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Abstract. This paper provides a decision support tool (DST) to analyze and evaluate the project value of offshore wind energy projects within the framework of project finance. The DST is based on a discounted cash-flow model in combination with a Monte Carlo simulation (MCS) to measure project risks and manage these risks. To consider the special requirements of debt capital providers in this context, key figures like the debt service cover ratio (DSCR) are calculated. The DST is realized in Excel/VBA with the Excel Add-In Oracle Crystal Ball. An offshore wind park example in the German North Sea is simulated to validate the underlying simulation model and the DST.

Keywords: Decision support tool (DST), Monte Carlo simulation, offshore wind energy, risk management

1   Introduction

Offshore wind energy has been developed rapidly in the last twenty years. The technical aspects have been in the foreground for most of the time so that a continuous enlargement of wind turbines could be observed. In contrast to this development there has been no comparable expansion of the amount of constructed offshore wind energy plants. This is because the costs for such investments go up to two billion euros per wind park with a typical nominal power output of 400 MW [1]. Another reason is the large number of significant risk factors. Some are based on the low technical experience with these kind of plants. Others are inherent in this type of projects as the plants are difficult to access due to the great distance to the coastline. Thus also small failures can lead to long downtimes.

To further international efforts of climate protection the European Commission set their own goals regarding the reduction of greenhouse gas emissions which are widely known as the 20-20-20 targets. Furthermore, the current Renewables Directive defined that 20 % of the total EU energy consumption shall come from renewable energy sources [2]. To meet these goals the member states have set up National Renewable Energy Action Plans. In this context, different incentive systems and feed-in tariffs for supporting the extension of the installed offshore wind capacity have been

established. Currently, it can be observed that more and more offshore wind projects are being realized [3].

A majority of the few realized projects was carried out in the framework of corporate finance by large energy supplying companies [1]. At present, most of the projects are conducted in the context of project finance which means taking into account the different concerns of all involved participants. Here, the lenders are of major importance as projects depend to a great part on the debt capital. The latter is only provided against the background of expected future cash-flows of a project.

It is particularly important to consider the numerous risk factors of an offshore wind project associated with these different requirements within the risk management in order to ensure the economic success of such projects. In the context of this paper, risk is defined as an uncertainty with regard to expected realizations of parameters in combination with possible negative effects on various aspects [4]. Additionally, also positive deviations from the expected values are included.

The objective of this paper is to introduce a tool which gives an answer to the question whether a specific offshore wind project provides adequate returns for investors as well as sufficient debt service coverage from the perspective of lenders. For this purpose, the offered solution delivers aggregated financial data and ratios of central aspects that support an economic evaluation that aims at deciding whether a project can be realized. Regarding the fact that a majority of future offshore projects will be realized in the framework of project finance, several key figures related to the demands of the lenders are also determined. A simultaneous consideration of potential risks is not only necessary but also required for a reasonable analysis due to important technological and economic challenges as a product of limited experiences with offshore wind parks. The latter is realized by the estimation and determination of appropriate risk indicators.

2   Related Work and State of the Art

In this section, publications that conduct economic evaluations of offshore wind parks are presented. The aim of this section is to identify interesting approaches, whose fragments can be used to define a model and build a tool that takes all aspects mentioned above into consideration.

Hirschhausen and Jeske [5] use a discounted cash-flow model to evaluate the net present value of three fictitious offshore wind parks in the German North and Baltic Sea. They consider only pure corporate finance and do not take project risks into account. The research of Madlener et al. [6] provides a cash-flow model on which a MCS is applied. Their quantitative model makes use of the weighted average cost of capital method to discount the future project cash-flows of an offshore wind park in order to calculate the present value of the project. Additionally, a comprehensive analysis of various risk factors and their influences on different parts of a project is performed. On the result of the subsequent MCS which results in a distribution of the discounted project value, the value-at-risk principle is applied. A consideration of further key figures or aspects of project finance does not take place. Levitt et al. [7]

perform an analysis of the breakeven price of electricity for offshore projects in various countries with a cash-flow model. Different financing concepts are considered as well as variances in the investment or operating costs within a sensitivity analysis. An examination of the influence of specific risk factors is not performed, neither are financial key figures calculated. KPMG [1] provides multiple results of scenario analyses and takes project finance in combination with related key figures into consideration. Neither is a detailed model presented nor is a comprehensive risk analysis performed. Prässler and Schaechtele [3] conduct a comprehensive assessment of the financial attractiveness of offshore wind power markets in Europe. In this context a DCF model is set up, key figures like the internal rate of return (IRR) are calculated and multiple scenarios are scrutinized. Aspects of project finance or the consideration of risk factors are not examined. Schillings et al. [8] provide a DST to identify the potential of offshore wind energy and its costs in the North Sea. Their research provides a detailed evaluation of various aspects but does not aim at individual projects so that their findings do not support decisions of an entitlement group which is relevant in this paper.

The result of the literature research indicates that no publication exists that addresses the demands of investors as well as lenders under simultaneous consideration of project risks. Therefore, an approach that includes the determination and provision of financial data which are decision-relevant for all stakeholders is introduced in this paper. According to the categorization of Wilde and Hess [9] a formal-deductive analysis in combination with a simulation is seen as an appropriate research method. This results in the creation of a mathematical model in the shape of a discounted cash-flow model to illustrate and analyze the economic connections of individual aspects on which a MCS is applied to evaluate the effects of risk.

Due to the closeness regarding the approach and content with the research of Madlener et al. [6] this paper is based partly on their model.

3 Decision Support Tool

A DST is a computer-based support for management decision makers who are dealing with semi-structured problems [10]. In the context of project finance in the offshore wind energy sector such a tool has to consider the previously mentioned financial aspects and influences of risk. As a basis of this tool a cash-flow model is set up. For the implementation of this cash-flow model any table calculation software is suitable. Microsoft Excel 2010 is chosen due to its wide use and expandability with Add-Ins. In order to perform a MCS the Add-In Oracle Crystal Ball 11.1.2 is used. It extends Excel with simulation, forecasting and evaluation capabilities. Alternative Add-Ins such as Palisade @Risk have almost the same relevant functionality and would also be applicable. The simulation output is processed with Visual Basic for Applications (VBA) macros in order to implement an automated visual output in the form of diagrams.

3.1   Cash-flow Model

The basis of the DST is a cash-flow model. Figure 1 illustrates the main components and their relationships. The investment cash-flow consists of several individual cost factors referring to the planning process and the construction period of the wind park.

The earnings within the operating cash-flow result directly from selling the produced energy. The latter depends on the theoretical full load hours multiplied with the nominal power output of the entire wind park. In addition to all costs resulting from the operation of the wind park possible costs of deconstruction are also considered in the expenditures within the operating cash-flow.

Furthermore, the cash-flow model makes use of some parameters with an influence on multiple factors in several years. An increase of all operating cost components is conducted by the inflation rate in every year. For the increase of the electricity market price an independent key figure is used to supply a better possibility of setting. This parameter, the construction period and the net full load hours affect only the earnings within the operating cash-flow.

Operating cash-flow, depreciation of the fixed assets and tax rate are used for the calculation of the taxes. The sum of investment cash-flow, operating cash-flow and taxes results in the free cash-flow.
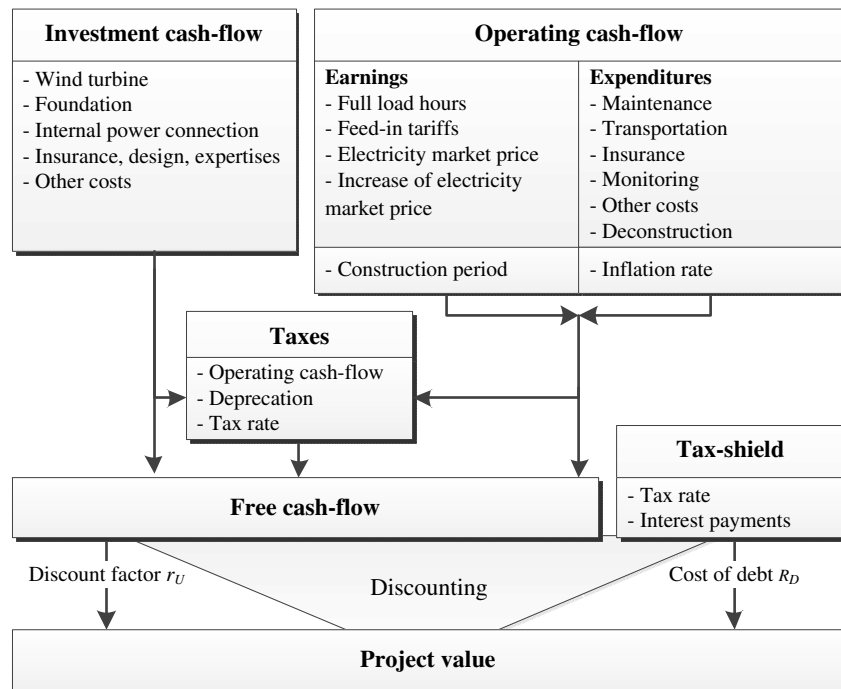

Fig. 1. Project value calculation in the cash-flow model

3.2 Discounted Cash-flow (DCF) Method

The calculation of the project value as well as financial key figures is performed by discounting the project cash-flows. There are several approaches to apply this method. The use of the adjusted present value (APV) approach is a good choice in case the debt-equity ratio is not constant in the course of time [11]. This holds for project finance. The first part of the net present value or project value calculation in equation 1 represents the present value of all free cash-flows (FCF) and the second part the present value of the tax shield of the project [12]. The latter defines an increase in the company's value as a result of the tax saving obtained by the payment of interest [13].

$$Project\ Value = \sum_{t=1}^{T} \frac{FCF_t}{(1+r_U)^t} + \sum_{t=1}^{T} \frac{\tau * [r_{D,t} * D_{t-1}]}{(1+r_{D,t})^t} \tag{1}$$

The present value of the tax shield is based on the multiplication of the tax rate r and the interest expense $[r_{D,t} * D_{t-1}]$ discounted with the cost of debt of the respective period. The discounting of the FCF is done by applying the discount factor r_U which is the average of the return on equity r_E and the cost of debt r_D weighted with the share of equity E and debt D on the company value V (equation 2).

$$r_U = r_E * \frac{E}{V} + r_D * \frac{D}{V} \tag{2}$$

The costs of debt are determined by loan agreements while the return on equity has to be determined with the capital asset pricing model (CAPM) in equation 3:

$$r_E = r_f + (r_M - r_f) * \beta \tag{3}$$

It is based on the risk free interest rate r_f, the market risk premium $(r_M - r_f)$ which includes the market interest rate r_M and the beta factor. The latter involves the systematic risk of the investment compared to risks on general markets [14].

3.3 Financial Key Figures

For project developers not only the calculation of the project value is important but also the determination of the internal rate of return (IRR). The IRR for an investment is the discount factor that will make the present value of the project zero [15]. It indicates the interest yield an investor can reach with an investment.

The relationship between project developers and lenders is characterized by the supply of debt capital and the regular repayment of the loan. For the lender it is important to have key figures that aim at the valuation of the possibility of debt service coverage. The basis for the calculation of every subsequent key figure is the cash-flow available for debt service (CFADS). It is the FCF on which the investment cash-flow is added or, in other words, the operating cash-flow after taxes.

The most important key figure for lenders is the debt service cover ratio (DSCR) [16]. It is the quotient of the CFADS and the debt service (DS) and represents the coverage of debt service for every single period of a project (equation 4).

$$DSCR_t = \frac{CFADS_t}{DS_t} \tag{4}$$

Additional key figures are the loan life cover ratio (LLCR) and the project life cover ratio (PLCR) which are only useful in combination with the DSCR. They are calculated as quotient of future CFADS discounted by the cost of debt r_D and the amount of outstanding debt of one period D_{t-1}. The LLCR refers to the CFADS of the remaining loan life, whereas the PLCR refers to all outstanding CFADS of a project.

$$LLCR_t = \frac{\sum_{l=t}^{L} \frac{CFADS_l}{(1 + r_{D,l})^l}}{D_{t-1}} \tag{5}$$

$$PLCR_t = \frac{\sum_{p=t}^{P} \frac{CFADS_p}{(1 + r_{D,p})^p}}{D_{t-1}} \tag{6}$$

3.4 Monte Carlo Simulation

As a pure contemplation of the expected values does not provide a sufficient basis for investment decisions due to an inadequate consideration of possible risks, the model is extended by a MCS. This aims at the inclusion of a wide variety of different risk factors which have an effect of an offshore project.

In order to take the effects of these risks into consideration individual probability distributions are set up for every factor within the investment and the operating cash-flow as well as for the parameters with an influence on multiple factors (see 3.1). Due to an insufficient database on risks in the offshore wind sector, BetaPERT distributions are used because they only need a minimum, a maximum and a most likely value in order to be completely described [17]. The distribution shows a similar shape as a normal distribution if the defined minimum and maximum values have the same absolute deviation from the expected value. The simulation results in a variety of different forms of every target variable (e.g. project value, DSCR).

One key figure which considers the project risks and expresses them in one ratio is the value-at-risk (VaR). It originally indicates the maximum loss in monetary units that is not exceeded within a specific time frame and a specific confidence level [18]. In combination with the MCS this principle can be applied on every target variable of the cash-flow model.

In relation to the project value the VaR expresses the minimum value of the project that is not undercut by a certain probability (confidence level). For the DSCR, LLCR and PLCR it expresses the minimum value of the key figure for a defined probability analogous to the project value.

4 Simulation and Results

The theoretical part with its presented model and methods is now used to perform a simulation of a fictitious offshore wind park in the German North Sea. The assumptions about the characteristics of the wind park are presented in Table 1. They are based on German projects which are currently being planned and supposed to be realized in the near future [1], [6], [19]. The fictitious wind park therefore represents a typical offshore wind project in Germany.

Table 1. Assumptions about the fictitious offshore wind park

Key parameters			
Parameter	Value	Parameter	Value
Wind energy plants	80	Distance to coast	90 km
Nominal output	5000 kW	Depth of water	40 m
Expected annual energy output	1540 GWh	Tax rate	35 %

Investment costs			
Component	Costs per kW	Costs (total)	Discount / Surcharge
Wind turbine	1706 €	682.4 M€	- 5 % / + 5 %
Foundation	852 €	340.6 M€	- 10% / + 10 %
Internal power connection	595 €	238.0 M€	- 5 % / + 5 %
Design / Insurance / Expertise	169 €	67.5 M€	- 10 % / + 15 %
Other costs	279 €	111.5 M€	- 25 % / + 25 %
Total investment costs	3600 €	1440.0 M€	

Operating costs (per year)		
Component	Costs (total)	Discount / Surcharge
Maintenance	22.5 M€	- 25 % / + 25 %
Insurance	18.8 M€	- 5 % / + 25 %
Transportation	3.0 M€	- 25 % / + 25 %
Monitoring	1.0 M€	- 5 % / + 5 %
Other costs	0.9 M€	- 5 % / + 5 %
Total operating costs	46.2 M€	

Parameters with an influence on multiple factors		
Parameter	Value	Discount / Surcharge
Annual inflation rate	2 %	- 25 % / + 50 %
Annual increase of electricity market price (5 ct/ kWh today)	2 %	- 20 % / + 20 %
Net full load hours	3850	- 20 % / +10 %
Construction period	30 months	- 6.67 % / + 20 %

The park consists of 80 wind energy plants with a nominal power output of 5000 kW per engine. Against the background that, in theory, 4000 full load hours can be achieved if internal shadowing effects are considered [20], an assumption of 3850 full load hours after technical unavailability should be suitable. The anticipated annual energy output is calculated as follows: 80 wind energy plants · 5000 kW nominal output 3850 full load hours = 1540 GWh [3]. The project lifetime is set to 20 years beginning at the time when the power generation starts.

Investment costs are set at 3600 € per kW nominal power output. This value is based on different findings in the literature [1], [3], [21]. For the entire OWP with a 400 MW power output the costs amount to 1440 million €. These costs are divided into multiple cost components. The breakdown of the total costs to individual components is based on analyses of the recent past [3], [19], [21].

According to different reports the operating costs are set at 30 € per MWh power output in the year of the commissioning of the wind park in the middle of 2015 [1], [19]. For an expected energy output of 1540 GWh the yearly costs are 1 540 000 MWh · 30 €/MWh = 46.2 M€ and initially 23.1 M€ in 2015. The breakdown to cost components is based on the research of Madlener et al. [6]. For all components of the operating costs an annual increase is assumed due to the annual inflation rate. Besides the investment and operating costs, deconstruction costs of 80 M€ are assumed at the end of the project lifetime [6].

Conforming to the actual market situation for project finance an equity ratio of 40 % is assumed so that the total amount of debt is 864 M€. Two different debt service providers offer the debt for a duration of 12 years. Firstly, there is a banking consortium with a debt amount of 564 M€ and an interest rate of 7 % p.a. Secondly, there is the European Investment Bank (EIB) with a debt amount of 300 M€ and an interest rate of 6 % p.a. [1], [19].

A further important aspect is the compensation of the produced energy. For the first 9 years the initial compensation is 19 cents/kWh due to the use of the compression model offered by the German Renewable Energy Sources Act 2012. After that a location-based compensation of 15 cents/kWh is paid due to the water depth of 40 m and the distance to the cost of 90 km. After the initial and the location-based compensations have expired, the generated power is sold on the general market with a price which is currently around 5 cents / kWh [22].

4.1 Determination of the Discount Rates

In order to apply the APV method for the discounting of the project cash-flows, the discount rates must be determined first. The return on equity has to be determined as shown in equation 3. For this, a risk free interest rate of 2.0 % is used [23]. The market risk premium is approximated to a value of 10 % which implies a market interest rate of 8 %. A beta value of 1.8 is assumed which is based on the following considerations: The unlevered beta for companies which operates in the wind energy sector has an average value of 1.2 [24]. The risk for a single project is likely to be higher than that average, especially in the relatively new offshore wind sector which allows to apply an additional risk premium of 0.3. Due to the use of the compression model for

the initial compensation the financial risk is increased even further [19] which provides a repeated rise of the beta of 0.3. These assumptions result in a return on equity of r_E = 2 % + 8 % · 1.8 = 16.4 %. This is similar to the result of a survey about the expectations of the return on equity of project developers. Without the consideration of a higher risk due to the compression model they require a return on equity of 14-15 % [19].

The costs of debt are determined as 6.66 % by the average weighted interest rate of debt over the project lifetime. The insertion of the return on equity and the costs of debt with their percentage of shares of the total capital into equation 2 results in a discount factor of r_U = 16.4 % · 40 % + 6.66 % · 60 % = 10.56 %.

4.2 Definition of Probability Distributions

Due to the use of BetaPERT probability distributions for performing a MCS it is necessary to specify a minimum, a maximum and a most likely value for every risky parameter. While all expected values of these parameters are used as most likely points of the probability distributions, the minimum and maximum points are calculated with percentage discounts from and surcharges on top of the expected values. These discounts and surcharges are presented in Table 1 next to their respective parameter and are mostly based on the research of Madlener et al. [6]. As an example of this procedure the minimum and maximum points of the probability distribution of the annual inflation rate are calculated. The annual inflation rate in Germany has been between 1 % and 3 % in the last years [25]. The variances of the expected value at a height of 2 % are assumed to be close to the statistic values with -25 % and +50 %. Consequently, the minimum is 75 % · 2 % = 1.5 % and the maximum is 150 % · 2 % = 3.0 %.

4.3 Results

All previously mentioned values of the different parameters are inserted into the cash-flow model. A part of all resulting project cash-flows is presented in Table 2. The use of the APV method can be followed by the presentation of the discounted values of the free cash-flow and the tax-shield and the subsequent addition of these values. The result allows different statements about the OWP:

1. The project value of 72.1 M€ is positive and consequently the investment opportunity offers a return on equity which is bigger than the required 16.4 %.
2. On the basis of this project value the IRR is 12.05 %. The return on equity which results in this value under otherwise equal conditions and assumptions is 20.14 %, an increase of 22.8 % compared to the required return on equity.
3. The cumulative project value provides an answer to the question at which time the project is expected to turn into a positive investment. For the first time, this is the case after 14 years in the year 2027.

Table 2. Calculation of the expected project value (millions of €)

|	∑	2013	2014	2015	2016	2017	…	2035
1. Investment cash-flow		-145.0	-575.0	-720.0			…	
2. Operating cash-flow				123.2	245.5	244.5	…	-89.1
2.1 Earnings				146.3	292.6	292.6	…	59.5
2.2 Expenditures				-23.1	-47.1	-48.1	…	-148.7
3. Taxes						-21,2	…	
Free cash-flow		-145.0	-575.0	-596.8	245.5	223.3	…	-89.1
Tax-shield			6.7	20.6	21.1	19.8	…	
Discounted free cash-flow	-49.8	-131.2	-470.4	-441.7	164.3	135.2	…	-8.9
Discounted tax shield	121.9		6.3	18.1	17.4	15.3	…	
Project value	72.1	-131.2	-464.2	-423.6	181.7	150.5	…	-8.9
Cumulative project value		-131.2	-595.3	-1018.9	-837.2	-686.7	…	72.1
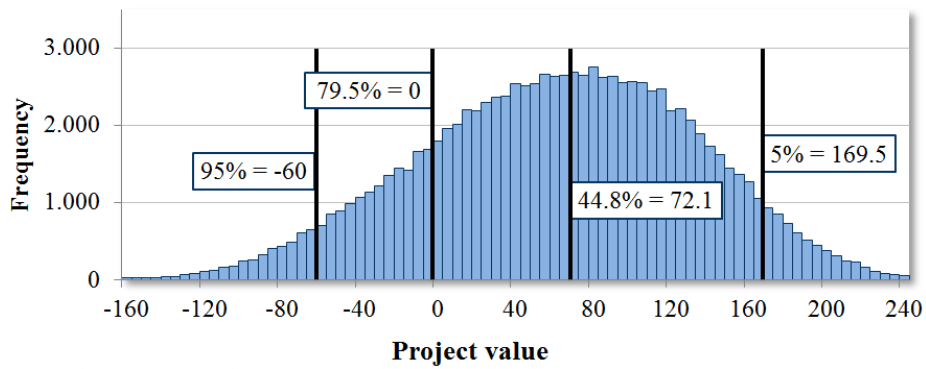
Fig. 2. Distribution of the project value (millions of €, 100000 simulations)
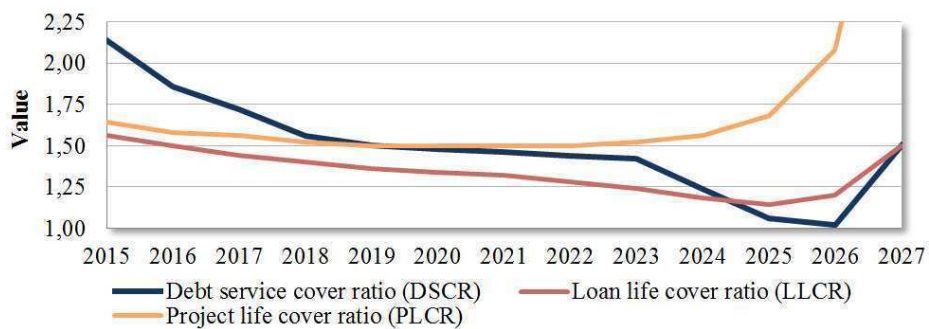

Fig. 3. Key figures at a specified confidence level of 95%

On the cash-flow model the MCS is applied. It is performed with 100 000 simulation runs. It needs 428 seconds on an Intel Core i7-2640M CPU with 2.80 GHz, 8GB Ram

and Microsoft Windows 7 64bit as operating system. The effect on the project value is shown in Figure 2. Some statements can be derived from the distribution:

1. At a confidence level of 95 % the project value is -60 M€. Therefore, with a certainty of 95 %, the value of the project is at this or a higher amount.
2. The calculation of the IRR for the project value of -60 M€ can be made analogous to point 2 of the considerations about the expected project value. In this case the IRR is at least 9.26 % with a certainty of 95 %,
3. With a probability of 79.5% the minimum project value is 0 and investors get an interest yield that is at least at the same level as other investments with similar risk.
4. The probability to reach a project value of at least 72.1 M€ which correspondents with the expected project value is only 44.8 %.

The consequences of the MCS on the financial key figures in combination with the VaR principle are presented in Figure 3. Lenders normally demand a value of the DSCR between 1.35 and 1.45 [1]. Most of the time, the DSCR has an uncritical value greater than this range. In the years between 2023 and 2027, in which the compensation for the produced energy guaranteed by law will have ended, the DSCR is only over a value of 1. Due to the consideration of the project risks at a 95 % confidence level and values of the LLCR and especially the PLCR which are significantly higher and partly rapidly increasing in the previously mentioned critical periods, the project cash-flows offer adequate debt service coverage for the entire loan life.

5   Discussion

The presented results clearly indicate that an investment into an offshore project in the German North Sea is in the average profitable for project developers and lenders. It is obvious that the DST provides an aggregated representation of important financial key figures and gives an answer about the economic efficiency of offshore wind projects which are constructed and operated within the context of project finance.

5.1   Evaluation

This section addresses the question whether the DST with its underlying model meets the criteria of the scientific rigor and the practical relevance.

Applicability to a Class of Problems. The presented model is focused on offshore wind energy projects in Germany which are constructed and operated in the context of project finance. Although this focus exists, the DST can be used for projects with other framework conditions with some restrictions. The main restriction is based on the modeling of the compensation for the produced energy. It is tailored to suit the requirements of the feed-in tariffs guaranteed by law in Germany with its initial and location-based compensation before the produced energy is sold on the general market.

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With little adjustments of the parameters for the compensation structure it is possible to fulfill the economic conditions for the sale of energy in other countries. Three conditions must be met for the transfer: the guaranteed feed-in tariff in the respective country (1) has to consist of at most two different amounts (2) which are respectively paid for a predefined time period (3) without any other subsidies regarding the electricity. It is possible that the compensation is based on the provided feed-in tariff for the entire project life or until a market-based compensation starts. With an adjustment of the parameters for the compensation structure it is possible to use the DST at least for projects in Ireland and France [1], [3]. An evaluation of onshore projects is also possible if the same conditions are fulfilled. Additionally, the model can be applied to projects within the context of corporate finance. In this case the special key figures play an insignificant role. In total, the DST can be used for a variety of different projects in at least three countries.

Innovative Contribution to the Published Level of Knowledge. The results of the literature research in section 2 have shown that no contribution exists which provides aggregated financial data and ratios of central aspects under simultaneous consideration of project risks. Those have also to support decisions of project developers and meet the special demand of lenders.

The DST with its underlying cash-flow model focuses on this gap to provide a contribution which extends the current level of knowledge. Aiming at project developers, it provides a detailed presentation of all project cash-flows and a calculation of the project value and the IRR. Lenders focus on the debt coverage by the project cash-flows. An analysis of the debt service coverage is possible with the provided financial key figures. While the DSCR only considers the debt service coverage of one single period, the LLCR and PLCR offer the possibility to extend this consideration and include additional data. Risk factors are taken into account due to the assignment of probability distributions for all parameter within the investment and operating cash-flow and the performing of a MCS. The results show the influence of the risks on the project value and all other mentioned key figures.

Reasonable Reproducibility and Validation. Setting up a cash-flow model with the aim to calculate a project or corporate value is a standard practice. The structure of the cash-flow model and the simulation described in section 3 are based on the published knowledge and reasoning based on that. For an expert in the field of business computer science and finance it should be intersubjectively comprehensible.

Future Benefits for Stakeholders. This paper has both theoretical implications for the entitlement group of scientists as well as practical implications for project developing companies and lenders.

Theoretical Implications. Regarding the discussion of the consideration of project risks, the performed simulation points out the effects of risk factors on different financial key figures. There are no findings in the literature about these effects on the indicators which are particularly important for the lenders. This indicates that the

consideration of risk factors within the relationship between project developers and lenders for offshore wind energy projects has not yet been sufficiently researched.

Against the background of ambitious expansion targets for the offshore wind energy in various countries there is an increasing examination of regions with greater distances to the coastline and higher water depths with regard to their suitability for offshore projects. The economic attractiveness of these regions tends to be lower [3] and therefore a detailed analysis of all relevant aspects has to be performed in order to be able to reduce the effect of individual risks in the future.

Furthermore, the presented model can be modified and expanded easily to take future changes in the general conditions or new insights into consideration.

Practical Implications. The tool can support decision makers to evaluate the economics of specific offshore wind projects. For project developers the interest rate for the invested equity is of major importance and the provided determination of this value and of the IRR is of great significance. Lenders require a covered debt service. Through the calculation of relevant key figures like the DSCR an evaluation of a project's ability to cover the debt is possible. Additionally, the model helps to understand the effects of changes in the general conditions like feed-in tariffs, a changed cost situation of individual cost factors, a different amount of annual full load hours or alternative discount factors.

Furthermore, the influence of risks on the success of a project becomes clear. Against this background the importance of risk management is emphasized. The examination of individual risk factors offers a possibility to detect which risk factors are the greatest threats for the success of a project and at which point of time in the project planning or operating process it is most important to establish and apply risk management methods.

5.2   Limitations and Further Research

The model uses one single tax rate. In particular with regards to the complex German tax system the cash-flow model provides only an approximation. Deviations of the real situation depend strongly on the individual case of the project. However, the key findings of the model retain their validity.

The technical availability is not an independent parameter in the model but a flat adjustment of the theoretical achievable full load hours. A further development of the model could consider the full load hours and the technical availability independently which would also add the possibility to take improvements of the technical availability in the long term [7] into consideration.

The parameter of the construction period only affects at which time the compensation for the produced energy starts. Especially within the framework of the MCS with its different generated values it is neither intuitive nor realistic that a longer construction period does not result in increased construction costs.

All conclusions derived from the results of the MCS are based on BetaPERT probability distributions and an adequate description of possible distributions of risks. This is only a rough approximation. A better consideration of individual risk factors can be

realized when the knowledge about these risks could be increased by more and longer experiences and better scientific investigations of planning, construction and operation of offshore wind parks. In this case the BetaPERT probability distributions can be replaced by more realistic ones. However, in the near future, no improvement of the data situation can be expected because involved companies classify the majority of this data as secret information.

The aspects mentioned in the discussion of the applicability to other countries in section 5.1 should also be included in a further development of the model. An expansion in order to take different feed-in tariffs of various countries with their respective compensation systems into consideration would provide a larger scope of possible applications and scientific investigations.

6   Conclusion

In this paper a decision support tool is presented which helps to evaluate the economic potential of offshore wind projects. The present value of such projects is calculated with a discounted cash-flow model. Due to the different requirements of project developers and lenders additional key figures like the IRR, DSCR, LLCR and PLCR are calculated to meet the requirements of all stakeholders. A consideration of risk factors is done by the assignment of probability distributions to specific components of the cash-flow model. This is followed by performing a Monte Carlo simulation and applying the value-at-risk principle on the distribution of each target key figure. Overall, the tool allows to evaluate the impact of single input parameters or risk factors so that critical aspects can be identified to give a special consideration of these aspects within the risk management process. Generated results can serve as a useful guidance for project decision makers and scholars alike.

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