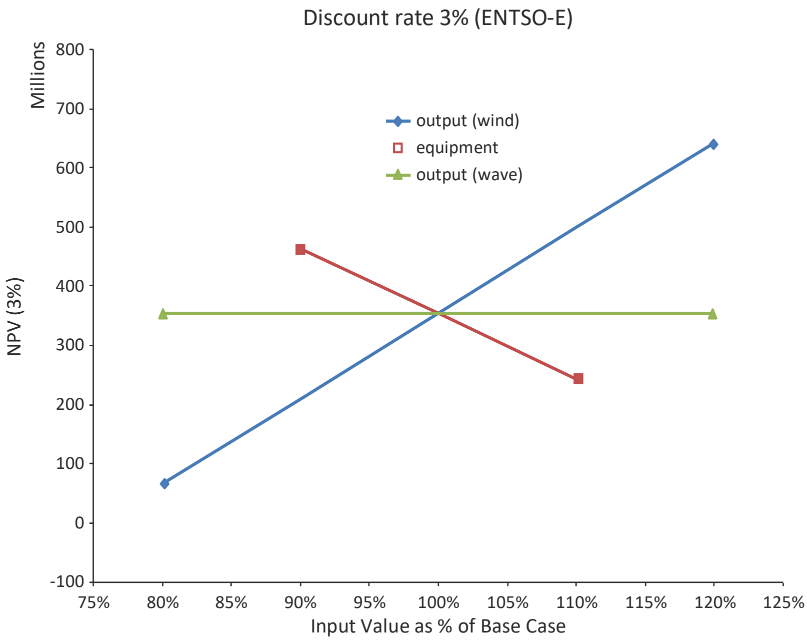


Fig. 7.2 Sensitivity analysis on SCBA (3% discount rate, compared to ENTSO-E energy production)

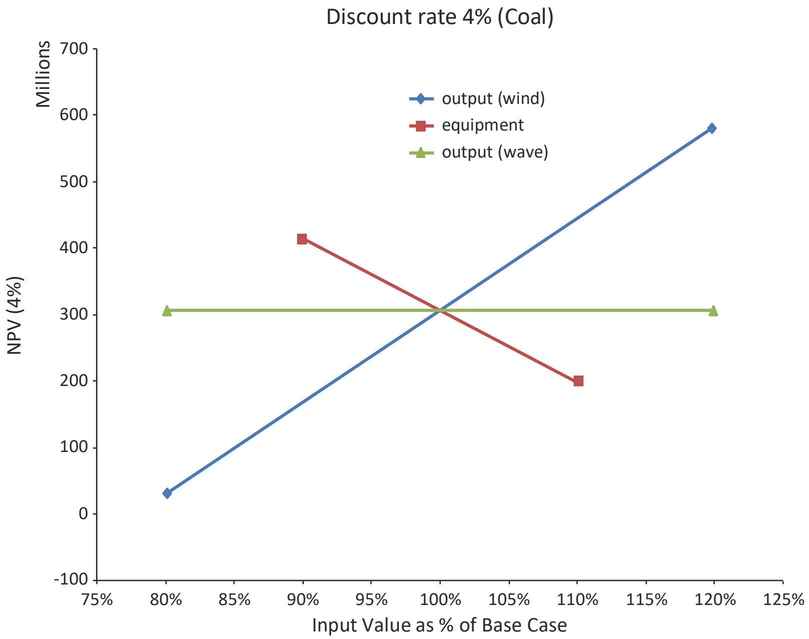


Fig. 7.3 Sensitivity analysis on SCBA (4% discount rate, compared to coal energy production)

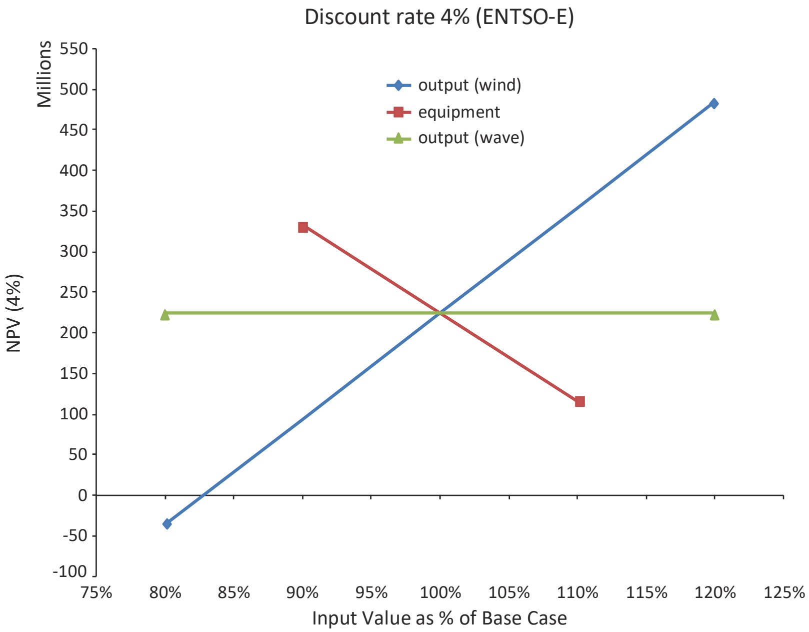


Fig. 7.4 Sensitivity analysis on SCBA (4% discount rate, compared to ENSTSO-E energy production)

cumulative chart we can conclude that the probability of having an NPV less than 450 million is approximately 55% (Fig. 7.5 and Table 7.2).

7.2.2.2 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% (Fig. 7.6 and Table 7.3).

7.2.2.3 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% (Fig. 7.7 and Table 7.4).

7.2.2.4 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% (Fig. 7.8 and Table 7.5).

7.3 Risk Analysis of 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

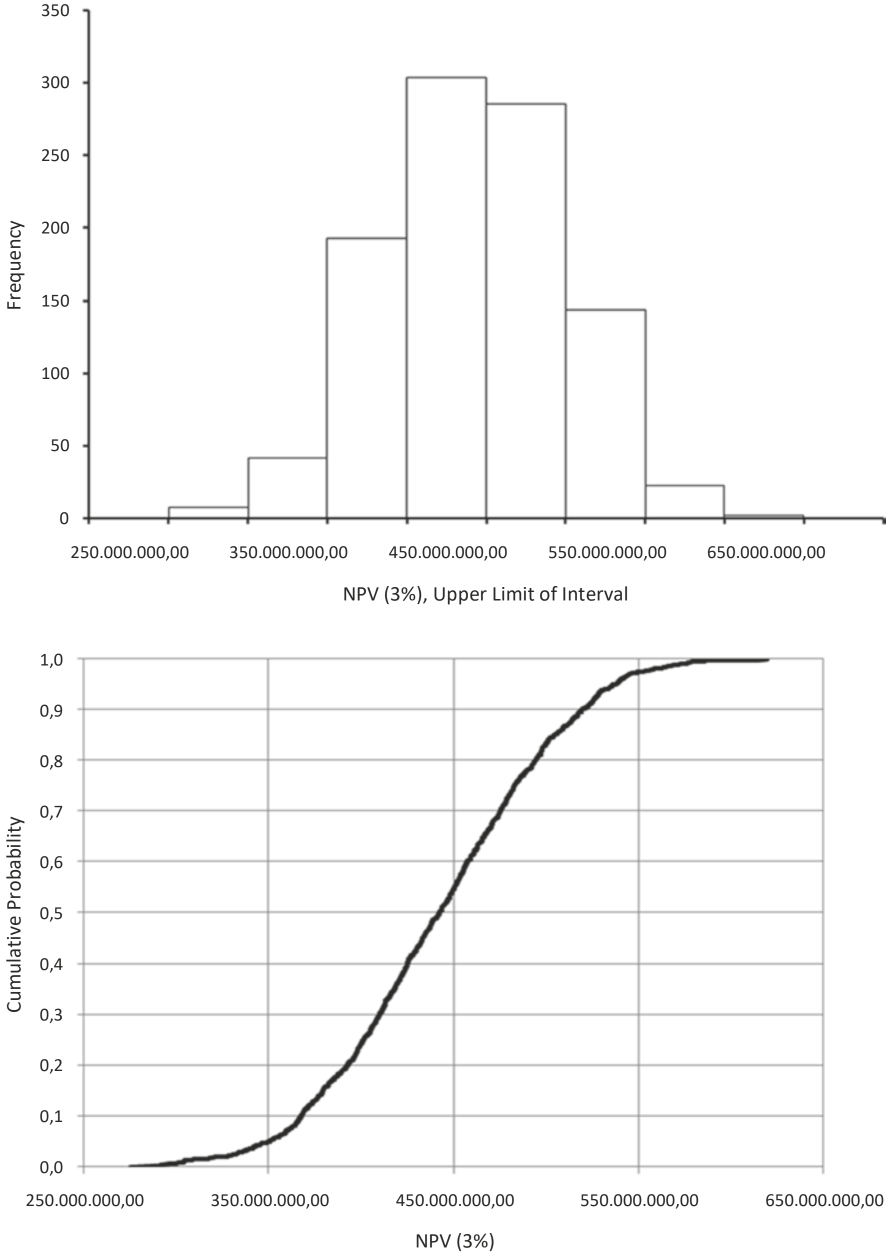
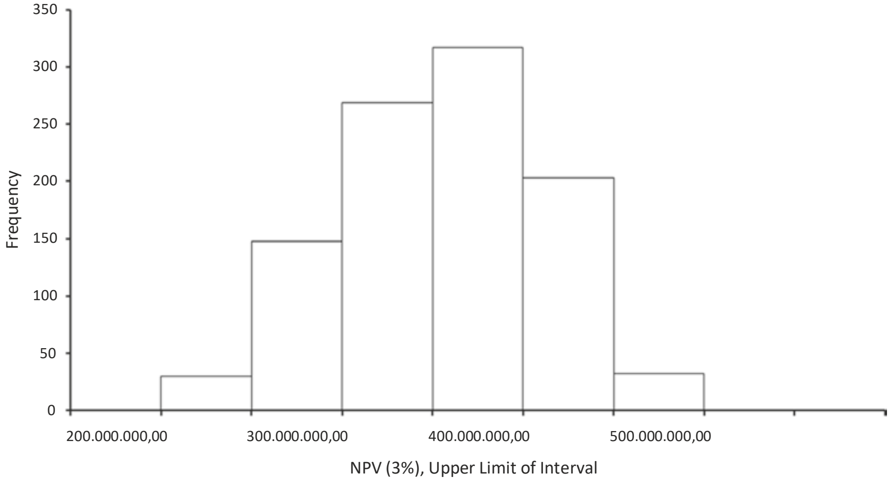


Fig. 7.5 Monte Carlo simulation for “Wind & Wave” compared to coal energy production (NPV, 3% discount rate)

Table 7.2 "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



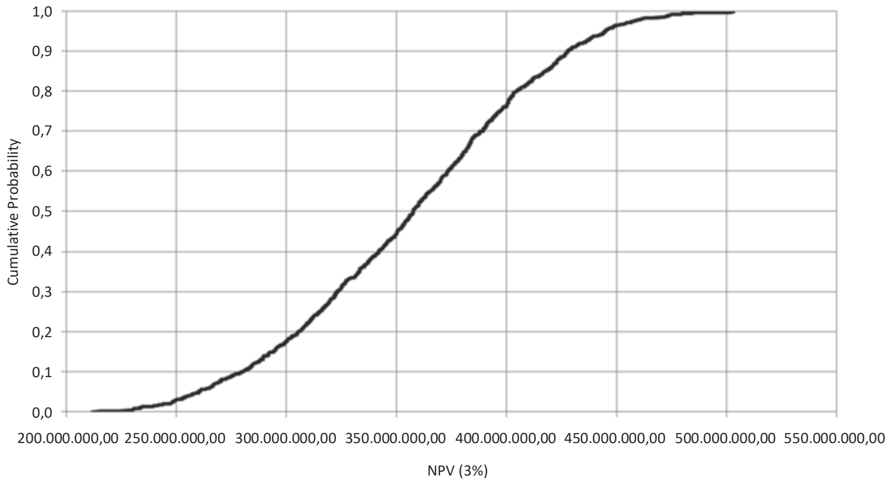


Fig. 7.6 Monte Carlo simulation for "Wind & Wave" compared to ENTSO-E energy production (NPV, 3% discount rate)

Table 7.3 "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

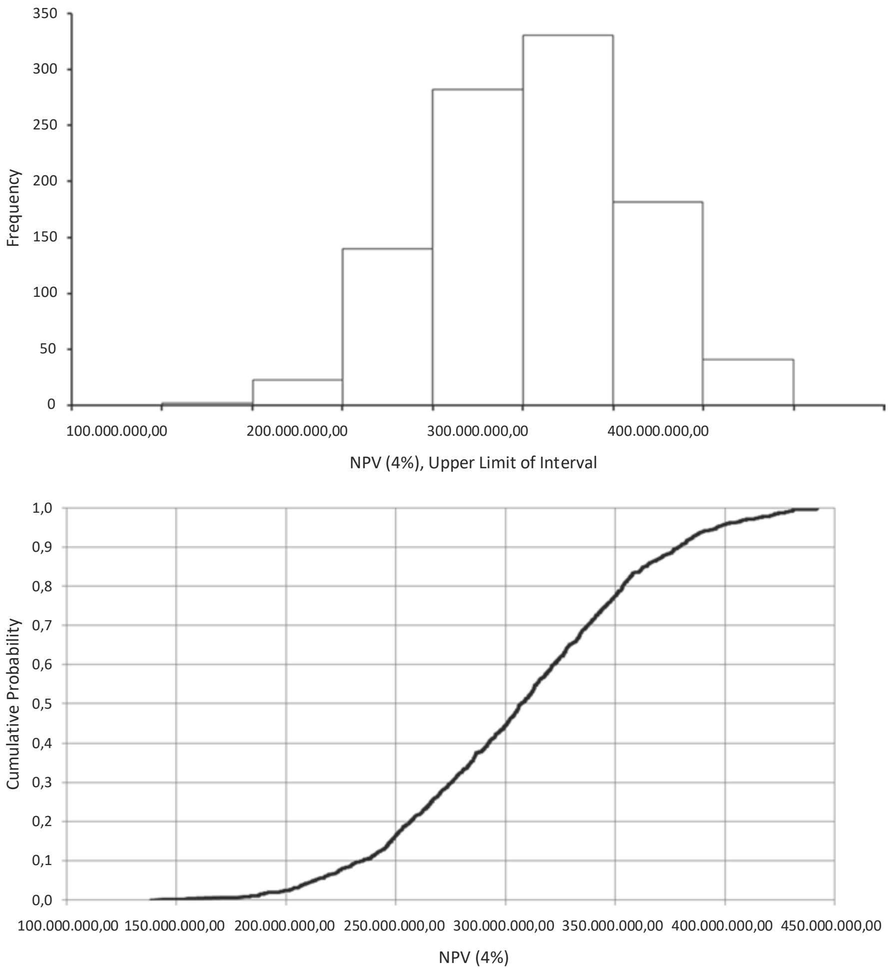


Fig. 7.7 Monte Carlo simulation for "Wind & Wave" compared to coal energy production (NPV, 4% discount rate)

Table 7.4 "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

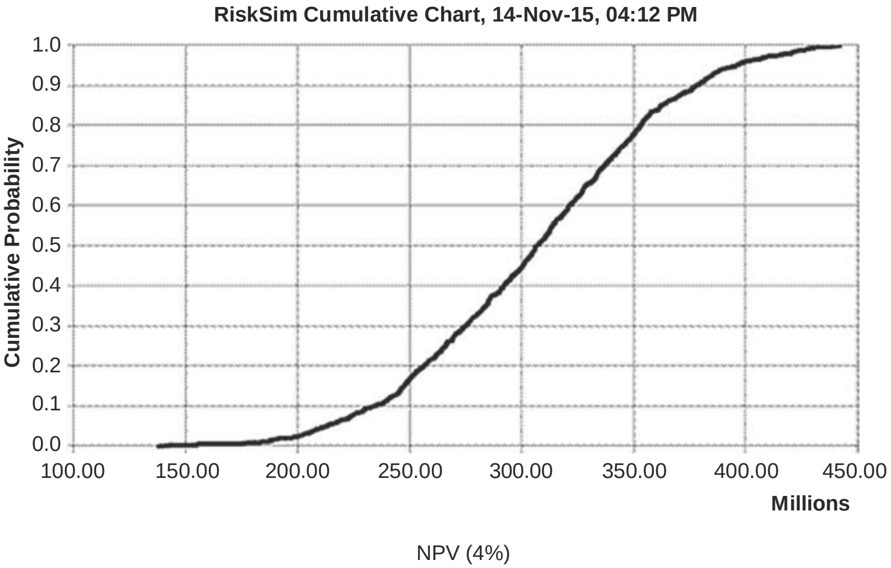


Fig. 7.8 Monte Carlo simulation for "Wind & Wave" (NPV, 4% discount rate)

Table 7.5 "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

Table 7.6 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.

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.

7.3.1 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 7.6).

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 (Figs. 7.9, 7.10, 7.11 and 7.12).

7.3.2 Monte Carlo Simulations

7.3.2.1 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% (Fig. 7.13 and Table 7.7).

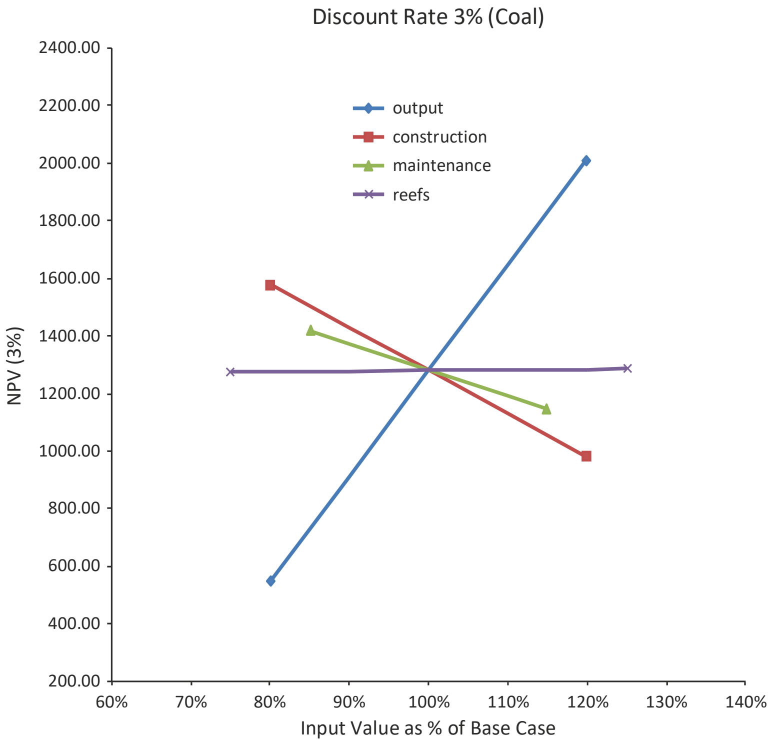


Fig. 7.9 Sensitivity analysis on SCBA (3% discount rate, compared to coal energy production)

7.3.2.2 Wind, 3% 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 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% (Fig. 7.14 and Table 7.8).

7.3.2.3 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

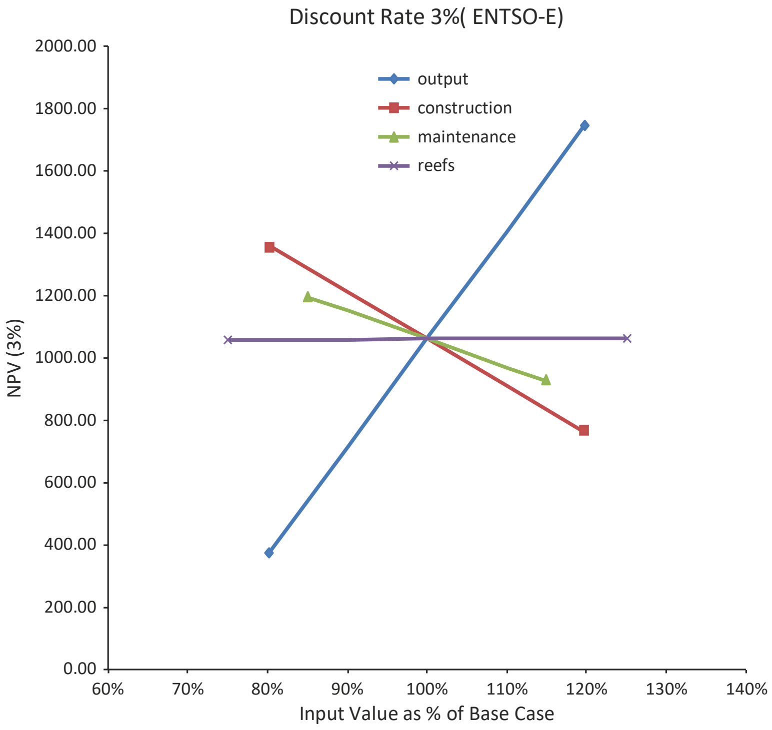


Fig. 7.10 Sensitivity analysis on SCBA (3% discount rate, compared to ENTSO-E energy production)

NPV. From the cumulative chart we can conclude that the probability of having an NPV less than 1026 million is approximately 50% (Fig. 7.15 and Table 7.9).

7.3.2.4 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% (Fig. 7.16 and Table 7.10).

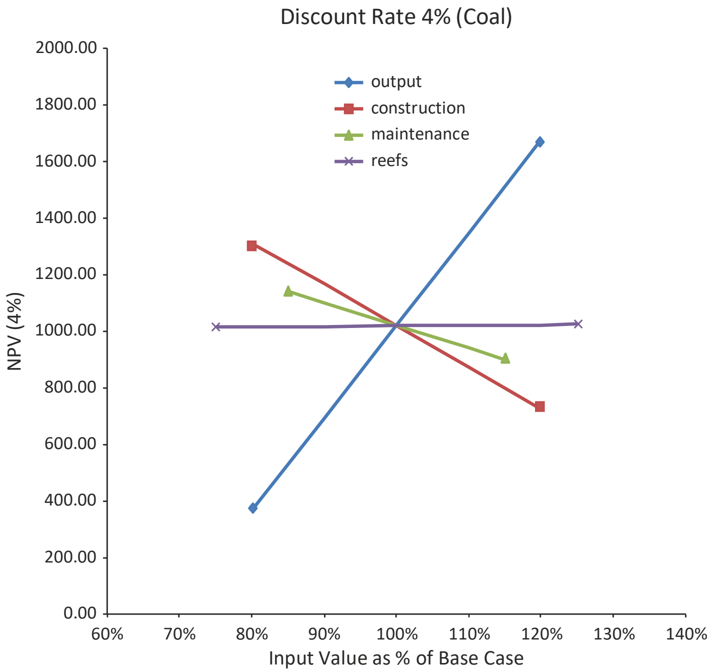


Fig. 7.11 Sensitivity analysis on SCBA (4% discount rate, compared to coal energy production)

7.4 Risk Analysis of 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.

7.4.1 Sensitivity Analysis

For the purposes of sensitivity analysis the scenarios refer only to the single-use of fish production (Table 7.11).

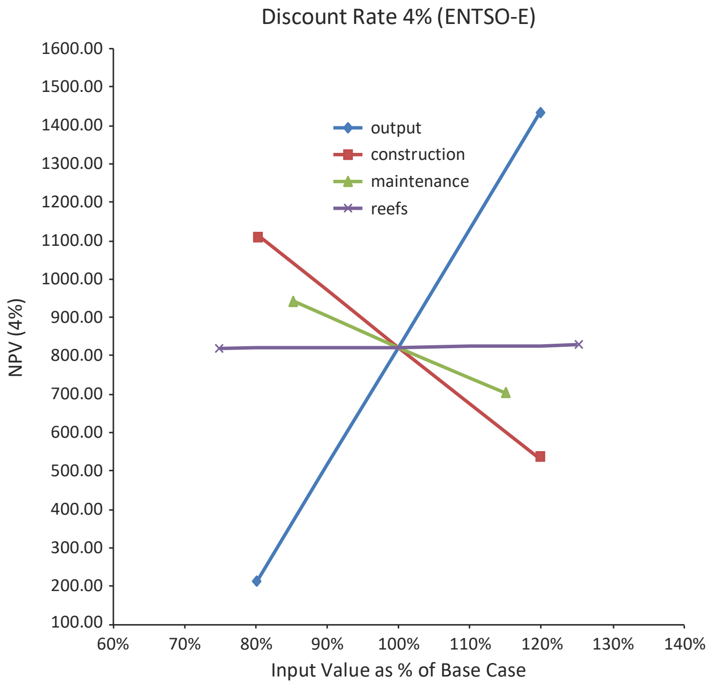


Fig. 7.12 Sensitivity analysis on SCBA (4% discount rate, compared to ENTSO-E energy production)

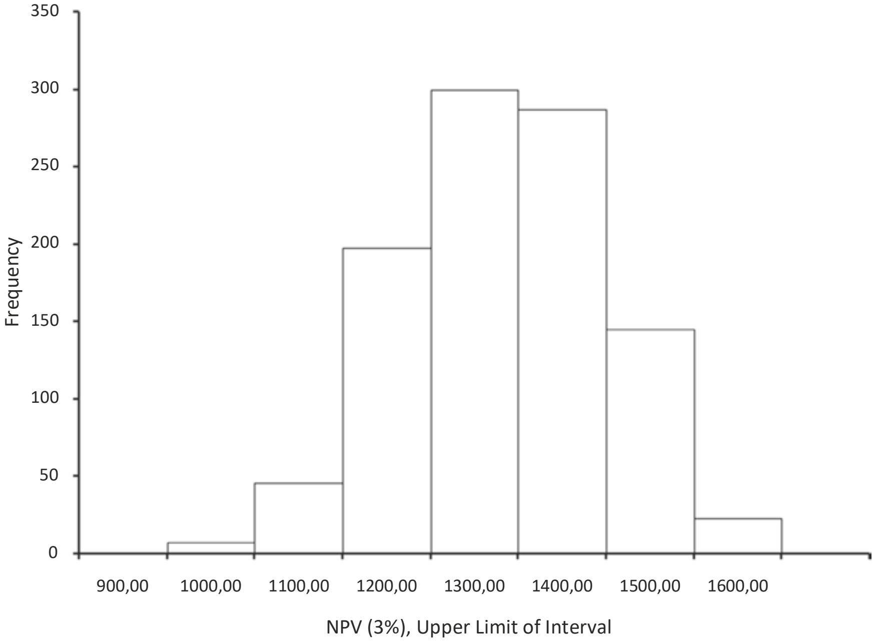
The results suggest that the critical variables are raw materials and fish revenue. There is a switching value for raw materials which is around 10–11% above the base case (110–111% in the spider graph), and a switching value for fish revenue which is around 6–7% below the base case (93–94% in the spider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

The spider graphs for the 3% and 4% discount rate are shown below (Figs. 7.17 and 7.18).

7.4.2 Monte Carlo Simulations

7.4.2.1 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% (Fig. 7.19 and Table 7.12).



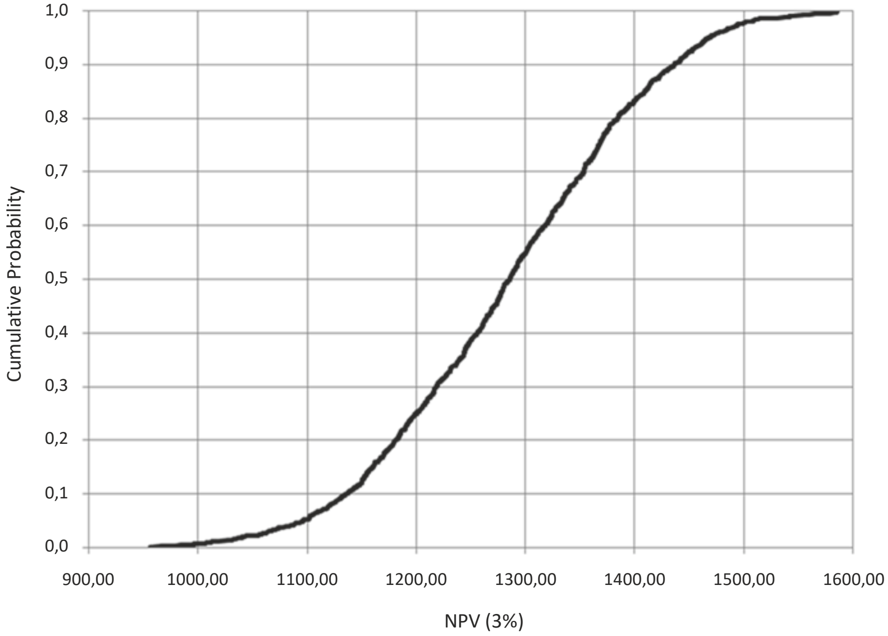


Fig. 7.13 Monte Carlo simulation for “Wind” compared to coal energy production (NPV, 3%)

Table 7.7 "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

7.4.2.2 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 a NPV less than 16.1 million is approximately 50%. However, the probability of having a negative NPV is less than 2% (Fig. 7.20 and Table 7.13).

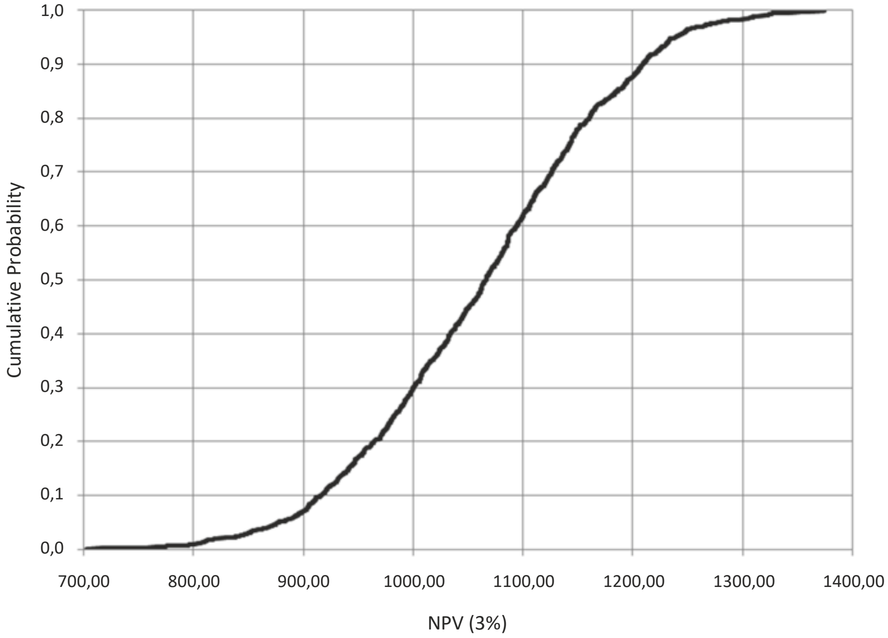
7.5 Risk Analysis of the North Sea Site

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.

7.5.1 Sensitivity Analysis

For the sensitivity analysis we consider seaweed, mussels and wind MUOP scenario (Table 7.14).

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



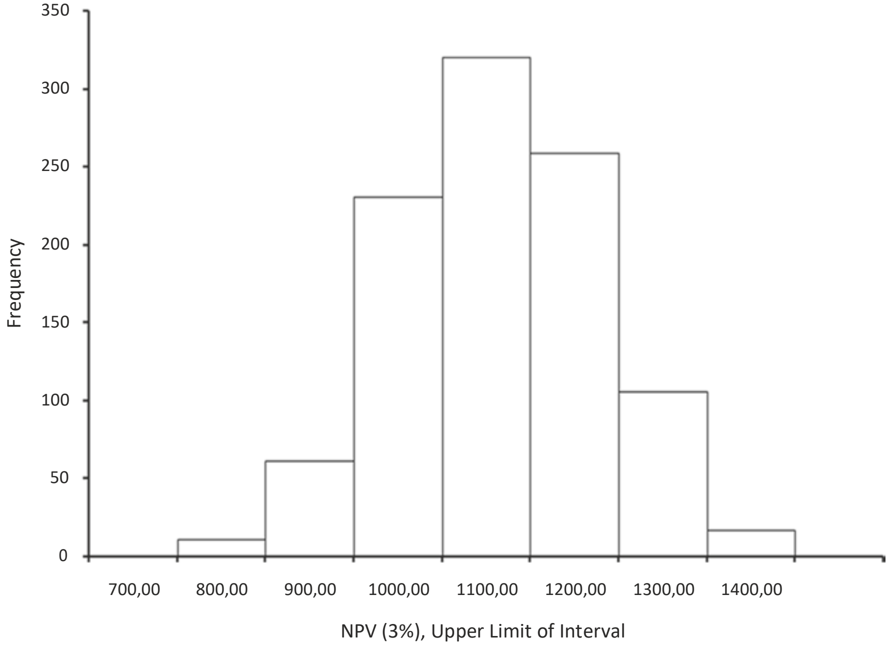


Fig. 7.14 Monte Carlo simulation for “Wind” compared to ENTSO-E energy production (NPV, 3%)

Table 7.8 "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

In the following we present spider graphs for the combined energy, seaweed and mussels project for 3% and 4% discount rate (Figs. 7.21, 7.22, 7.23 and 7.24). Spider graphs for the stand-alone energy, seaweed, mussels and the rest of possible pairs can be provided under request.

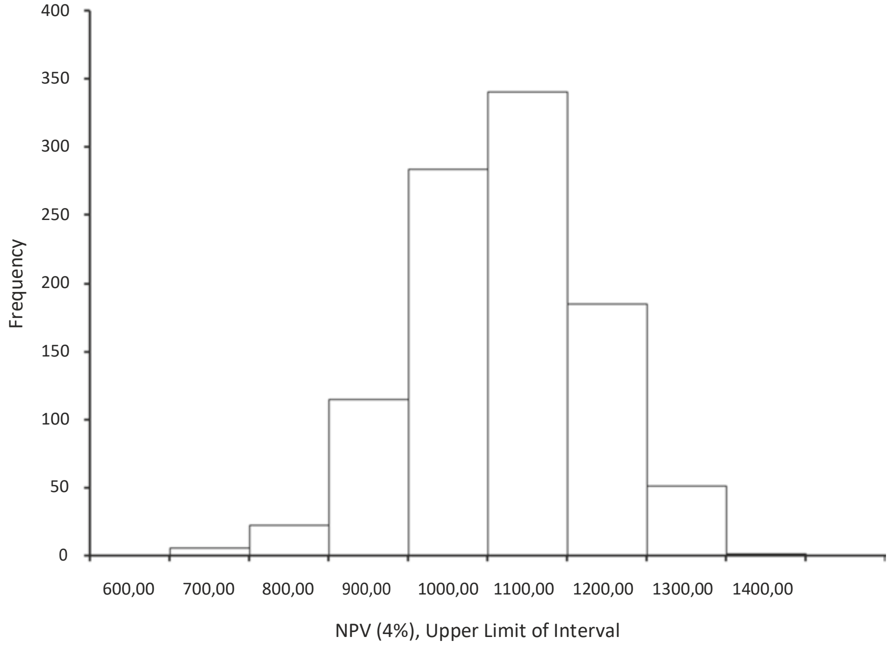
7.5.2 Monte Carlo Simulations

7.5.2.1 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 755.90 ± 1.96*153.43. 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 750 million is approximately 50% (Fig. 7.25 and Table 7.15).

7.5.2.2 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 328.12 ± 1.96*147. 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 330 million is approximately 50%. However, the probability of having a negative NPV is less than 1% (Fig. 7.26 and Table 7.16).



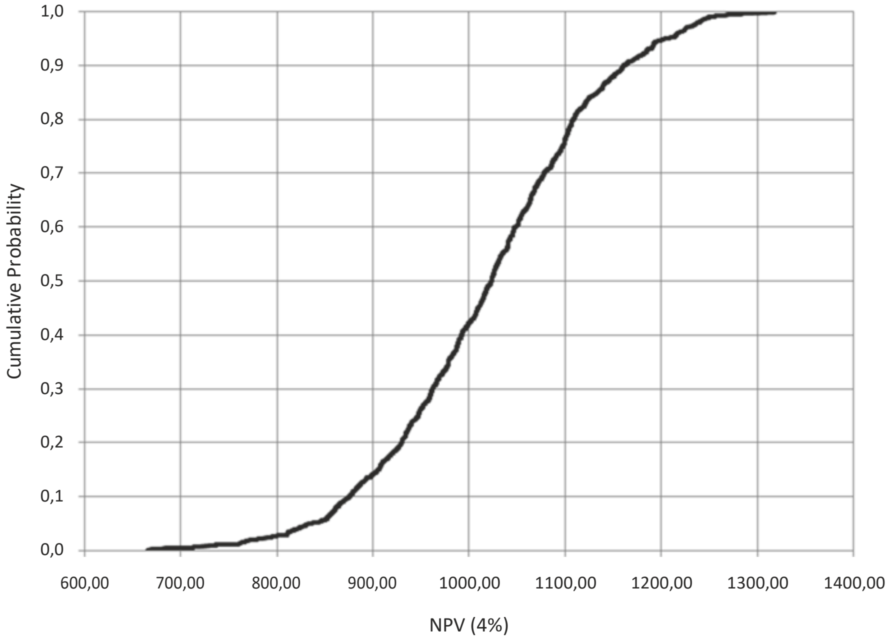


Fig. 7.15 Monte Carlo simulation for "Wind" compared to coal energy production (NPV, 4%)

Table 7.9 "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

7.6 Comparing Sensitivity Analysis and Monte Carlo Simulations

Comparing the sensitivity analysis and the Monte Carlo analysis we see that the results are consistent by looking at the base-case NPV for the sensitivity analysis and the expected NPV from the Monte Carlo simulations. Observing the risk analysis results for the Atlantic case study, 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. For the CBA test at a 3% discount rate and compared to coal energy production, the results of the two methods are also 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.

Moving on to the Baltic case study, 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. Hence, both methods are indeed consistent. Similar conclusions we have when comparing with coal energy production. For the CBA test at a 3% discount rate, the results of the two methods are still consistent (i.e. NPV equal to 1283.97 million estimated using Monte Carlo and around 1280 million derived from the sensitivity analysis). Similar conclusions we have when comparing with ENTSO-E energy production.

Same conclusions are derived with regards to consistency of the methods, when observing the results from the other two case studies, ie. Mediterranean case study and North Sea case study.

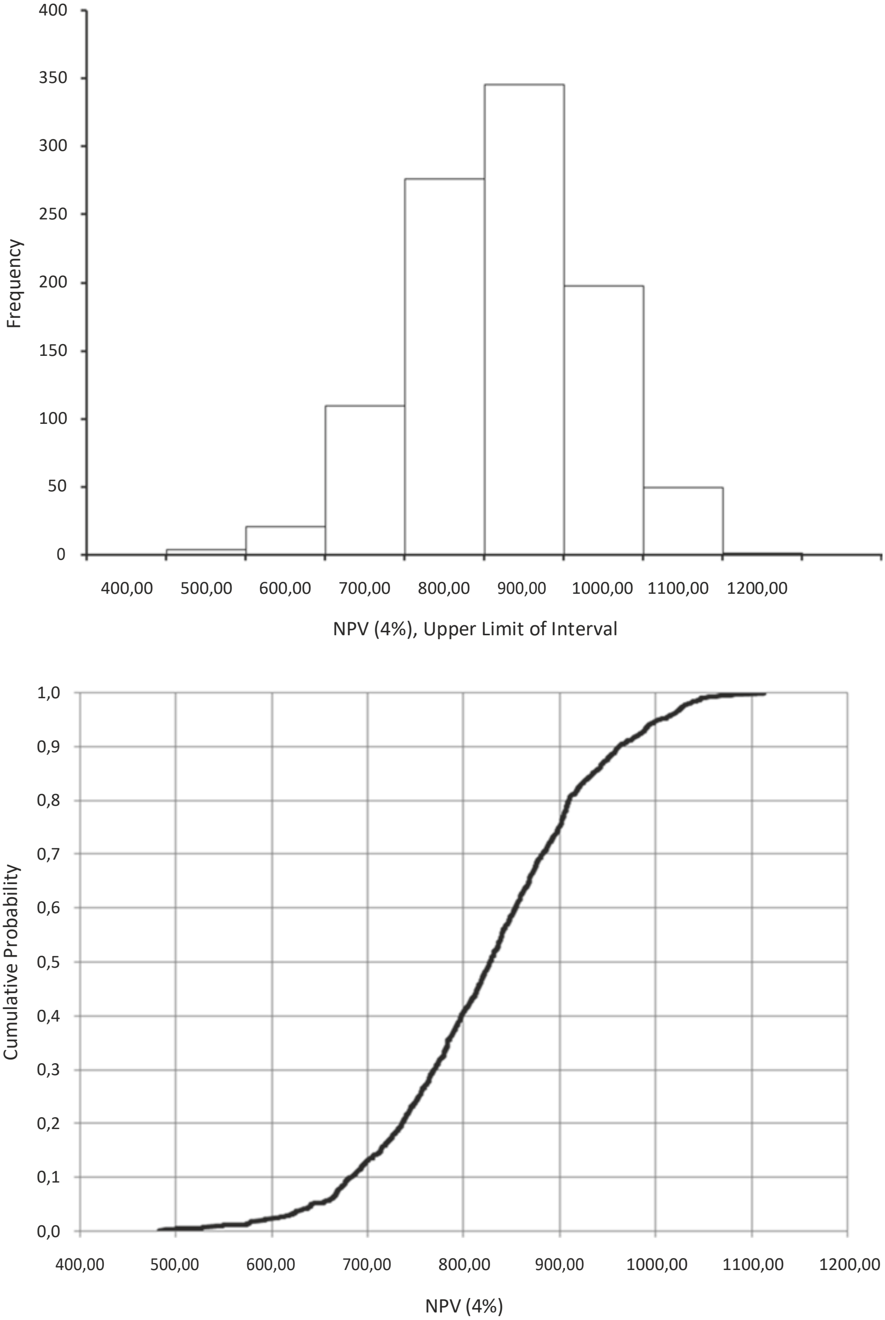


Fig. 7.16 Monte Carlo simulation for “Wind” compared to ENTSO-E energy production (NPV, 4%)

Table 7.10 "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

Table 7.11 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.

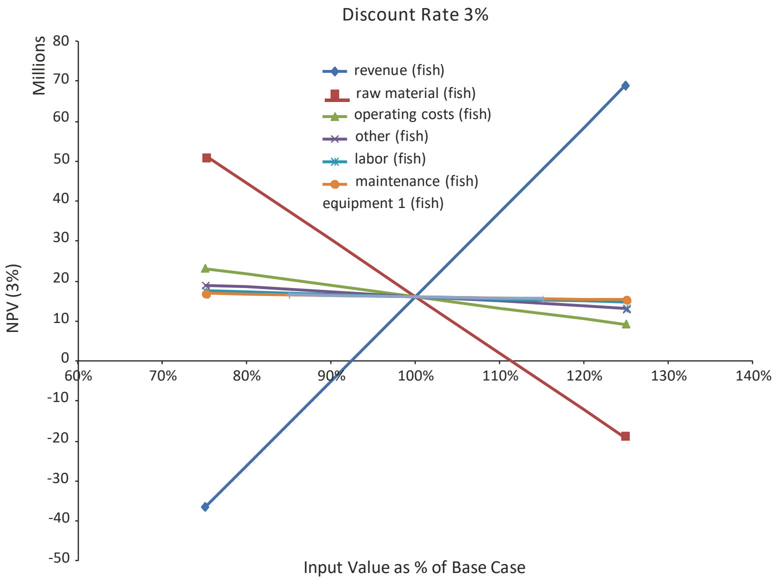


Fig. 7.17 Sensitivity analysis on SCBA (3% discount rate)

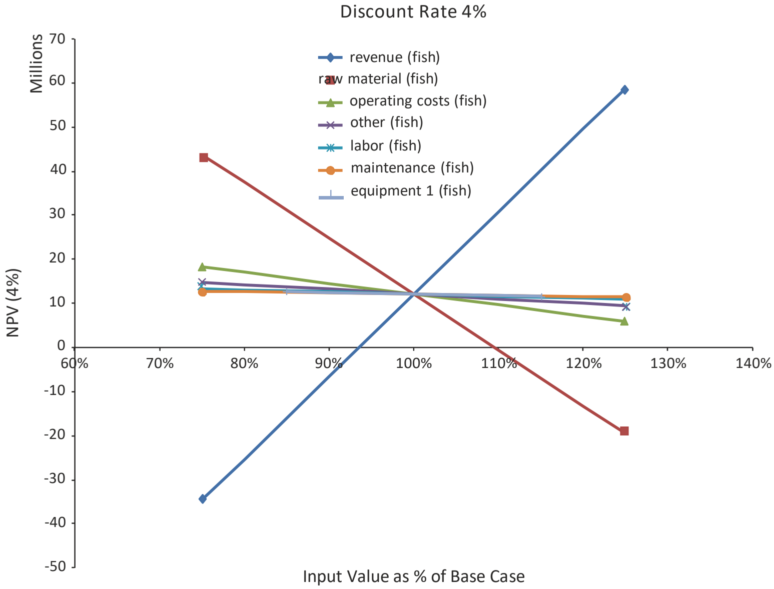


Fig. 7.18 Sensitivity analysis on SCBA (4% discount rate)

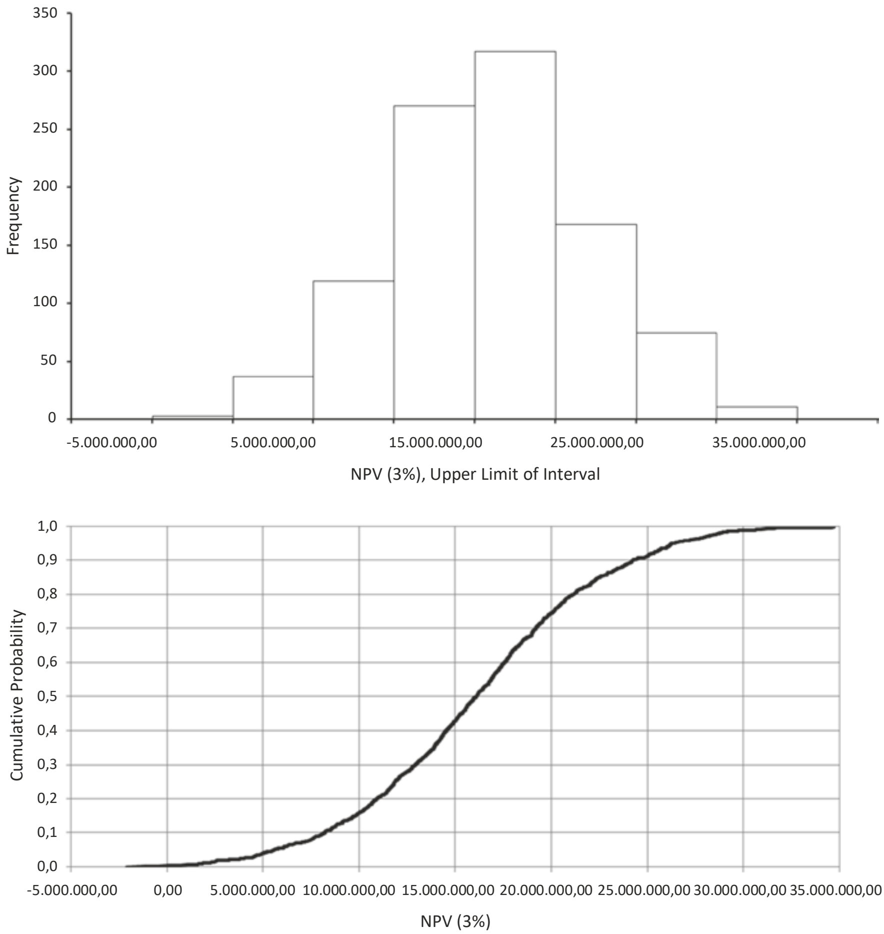


Fig. 7.19 Monte Carlo simulation for "Aquaculture" (NPV, 3%)

Table 7.12 "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

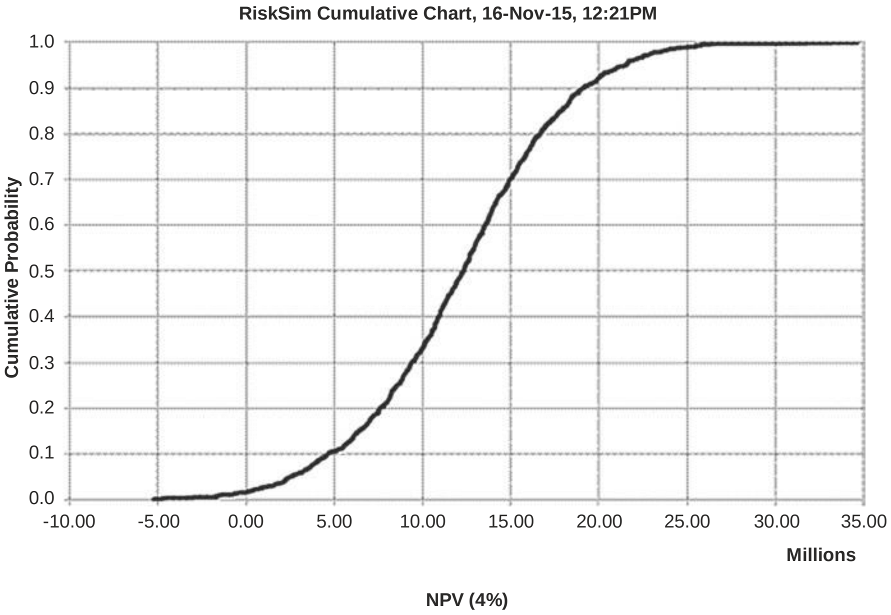


Fig. 7.20 Monte Carlo simulation for "Aquaculture" (NPV, 4%)

Table 7.13 "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

Table 7.14 Variables examined in the sensitivity analysis

	Min	Base*	Max
Seaweed investment cost	0,525	1,00	1475
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
Mussels investment cost	0.7805	1.00	1.2195
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
Energy output	0.885	1.00	1.115
Energy operation costs	0.5919	1.00	1.4081

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

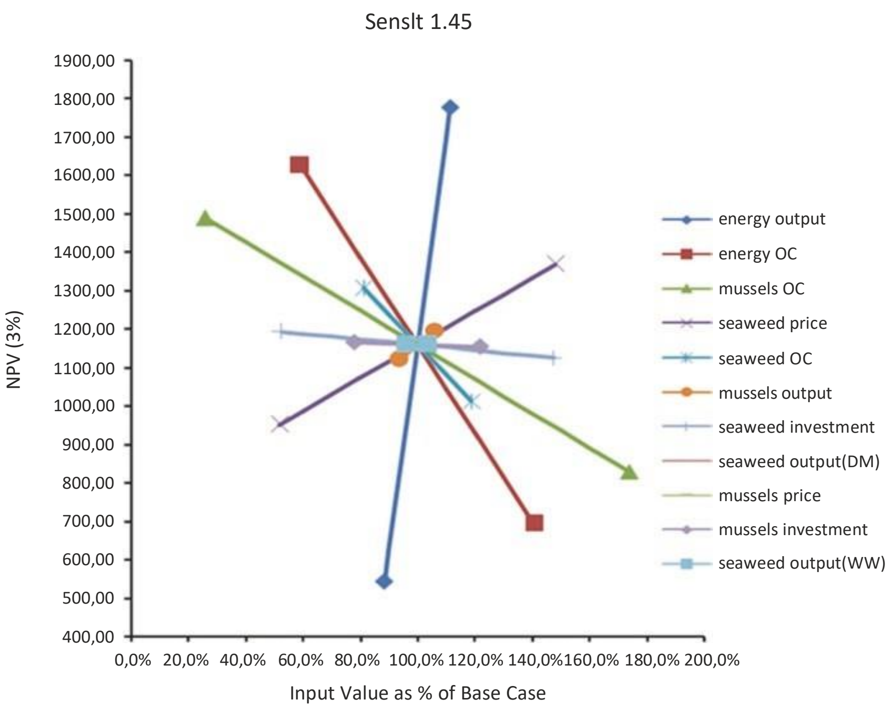


Fig. 7.21 Sensitivity analysis on SCBA (3% discount rate, compared to coal energy production)

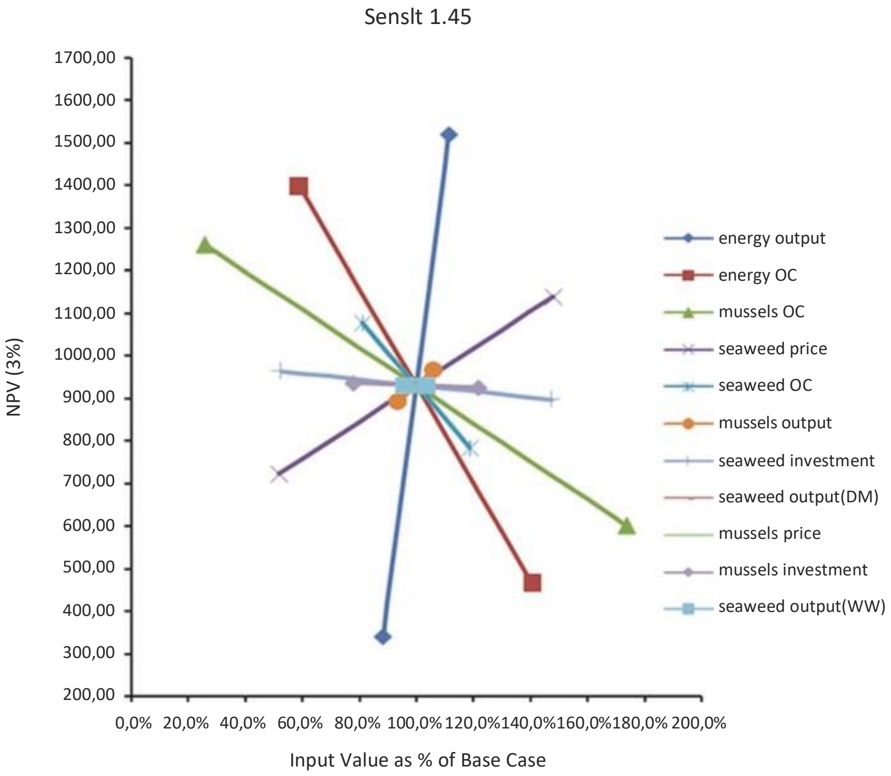


Fig. 7.22 Sensitivity analysis on SCBA (3% discount rate, compared to ENTSO-E energy production)

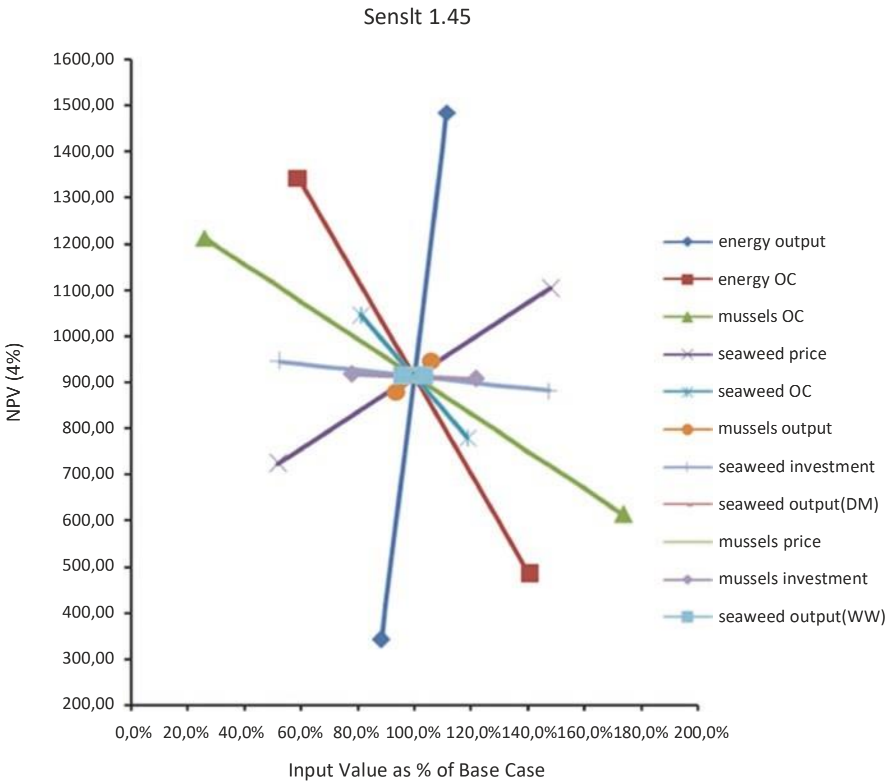


Fig. 7.23 Sensitivity analysis on SCBA (4% discount rate, compared to coal energy production)

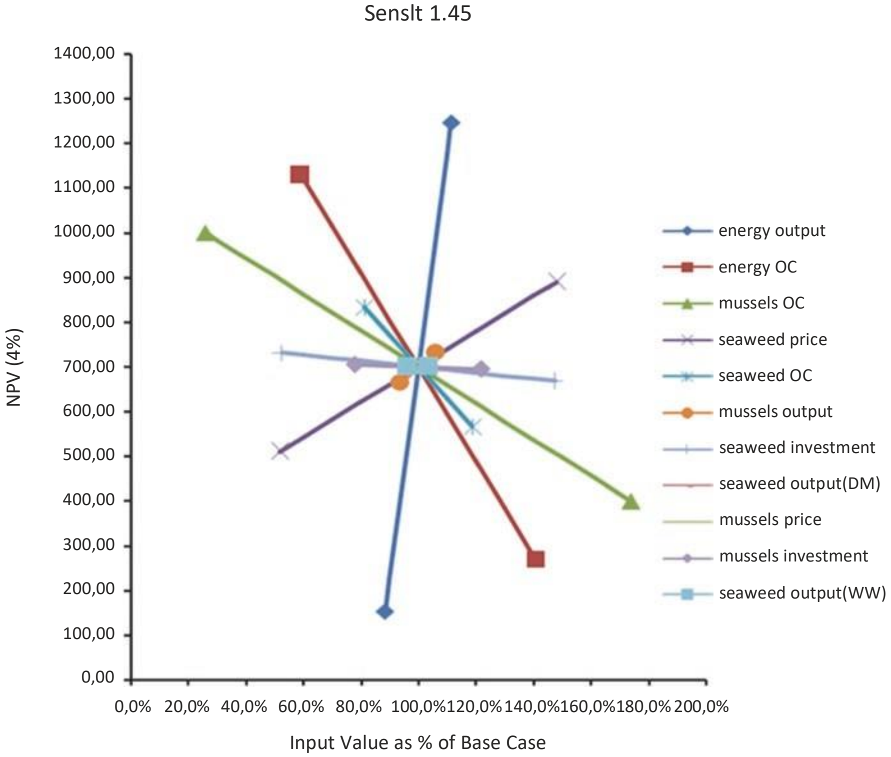


Fig. 7.24 Sensitivity analysis on SCBA (4% discount rate, compared to ENTSO-E energy production)

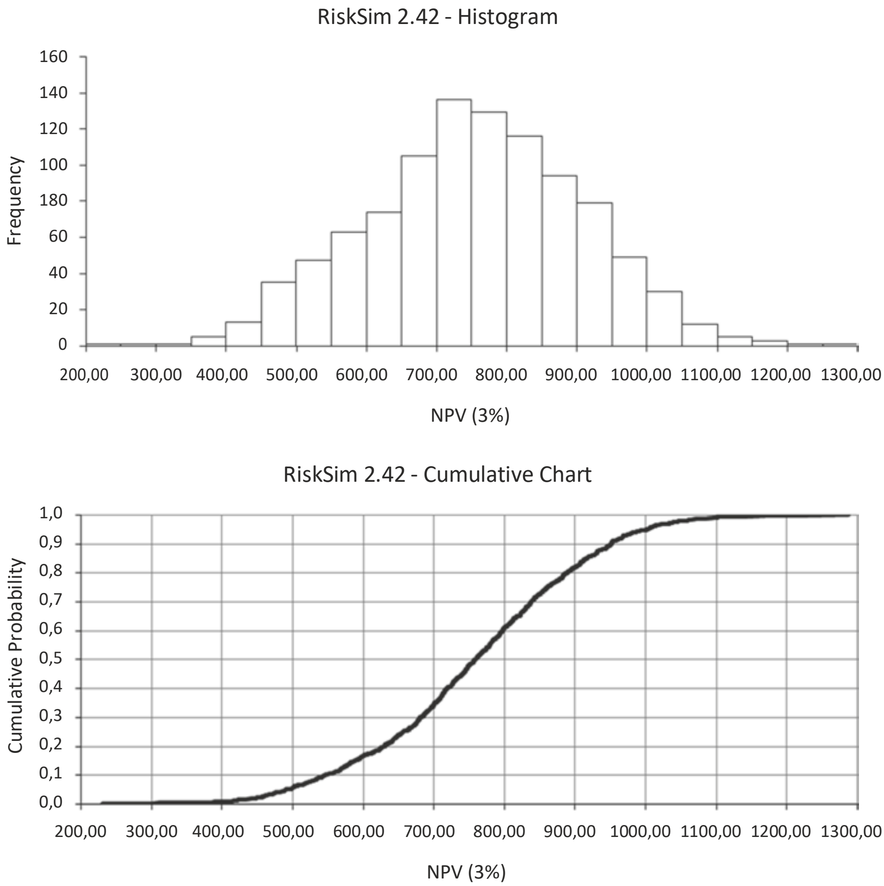


Fig. 7.25 Monte Carlo simulation for "Mussels & Seaweed & Wind" compared to coal energy production (NPV, 3%)

Table 7.15 "Mussels & Seaweed & Wind" compared to coal energy production (NPV, 3%)

Mean	755.90
St. dev.	153.43
Mean St. Error	4.85
Minimum	229.21
First Quartile	656.18
Median	758.34
Third Quartile	860.58
Maximum	1286.91
Skewness	−0.0763

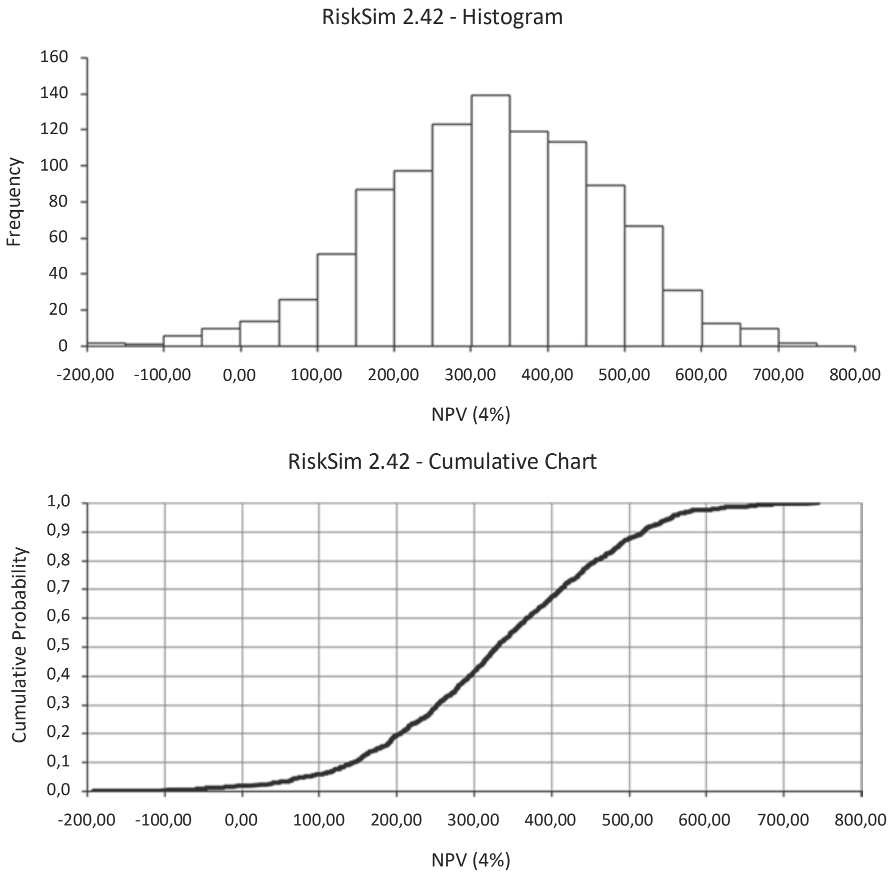


Fig. 7.26 Monte Carlo simulation for "Mussels & Seaweed & Wind" compared to ENTSO-E energy production (NPV, 4%)

Table 7.16 "Mussels & Seaweed & Wind" compared to ENTSO-E energy production (NPV, 4%)

Mean	328.12
St. dev.	147.00
Mean St. Error	4.65
Minimum	−193.24
First Quartile	230.31
Median	328.33
Third Quartile	434.11
Maximum	743.65
Skewness	−0.1878