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Economic feasibility analysis of a wind farm in Caldas da Rainha, Portugal

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Abstract
This paper presents the technical and economical feasibility of a wind farm. The method is applied to a potential wind farm site located in Caldas da Rainha, Portugal. The site is considered on technical and economical parameters for the complete plant and its running costs. For technical consideration wind speed, prevailing wind direction, and temperature measurements are performed by using *RETScreen Climate Database* and *Retscreen Product Database*. The economic and financial evaluation of the wind farm is made by the software *RETScreen® International Clean Energy Project Analysis* and the indicators calculated are WACC, NPV, IRR, SPB, DPB, TLCC, BCR, LCOE, RR and UPAC. The sensitivity analysis backs up the findings through the scenarios developed (*Current*, S_1, S_2 *and* S_3).

Keywords: Economic feasibility; Wind farm; Simulation; Caldas da Rainha.

1. Introduction

This paper presents simulation for economic-financial assessment of onshore wind energy project for the consolidation and comparison of models studied by Oliveira, W.S. *et al.* [1]. The figures presented in the simulations are based on studies of authors and institutions [2] for investment costs (ICC), operations and maintenance (O&M) and other relevant costs to the producing project of electricity by wind power onshore. This action aims at approximate the case study of a hypothetical wind farm with the actual investment opportunity in renewable energy projects.

The case study corresponds to a hypothetical wind farm located in Caldas da Rainha, Portugal, where we tried to use values as reported in the specialized and current literature. Values were attributed to taxes, to represent situation closer to nowadays reality to determine a consistent cash flow with onshore wind energy projects. Methods are applied economic evaluation of projects and costs for energy projects, without considering the uncertainty associated with the randomness of the wind speed. The main parameters adopted are presented in Tables 1 and 2.

For purposes of economic and financial evaluation of wind energy project, and their costs are calculated WACC, NPV, IRR, SPB, DPB, TLCC, BCR, LCOE, RR and UPAC. These indicators of attractiveness and economic and financial risk of the project are calculated using the software Microsoft Excel and still defines the energy model with the software *RETScreen ® International Clean Energy Project Analysis*. At the end of this paper are analyzed and comparisons of the values found in order to verify the type of information that may be provided to the investor or project manager for wind farm onshore.

A study of all considerations, including expected future financial and economic performance of a project, is necessary before undertaking new investment. The extent of details of such a study depends on the size, cost and complexity of the project. A study that looks into these aspects is called a feasibility study, its main purpose is to explore the project soundness. The feasibility study will look into all aspects of direct and indirect relevance to the project.

2. Parameters considered in the case study

2.1 Technical aspects of the system of energy production

For system design production onshore wind power project took into account the evaluation and availability of wind resources in the macro defined location for the installation of central power generation, Caldas da Rainha, Portugal. The assessment of wind resources and availability for this case study were taken from the *RETScreen Climate Database* and *Retscreen Product Database* for the characterization of the wind system, both available at the RETScreen Version 4 Software for evaluation of projects in renewable energy. The parameters adopted for the production system are presented in Table 1.

Table 1. Parameters of the production system

Item	Values	References
Wind turbine		
Manufacturer and model	Siemens, AN BONUS 2 MW	
Power capacity per turbine	2,0 MW_e	
Number of turbines	20	
Power capacity	40.000 kW_e	*RETScreen Product Database*
Hub height	64 m	
Rotor diameter per turbine	76 m	
Swept area per turbine	4.536 m^2	
Availability	96%	NWCC [3]
Total losses	5%	NREL [4]
Capacity factor	28,6%	Blanco [5]
Wind resource assessment		
Localization	Caldas da Rainha, Portugal	
Average wind speed (10m)	5,4 m/s	*RETScreen Climate Database*
Air temperature	16.7 °C	
Atmospheric pressure	101.0 kPa	
Annual energy output	100.188 MWh	*Software RETScreen*

2.2 Economic and financial aspects of the project

The calculation of LRC, it is considered the replacement of major equipment (turbines, control systems, generators) in the 15th year of operation and recorded the following year (16th year) of the project. The LRC value is given by formula 1, where *ICC= Initial Capital Cost*; *n* = occurrence year of cost; i_r = *inflation rate*; *Amort = cumulated depreciation* [4]:

$$LRC = \left(\frac{ICC}{n}\right) \times (1 + i_r)^n - Amort \qquad (1)$$

Table 2. Economic and financial parameters of the case study

Item	Values	References
Project investment costs		
Feasibility study	600.000 €	Blanco [5]
Development & engineering	1.400.000 €	Blanco [5]
Power system	42.000.000 €	EER [6]
Balance of system & miscellaneous	2.800.000 €	Blanco [5]
Total initial cost (ICC)	46.800.000 €	IEA [7]
Annual costs		
Operations & maintenance (O&M)	4 c€/kWh	EER [6]
Land leasing cost (LLC)	*Nihil*	Consider in O&M
Taxes and fees	25%	DGCI[1]
Periodic costs		
Levelized replacement cost (LRC)	1.445.543 €	NREL, [4]
Revenue reduction (16º year)[2]	5.828.793 €	Decree-Law nº 33-A/2005
Sale price of electricity[3]	88.20 €/MWh	Decree-Law nº 33-A/2005
Inflation rate	2,0 % per year	BCP [8]
Discount rate	9,0% per year	Harper *et al.* [9]
Project life	25 years	NREL, [4]
Depreciation method[4]	4% per year	NREL [4],[10]
Incentives and grants (PTC)	*Nihil*	
Debt ratio	31%	Harper *et al.* [9]
Debt interest rate	5,75% per year	SEFI [11]
Debt term	15 years	EWEA, [12]; Harper *et al.* [9]

3. Results of the economic methods for projects and costs evaluation

The economic assessment of hypothetical wind farm installed in Caldas da Rainha, we obtained the following results:

Table 3. Economic and financial indicators of the current scenario

	Indicators	Results
Attractiveness	WACC	5.0681% per year
	NPV	53,360,255 €
	IRR	4.5896% per year
	SPB	5 years
	DPB	9 years
	$RR_{levelezed}$	86,096,753 €
	BCR	1.21
Costs	LCOE	59.3638 €/MWh
	TLCC	87,017,004 €
	NPC	87,594,407 €
	LEGC	72.8080 €/MWh
	UPAC	0.014625 €/kW

Source: own elaboration

[1] For more information, see http://www.portaldasfinancas.gov.pt/pt/home.action.

[2] The Decree-Law nº 33-A/2005 ensures energy sales flat rate up to 15 years of the project and after this period beginning to pay the market value. In this case it was considered tariff-in 55.00€/MWh adjusted for inflation.

[3] According to Decree-Law no. 33-A/2005 the sale price for renewable sources in Portugal is 88.20€ per MWh, adjusted by inflation rate for the period. This figure was updated to the year 2010 (reference year of the project).

[4] The linear scaling of tangible assets amortization of the project results in a rate of 4% a year, because lifetime considered is 25 years. The amount to be amortized in the case study will be € 1,872,000 per year, adjusted for the inflation rate applied to the project.

It is concerned about the structure and capital costs associated with this project, "Weighted Average Cost of Capital or WACC, amounting to 5.0681% per year. The equity[5] of 32,292,000 € with 9% per year and 14,508,000€ in debt capital, financed for 15 years at an interest rate of 5.75% per year, updated by the inflation rate in the period. The wind power project, considering economic, financial and production system characteristics the NPV was estimated about 53,360,255 €, that means a wealth increase for the investor in the same amount. As for the IRR, or profitability of the project, estimated at 4.5896% per year, lower than the WACC, so the project is high risk for the financial aspect.
In this case study, the production of energy is constant over the lifetime of the project, with the capacity factor of 28.5925% per annum. The installed capacity of the hypothetical wind farm is 40 MW (40,000 kWe) with annual output of 100,188 MWh (100,188,000 kWh). Considering the structure of revenues and costs of the project, an estimated 5 years of SPB and DPB 9 years. The returns on capital invested, both simple and discounted, occurring in less than 10 years.
As the project is in the renewable energy sector RR level analysis is necessary, as is the analysis of total revenues (cash inflows), the project received from clients to compensate for all costs associated with the project during its lifetime. For the wind farm in question is the RR in the order of € 86,096,753.
For the BCR analysis, it is the ratio of the sum of the present value of benefits (revenues) divided by the current value of the sum of costs (exploration). For the case study analyzed here, has BCR equal to 1.21, *i.e*, for each unit of electricity sold, has returned 1.21 in monetary units.
In the analysis of project costs[6], we obtained interesting results by the manager/investor of the project. to LCOE of 59.3638 €/MWh; TLCC of € 87,017,004, NPC of € 87,594,407; LEGC of 72.8080 €/MWh and UPAC of 0.014625 €/kW.
It is highlighted in the indicators of cost analysis of electricity produced by wind energy project some typical aspects of these indicators:

1. The LCOE of 59.3638 €/MWh implies that the real cost of electricity for a year of operation of the wind farm;
2. The TLCC of € 87,017,004 reflects the total cost of production date for the investor/project manager. All the above represent a real increase in production costs. For values below imply gains for economies of scale;
3. € 87,594,407 for NPC also represents the total cost of production date for the investor/project manager. Note that the average NPC and TLCC is € 87,305,705, with a standard deviation of 0.33%, so we have the same analysis of the TLCC, even with a different methodology of calculation;
4. In the case of the LEGC 72.8080 €/MWh, this value has been the annual cost of electricity production date. Note that the average LEGC and LCOE is € 66.0859 with a standard deviation of 10.17%, so we have the same analysis of the TLCC, even with a different methodology for calculating cost for each indicator;
5. To analyze the unit cost of electricity, we used the UPAC is that the average unit cost is updated separately where they are updated project costs (investment, operations and maintenance, fuel, etc.) and total output during the life the project. In the case of wind energy project in Caldas da Rainha, the UPAC is 0.014625 €/kW. This means to say what it costs the investor/manager of a unit installed power (1 kW) for wind energy project.

4. Software RETScreen ® analysis of renewable energy projects

The software *RETScreen International Clean Energy Project Analysis* is a tool to support the decision make to invest in renewable energy globally adopted by experts from government, industry, and academia. It aims to evaluate the production and energy savings, costs, emission reductions, financial viability and risk for various types of Renewable Energy Technologies (RET's) and Energy Efficiency. The analysis flow of the *RETScreen* ® obey the order as shown in Figure 1.

[5] As the equity is the biggest part of capital (69%) for this project, it was considered a discount rate equal to the cost of the project equity.
[6] It was not considered any kind of incentive for production (PTC = 0) for the renewable energy project in question in order to ensure the techno-financial feasibility of the project without government support.

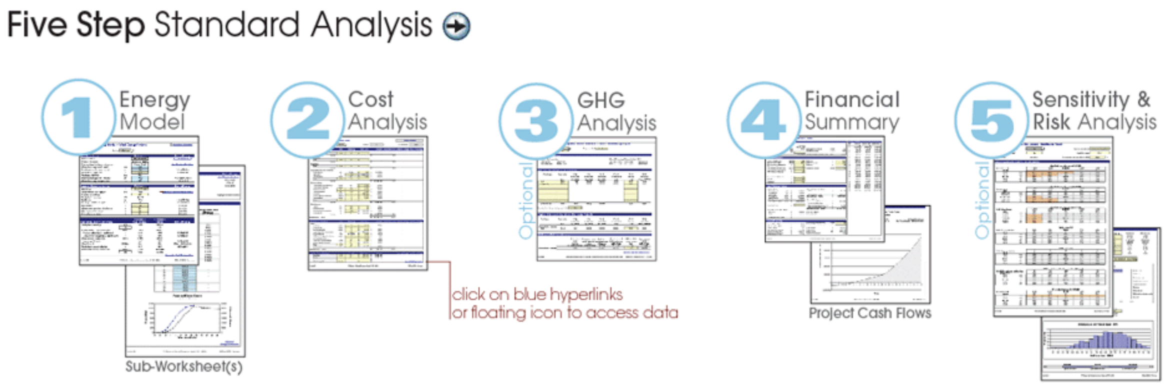

Figure 1. Five Steps of the *RETScreen®* standard analysis [13]

The methodology of the *RETScreen®* presents five steps in an integrated and consistent manner for proper analysis of economic viability of an alternative investment in renewable energy projects. The analysis steps are described briefly below:

1. *Step 1 - Model Energy*: In the initial stage of the analysis parameters are defined according to the specific location of the project, such as type of system, technology for the proposed case (to consider), charges (where applicable), and renewable energy sources. In response to the inputs, determines the *RETScreen* annual energy production or energy savings.
2. *Step 2 - Cost Analysis*: With the definition of the energy model in the first step of the project, prepare the composition of annual and periodic costs for the proposed system as well as credits earned with renewable energy project.
3. *Step 3 - Analysis of emissions of greenhouse gases (optional):* Here are some annual GHG reductions, given the renewable technology used.
4. *Step 4 - Financial Summary:* In this step, specifying financial parameters related to energy cost, production credits, GHG reduction credits, tax incentives, inflation rate, discount rate, level of indebtedness, and taxes. From the financial parameters are determined the main financial indicators (eg NPV, IRR, SPB, among others) to assess the feasibility of the project. A graph of cumulative cash flow is also included in this financial summary.
5. *Step 5 - Sensitivity & risk analysis (optional):* In this final step, we analyze uncertainty of financial estimates several parameters that can affect the financial viability of the project. Can be performed sensitivity analysis or risk or both.

For study purposes, were considered the same parameters defined in Tables 1 and 2 in Software *RETScreen International Clean Energy Project Analysis* in order to make an analysis of economic and financial viability of wind energy project located in Caldas da Rainha.

5. Results and comparisons

By comparing the results calculated for this case study in this work through the formulas of the methods of energy projects evaluation and its costs, some differences are noticed what drives us to explains them and check each indicator studied. In Table 3, it has the summary of the indicators defined in the current scenario, with the respective calculated results and by Software *RETScreen International Clean Energy Project Analysis*.

For the NPV (Net Present Value) found the difference of -9.27% compared to the result calculated by *RETScreen®*. It is because the calculation performed with MS Excel is done with $NPV = AAR\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] - ICC$ and the *RETScreen®* uses the method of discounted cash flow. It is also worth remembering that the updating of the revenues in *RETScreen®* happens since the second year of the project while the NREL (1995) suggests that this update of the values is made from the first year of operation of the power project.

As for the IRR (Internal Rate of Return), we get the difference of -28.79% compared to the result calculated by *RETScreen®*. It is because the calculation performed with MS Excel is done with

$NPV = AAR\left[\frac{(1+IRR)^N - 1}{IRR(1+IRR)^N}\right] - ICC = 0$ and *RETScreen*® uses the method of discounted cash flow (Table 4).

Table 4. Comparison of economic and financial indicators

	MS Excel		*RETScreen*®	
	Indicator	Results	Indicator	Results
Attractiveness	$WACC_{proj}$	5.0681% per year	$WACC_{proj}$	5.0681% per year
	$VAL_{(9\%a.a)}$	53,360,255 €	$VAL_{(9\%a.a)}$	48,411,256 €
	$TIR_{(9\%a.a)}$	4.5896% per year	$TIR_{(9\%a.a)}$	6.4452% per year
	SPB	5 years	SPB	7 year
	DPB	9 years	DPB	11.5 years
	$RR_{levelezed}$	86,096,753 €	$RR_{levelezed}$	Not calculated
	BCR	1.21	BCR	1.07
Costs	LCOE	59.3638 €/MWh	LCOE	Not calculated
	$TLCC_{(9\%a.a)}$	87,017,004 €	$TLCC_{(9\%a.a)}$	Not calculated
	$NPC_{(9\%a.a)}$	87,594,407 €	$NPC_{(9\%a.a)}$	Not calculated
	$LEGC_{(9\%a.a)}$	72.8080 €/MWh	COE	95.3448 €/MWh
	$UPAC_{(9\%a.a)}$	0.014625 €/Kw	$UPAC_{(9\%a.a)}$	Not calculated

Source: own elaboration

In the analysis of return on investment, SPB and DPB, these differences become more accentuated. For the simple payback time (SPB), the difference was 40.00% compared to the result calculated by *RETScreen*®. SPB In this implies a further two years to return the invested capital (from 5 to 7 years). This is because the calculation performed with MS Excel is done with $SPB = \frac{ICC}{AAR}$ and *RETScreen*®. uses the method of discounted cash flow. For the DPB is noted difference of 27.78% compared to the result calculated by *RETScreen*®. In BPD this implies two and a half years to return the invested capital (from 9 to 11.5 years). It is because the calculation performed with MS Excel is done with $DPB = \frac{ICC}{[AAR - (O\&M + LLC)]}$ and *RETScreen*® uses the method of discounted cash flow, excluding the financial burden of debt.

In the case of cost-benefit analysis or BCR, is the difference of -11.57% compared to the result calculated by *RETScreen*®. In this implies BCR least € 0.14 in benefits (income) earned by the project. It is because the calculation performed with MS Excel is done with $B/C = \sum \frac{\sum \frac{Ci_t}{(1+i)^t}}{\sum \frac{Co_t}{(1+i)^t}}$ and *RETScreen*® calculates as the ratio of the current value of the annual revenue (income and / or savings) minus the annual costs for the equity of the project.

For the analysis of the costs of energy project, you can make an approximation of Levelized Cost Electricity Generation (LEGC) and the Cost of Energy Production (CEP) in *RETScreen*®. The LEGC of 72.8080 €/MWh and CPE of 95.3448 €/MWh have an average value of 84.0741 €/MWh with a standard deviation of 13:40%. The LEGC shows a difference of 30.95% compared to the result calculated by *RETScreen*®. This implies an increase of 22.54 €/MWh in cost of energy produced. It is because the calculation performed with MS Excel is done with $LEGC = \frac{\sum\left[(I_t + M_t + F_f)(1+r)^{-t}\right]}{\sum\left[AAR\,(1+r)^{-t}\right]}$ and *RETScreen*®uses the method of discounted cash flow.

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Finally, when considering the technical economic and financial aspects of onshore wind energy project in Caldas da Rainha, Portugal, were calculated and used the following values in the analysis (Table 5).

Table 5. Values calculated in the current scenario of the project

Item	Values
ICC	46,800,000 €
$AAR_{average}$	10,196,940 €
Operating $cost_{average}$	9,480,561 €
$O\&M_{average}$	5,237,172 €
$Debt_{average}$	1,694,154 €
$Tax_{average}$	2,549,235 €
LRC	1,445,543 €
Dv	12,914,392 €

Source: own elaboration

Taking into account the differences in values found in the economic and financial analysis of the wind power project and its costs, it is interesting to note the degree of interdependence of economic variables and techniques in this same project. These relationships are tested and verified from the sensitivity analysis of the project. In the next section is carried out this analysis of the project.

6. Sensitivity analysis of the project

Sensitivity analysis is the procedure that examines the impact on economic and financial swings when certain parameters relevant to the investment. Therefore, this analysis allows detecting which of the estimates of the project indicators are more sensitive and relevant. It is important to remember that sensitivity analysis treats each variable separately while in practice all the variables involved in the project tend to be related, besides the fact that some variables are easier to predict than others [14].

For better understanding of economic and financial behavior of the project were built three scenarios in relation to the current scenario, already mentioned above. We developed three scenarios for sensitivity analysis of a hypothetical wind farm located in Caldas da Rainha. For the scenario S_1 the following parameters were considered as amended in relation to the current scenario (reference), as summarized in Table 6.

Table 6. Changes in the parameters for scenario S_1

Parameters	Action	(%)
1. Sale price contracted	Decrease	10.00
2. Market price	Decrease	10.00
3. Discount rate	Increase	25.00
4. Inflation rate	Increase	25.00
5. Interest rate	Increase	25.00
6. O&M cost	Increase	30.00
7. ICC cost	Decrease	25.00
8. Taxes	Decrease	5.00

Source: own elaboration

The other parameters were assumed constant as defined in Table I. After these changes, we have the results presented in Table 7.

Table 7. Economic and financial indicators of scenario S_1

Indicators		Results	
Attractiveness	$WACC_{S1}$	6.4407%	Per year
	$VAL_{(S1)}$	45,576,320 €	
	$TIR_{(S1)}$	3.5982%	Per year
	$SPB_{(S1)}$	4	years
	$DPB_{(S1)}$	14	years
	$RR_{levelezed(S1)}$	82,089,476 €	
	$BCR_{(S1)}$	1.00	
Costs	$LCOE_{(S1)}$	56.6020	€/MWh
	$TLCC_{(S1)}$	82,813,856 €	
	$NPC_{(S1)}$	82,985,980 €	
	$LEGC_{(S1)}$	120.9393	€/MWh
	$UPAC_{(S1)}$	0.018639	€/kW

Source: own elaboration

For the scenario S_2 the following parameters were considered as amended in relation to the current scenario (reference), as summarized in Table 8.

Table 8. Changes in the parameters for scenario S_2

Parameters	Action	(%)
1. Sale price contracted	Increase	10.00
2. Market price	Increase	10.00
3. Discount rate	Decrease	25.00
4. Inflation rate	Decrease	25.00
5. Interest rate	Decrease	25.00
6. O&M cost	Decrease	30.00
7. ICC cost	Increase	25.00
8. Taxes	Increase	5.00

Source: own elaboration

The other parameters were assumed constant as defined in Table I. After these changes, we have the results presented in Table 9.

Table 9. Economic and financial indicators of scenario S_2

	Indicators	Results	
Attractiveness	$WACC_{(S2)}$	3.7377%	per year
	$VAL_{(S2)}$	67,402,912 €	
	$TIR_{(S2)}$	5.5389%	per year
	$SPB_{(S2)}$	6	years
	$DPB_{(S2)}$	8	years
	$RR_{levelezed(S2)}$	89,875,638 €	
	$BCR_{(S2)}$	1.47	
Costs	$LCOE_{(C2)}$	54.7153	€/MWh
	$TLCC_{(C2)}$	91,017,196 €	
	$NPC_{(S2)}$	92,069,832 €	
	$LEGC_{(S2)}$	43.5621	€/MWh
	$UPAC_{(S2)}$	0.010967	€/kW

Source: own elaboration

For the scenario S_3 following parameters were considered as amended in relation to the current scenario (reference), as summarized in Table 10.

Table 10. Changes in the parameters for scenario S_3

Parameters	Action	(%)
1. Sale price contracted	Decrease	30.00
2. Market price	Decrease	30.00
3. Discount rate	Decrease	30.00
4. Inflation rate	Decrease	30.00
5. Interest rate	Decrease	30.00
6. O&M cost	Decrease	30.00
7. ICC cost	Decrease	30.00
8. Taxes	Decrease	5.00

Source: own elaboration

The other parameters were assumed constant as defined in Table I. After these changes, we have the results presented in Table 11.

Table 11. Economic and financial indicators of scenario S_3

	Indicators	Results	
Attractiveness	$WACC_{(S3)}$	3.6068%	per year
	$VAL_{(S3)}$	49,771,088 €	
	$TIR_{(S3)}$	4.9328%	per year
	$SPB_{(S3)}$	5	years
	$DPB_{(S3)}$	10	years
	$RR_{levelezed(S3)}$	69,567,877 €	
	$BCR_{(S3)}$	1.24	
Costs	$LCOE_{(S3)}$	29.5827	€/MWh
	$TLCC_{(S3)}$	70,619,559 €	
	$NPC_{SC3)}$	70,819,831 €	
	$LEGC_{(S3)}$	48.2488	€/MWh
	$UPAC_{(S3)}$	0.006968	€/kW

Source: own elaboration

7. Summary and conclusions

In the study it was found that the evaluation and management of onshore wind energy projects and their costs are influenced by various factors such as characteristics of the production system, economic and financial parameters of the project, as well as the climatic characteristics of the site of the wind farm.

To understand the behavior of the variables involved in economical and financial assessing of a wind farm as a manner of validating the indicators of attractiveness and risk of energy projects and analysis of production costs sensitivity analysis was done by considering the following aspects:

1. The production is constant throughout the analysis of the wind farm, *i.e.* the capacity factor is constant and equal to 28.5925% for the life of the project (25 years);
2. All values are corrected the annual inflation rate defined for each scenario of sensitivity analysis, included the current scenario, made to avoid cost inflation in the 25-year analysis of the project;
3. The variables considered in the sensitivity analysis were contracted sale price, market price, the project discount rate, inflation rate, interest rate, debt, tax rate, O&M costs and investment costs;
4. The project does not receive any tax incentives for the production of electricity from renewable energy carrier.
5. The other variables techno-economic and climate are provided *ceteris paribus*[7], it is not changing the objective to analyze all the variables involved in onshore wind energy project.

[7] Expression also spelled in Latin ceteris paribus, which can be translated as *"all else is constant" or "kept unchanged all the other things."*

In order to present the impacts on indicators of attractiveness and cost of wind energy project, it is the same sum with the respective variables in absolute figures and percentages. It also shows the values of investments, revenues, operating costs, costs of major repairs and divestitures.
Table 12 shows the values of attractiveness indicators used in economic and financial analysis of the wind energy project.

Table 12. Comparison in absolute values of the scenarios

	Indicators	Results				
		Unit	Current	S_1	S_2	S_3
Attractiveness	WACC	%/year	5.0681%	6.4407%	3.7377%	3.6068%
	VAL	€	53,360,255	45,576,320	67,402,912	49,771,088
	TIR	%/year	4.5896%	3.5982%	5.5389%	4.9328%
	SPB	year	5	4	6	5
	DPB	year	9	14	8	10
	$RR_{levelezed}$	€	86,096,753	82,089,476	89,875,638	69,567,877
	BCR		1.21	1.00	1.47	1.24
Costs	LCOE	€/MWh	59.3638	56.6020	54.7153	29.5827
	TLCC	€	87,017,004	82,813,856	91,017,196	70,619,559
	NPC	€	87,594,407	82,985,980	92,069,832	70,819,831
	LEGC	€/MWh	72.8080	120.9393	43.5621	48.2488
	UPAC	€/kW	0.014625	0.018639	0.010967	0.006968

Source: own elaboration

With the sensitivity analysis, you can clearly see that in scenario (S_1) reaches BCR analysis unit and discounted return on investment is more than 14 years, taking into account that the deadline for payment of debt (financing) is 15 years. When comparing with other scenarios, the largest WACC also occurs in the scenario (S_1). The cost of capital (WACC), considering the capital structure, has a strong influence on the internal rate of return of the project, which explains IRR of 3.5982% per year scenario (S_1). For analysis of the RR level energy project, one realizes that there is reduced need for revenue in relation to the current scenario of the project, which alone is conducive to energy project.
In scenario (S_2), even with IRR greater than the current scenario of the project and cost of capital (WACC) smaller returns to capital (SPB and DPB) are 6 and 8 years respectively. It stands out above the BCR analysis the current scenario, which is justified by the fact that NPV of € 67,402,912. To analyze RR level, has increased the need for revenue in relation to the current scenario of the project, which alone is unfavorable to the power project.
In scenario (S_3), even with slightly higher than the IRR of the project the current scenario and cost of capital (WACC) smaller returns to capital (SPB and DPB) are on 5 and 10 years respectively. It stands out above the BCR analysis the current scenario, which is justified by the fact that NPV of € 49,771,088. To analyze RR level, there is the slightest need of revenue compared to other scenarios, including the present scenario of the project, which alone is conducive to energy project.
As indicators of the project cost analysis of energy, comes to the following observations:

1. The LCOE has direct relation to the cost of capital (WACC) of the project, because the energy projects are capital-intensive, so the capital structure and costs affect the final cost of energy produced;
2. The TLCC is influenced by the level of the project income, as compared with the RR level analysis, there is clearly this relationship;
3. The NPC is also influenced by the level of the project income, as compared with the RR level analysis, there is clearly this relationship. It is worth noting that in this case study the production is constant during the lifetime of the project;
4. The LEGC is influenced by the level of the project income, as compared with the $AAR_{average}$ (average annual revenue), there is clearly this relationship. Perhaps producing variable year to year, would be able to mitigate this major influence increments in production;

5. The UPAC has an inverse level of investment of the project (ICC), because this behavior is repeated in scenarios S_1 and S_2. The project's cost of capital (WACC) also influences this indicator of cost because the financial burden of debts are recorded as operating costs of the project or O&M.

These considerations about the attractiveness and indicators for assessing the cost of renewable energy projects, an example of onshore wind energy projects, through simulations of the total costs of a hypothetical wind farm of 40 MW of installed electrical power, as well as the sensitivity analysis explain the importance of this is work in the area of renewable energy.

The main values calculated for this simulation and sensitivity analysis are summarized in Tables 12, 13, 14 and 15, in absolute and percentage values of case study scenarios analyzed.

Table 13. Comparison of percentage changes of the scenarios

	Indicators	Percentage variation of results			
		Unit	S_1	S_2	S_3
Attractiveness	WACC	%/year	27.08%	-26.25%	-28.83%
	VAL	€	-14.59%	26.32%	-6.73%
	TIR	%/year	-21.60%	20.68%	7.48%
	SPB	year	-21.60%	20.68%	0.00%
	DPB	year	51.29%	-13.14%	6.39%
	$RR_{levelezed}$	€	-4.65%	4.39%	-19.20%
	BCR		-17.19%	21.48%	2.46%
Costs	LCOE	€/MWh	-4.65%	-7.83%	-50.17%
	TLCC	€	-4.83%	4.60%	-18.84%
	NPC	€	-5.26%	5.11%	-19.15%
	LEGC	€/MWh	66.11%	-40.17%	-33.73%
	UPAC	€/kW	27.45%	-25.01%	-52.35%

Source: own elaboration

Table 13 presents summary of the scenarios studied with their variations in percentages relative to the current scenario of the wind power project has already featured in this chapter. When considering IRR and RR level, it is inserted in the project area largely governed by energy policies by the public sector, the S_1 is the worst because there are a greater fluctuation in the negative internal rate of return (for optical private) and BCR, while the best scenario is the S_2, to present the biggest swings positive IRR and BCR.

In the analysis of the costs of onshore wind energy project by considering LCOE, TLCC, LEGC and UPAC, the S_3 is the best scenario, because the additional cost savings in energy produced in this scenario occurred, while S_1 is the worst because it has rose by 66.11% and 27.45% in the cost of energy produced, LEGC and UPAC, respectively.

In the analysis of attractiveness and cost of the project for 40 MW wind electric capacity installed, it should be borne in mind that for each scenario studied, with an expected investment levels, revenues, operating costs, costs of major repairs (substitutions) and residual values (disinvestment) different, with annual production constant throughout the analysis performed. As can be seen in Tables 14 and 15 below, there is absolute and percentage variations of these significant items of great importance in engineering economic analysis carried out in any investment project.

As we see the ICC has direct reflection of the costs of financing (Debt), cost of major replacements (LRC) and residual values (disinvestment). As these projects there is always a portion of debt capital and financial cost associated with it, give the direct link. Since the LRC is also on the level of initial investment, because it is considered the ICC, the period of occurrence of the LRC and the amortization of the asset and the period to calculate the LRC. The residual values of the project (divestments) have direct, since they result from the difference of the ICC, the depreciation of the project and LRC.

For other operating costs such as taxes O&M and *Taxes* are based on the level of revenue (AAR) of the project. For this case study, the annual production is considered constant, which varies is the value of the contracted sales price and the market price after the 15th year of operation of the wind farm. Both prices are updated yearly by the inflation rate considered in the analysis.

Table 14. Comparison in absolute values of calculated parameters in the scenarios

Itens	Mean values in € of the calculated parameters			
	Current	S_1	S_2	S_3
ICC	46,800,000	35,100,000	58,500,000	32,760,000
$AAR_{average}$	10,196,940	9,754,852	10,561,606	6,641,317
Operating $cost_{average}$	9,480,561	11,058,052	8,050,268	5,965,568
$O\&M_{average}$	5,237,172	7,296,126	3,423,990	3,377,906
$Debt_{average}$	1,694,154	1,445,149	1,853,856	1,010,349
$Tax_{average}$	2,549,235	2,316,777	2,772,422	1,577,313
LRC	1,445,543	1,172,388	1,670,302	920,733
Dv	12,914,392	12,884,050	11,232,385	5,766,604

Source: own elaboration

Table 15. Comparison in percentage values of calculated parameters in the scenarios

Item	Percentage variation of results		
	S_1	S_2	S_3
ICC	-25.00%	25.00%	-30.00%
$AAR_{average}$	-4.34%	3.58%	-34.87%
Operating $cost_{average}$	16.64%	-15.09%	-37.08%
$O\&M_{average}$	39.31%	-34.62%	-35.50%
$Debt_{average}$	-14.70%	9.43%	-40.36%
$Tax_{average}$	-9.12%	8.76%	-38.13%
LRC	-18.90%	15.55%	-36.31%
Dv	-0.23%	-13.02%	-55.35%

Source: own elaboration

If the investor or the project manager could choose between the scenarios based on the information contained in Tables 14 and 15 would reach the conclusion that the best scenario is the S_3, as in this scenario with investments, revenues and operating costs reach smaller NPV of € 49,771,000; BCR of 1.24, DPB of 10 years and LCOE of 29.5827 €/MWh for electricity generated (see Table 12).
By comparing the variations in percentage terms in the scenarios becomes more evident that the scenario S_3 shows reductions ranging between 30.00% and 55.35% over the current scenario of the project.
The case study presented in this paper corresponds to a hypothetical wind farm located in Caldas da Rainha, Portugal. Referenced figures are used in Tables 1 and 2. Tax rates for other rates used in this case study are consistent with the reality of Portugal. We also adopted methods of economic evaluation of projects and costs for energy projects, without considering the uncertainty associated with the randomness of the wind speed (constant annual production).
In economic and financial analysis of the project hypothetical onshore wind energy and its costs are calculated WACC, NPV, IRR, SPB, DPB, TLCC, BCR, LCOE, $RR_{levelezed}$ and UPAC. At the end of this paper after performing the sensitivity analysis and comparisons of the scenarios defined, we highlight the following aspects:

1. The analysis techniques attractiveness and economic and financial risk used in this paper consider the characteristics of techno-economic and financial projects of renewable energy, specifically wind power projects onshore;
2. The real attractiveness and risk analysis of economic and financial power projects and their costs must take into account the indicators, so that, together reveal convergent information for decision-making more accurate and consistent;

3. All indicators adopted should be used in economic engineering to meet specific information needs of decision-making in situations of opportunity for investment in energy projects.

Appendix

Table A1. Formulas for calculating economic and financial attractiveness of projects

Evaluation of economic and financial attractiveness of energy projects	
$r_{WACC} = (1 - W_D) r_E + W_D r_D (1 - t)$	$W_D = \frac{Equity}{(Equity + Debt)}$
$SPB = \frac{ICC}{AAR}$	
$DPB = \frac{ICC}{[AAR - (O \& M + LLC)]}$	
$K_0 = \frac{K_t}{(1+i)^t} = K_t \times (1+i)^{-t}$	
$NPV = AAR\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] - ICC$	
$NPV = AAR\left[\frac{(1+IRR)^N - 1}{IRR(1+IRR)^N}\right] - ICC = 0$ and	$\left[\frac{(1+IRR)^N - 1}{IRR(1+IRR)^N}\right] = \frac{ICC}{AAR} = SPB$
$RR = TLCC = \sum\left(\frac{Co_t}{(1+i)^t}\right)$	
$LevelizedRR = TLCC \times UCRF = \sum \frac{Co_t}{(1+i)^t} \times \frac{i(1+i)^n}{(1+i)^n - 1}$	$UCRF = \left[\frac{i(1+i)^t}{(1+i)^t - 1}\right]$
$B/C = \sum \frac{\sum \frac{Ci_t}{(1+i)^t}}{\sum \frac{Co_t}{(1+i)^t}}$	

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References

[1] Oliveira, W.S., A.J. Fernandes, and J.J.B. Gouveia, Economic metrics for wind energy projects. International Journal of Energy and Environment, 2011. 3(6): p. 1013-1038.
[2] Oliveira, W.S., Evaluation and Management of Onshore Wind Energy Projects, in Department of Economics, Management and Industrial Engineering2010b, University of Aveiro: Aveiro. p. 176.
[3] NWCC. Wind Energy Costs NWCC Wind Energy Series. 1997 [cited 2009 February 2]; No.11.:[National Wind Coordinating Collaborative]. Available from: http://www.nationalwind.org.

[4] NREL, A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies., U.S. Department of Energy, Editor 1995, National Renewable Energy Laboratory.: Springfield. p. 120.

[5] Blanco, M.I., The economics of wind energy. Renewable & Sustainable Energy Reviews, 2009. 13(6-7): p. 1372-1382.

[6] EER. Wind power is competitive. 2007 [cited 2010 January 10]; Emerging Energy Research]. Available from: http://www.vestas.com/files//Filer/EN/Press_releases/VWS/2007/070110PMUK01EER.pdf.

[7] IEA. IEA Annual Report 2007 - IEA WIND ENERGY Annual Report 2007. 2007 [cited 2010 May 12]; International Energy Agency]. Available from: http://www.ieawind.org/AnnualReports_PDF/2007/2007%20IEA%20Wind%20AR.pdf.

[8] BCP. Harmonised index of consumer prices (y.r. %). 2010 [cited 2010 October 22]; Central Bank of Portugal]. Available from: http://www.bportugal.pt/en-US/grafIndEconomicos/Pages/GrafIHPC.aspx.

[9] Harper, J., M. Karcher, and M. Bolinger, Wind Project Financing Structures: A Review & Comparative Analysis., U.S. Department of Energy, Editor 2007, Lawrence Berkeley National Laboratory.

[10] K. George and T. Schweizer., Primer: The DOE Wind Energy Program’s Approach to Calculating Cost of Energy., U.S. Department of Energy, Editor 2008, NREL.: Rockville/Maryland.

[11] SEFI. Global Trends in Sustainable Energy Investment 2010 - Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency. 2010 [cited 2010 July 4]; Sustainable Energy Finance Initiative and Bloomberg New Energy Finance]. Available from: http://sefi.unep.org/english/globaltrends2010.html.

[12] EWEA. The Economics of Wind Energy. 2009 [cited 2009 November 3]; The European Wind Energy Association]. Available from: http://www.ewea.org.

[13] RETScreen® International Clean Energy Decision Support Centre. Clean Energy Project Analysis: RETScreen Engineering & Cases Texbook. 2008 [cited 2008 January 10]; Available from: www.retscreen.net.

[14] Lapponi, J.C., Projetos de Investimento: construção e avaliação do fluxo de caixa.2000, São Paulo: Lapponi Treinamento e Editora.

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