Applying a Novel Investment Evaluation Method with Focus on Risk—A Wind Energy Case Study

Jan-Hendrik Piel, Felix J. Humpert and Michael H. Breitner

Abstract Renewable energy investments are typically evaluated using traditional discounted cash flow (DCF) methods, such as the net present value (NPV) or the internal rate of return (IRR). These methods utilize the discount rate as an aggregate proxy for risk and the time value of money, which leads to an inadequate modeling of risk. An alternative to these methods represents the decoupled net present value (DNPV). Instead of accounting for risk in the discount rate, the DNPV utilizes so-called synthetic insurance premiums. These allow for the individual and disaggregate pricing of risk and can enhance the quality of investment decisions by facilitating a more detailed and comprehensive representation of the underlying risk structure. To reliably estimate and forecast synthetic insurance premiums requires the availability of appropriate data and expertise in interpreting this data. Thus, the practicality of the results calculated based on the DNPV depends on the quality of the inputs and the expertise of the analyst. After reviewing the main theory of the DNPV, we apply the method to a wind energy investment case to demonstrate its applicability and prospects. To illustrate the calculation of the synthetic insurance premiums, selected risk factors are modeled with probability distributions via Monte Carlo simulation (MCS). Our results show that the DNPV's seamless integration of risk assessment with investment evaluation is a promising combination and warrants further research.

J.-H. Piel (✉) · F.J. Humpert · M.H. Breitner
Information Systems Institute, Leibniz University Hannover,
Königsworther Platz 1, 30167 Hannover, Germany
e-mail: piel@iwi.uni-hannover.de

F.J. Humpert
e-mail: humpert@iwi.uni-hannover.de

M.H. Breitner
e-mail: breitner@iwi.uni-hannover.de

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1 Introduction

In theory [1] and practice [2–5], DCF methods, such as the NPV and the IRR, are often used for evaluating investments in infrastructure and renewable energy projects. Despite their popularity, their weaknesses and limitations are widely recognized in the scientific literature [1, 3, 6]. Most critical, but difficult is the selection of an appropriate discount rate in DCF analysis [2]. Often used are risk-adjusted discount rates (RADRs). By adding risk-free rate and risk premium, RADRs aggregate the time value of money and risk in a single metric [2, 6].

However, the bundling of time preference and risk in the discount rate obscures the appropriate modeling of investment risks. For instance, in the case of negative cash flows, selecting a higher RADR to account for an increase in risk, produces a more favorable NPV. Using RADRs is therefore a rather inconsistent way to account for risk [2, 7]. Consequently, the use of DCF methods based on RADRs distorts investment evaluations and can result in misguided investment decisions [8]. Even supplementing these methods with more sophisticated approaches, such as using probability distributions in combination with MCS and real option valuation [7] cannot overcome the problem of discount rate selection. This is for instance discussed by [9] with respect to the use of MCS in investment evaluations.

A solution to the shortcomings described above is the DNPV, which was first introduced by [2, 7]. It solves the issues surrounding discount rate selection by decoupling risk from the time value of money [2]. Further, it allows to deal with systematic and unsystematic risks individually [7]. Both is achieved through so-called synthetic insurance premiums (SIPs). Investors, as equity providers, are the last to be paid from investments' returns and absorb the losses when risks materialize. Consequently, the DNPV treats investors as insurance providers for any risk not allocated to third parties through risk management measures [8]. This being the case, SIPs are priced risks that have to be treated as costs to an investment. They render an investment's cash flows riskless and thereby legitimize discounting at the risk-free rate [2]. In addition, SIPs can help assess and communicate the degree to which an investment is expected to reward investors for taking on risk [2]. As a result, the DNPV can support a more thorough analysis of the risk profile of investments and can provide a broader and more consistent foundation for investment decisions.

Wind energy projects are technically complex, highly leveraged, illiquid and capital intensive investments. Comprehensively analyzing the risks of such investments and their impact on profitability is of particular importance, as these characteristics potentially heighten the exposure to unsystematic risks for a given investor. By applying the DNPV to a solar energy project, [8] were the first to demonstrate the DNPV's feasibility in the context of renewable energy investments. An application of the method to a wind energy case is still missing from the literature. We aim to address this gap by providing methodological support tailored to the needs of wind energy investors. We implement the DNPV and its related concepts in MATLAB and utilize probability distributions generated via MCS for modeling risk. In order to demonstrate the DNPV's prospects and functionality, we illustrate its application with a stylized wind energy investment case.

2 Wind Energy Investment Case

The design of our investment case is based on recent data from the German wind energy market [10] as well as a risk breakdown structure template for renewable energy projects by [11]. Within the case the perspective of a consortium of investors in negotiations with a project developer over a 70% stake in a fully developed and operational wind energy project is adopted. The investors want to negotiate a reasonable price for the investment such that they can expect to be compensated with a return for taking on the risks of the project. To support their negotiations, the DNPV in combination with the NPV is applied. The remaining operating life of the project is 19.5 years, whereas an additional decommissioning of six months is expected. Table 1 presents the expected revenues and operating expenditures (OPEX).

The project is organized as a special purpose vehicle with a debt ratio of 85%. The debt is provided in the form of an annuity loan of €15,903 T with an interest rate of 2.5%. Its repayment starts at the beginning of the third year of operation. OPEX increase with an inflation rate of 1%. In previous auctions, the project has been awarded a feed-in tariff of €85/MWh. The wind park consists of four turbines with an installed capacity of 2.5 MW each. The expected full load hours before losses amount to 2,933.55 h. The total park losses of 11.49% are a function of various influencing factors, such as wake losses and turbine availability. Consequently,

Table 1 Free cash flows to equity analysis of the investment case in thousand Euro (€T)

Parameter	Year 1	Year 2	Year 3	...	Year 20	Distribution[a]
Maintenance and repair	259.89	263.58	266.21	...	157.25	T(251.51, 90%, 120%)
Land lease	124.28	125.52	126.77	...	74.84	N(124.28, 10%)
Direct marketing	53.16	53.70	54.24	...	32.03	U(40.19, 66.13)
Other OPEX	194.06	195.98	197.96	...	116.94	N(194.06, 10%)
Total OPEX	**631.39**	**638.78**	**645.18**	**...**	**381.06**	
Decommissioning	**0.00**	**0.00**	**0.00**	**...**	**778.85**	U(311.40, 1,246.30)
Revenues before losses	2,493.52	2,491.30	2,491.60	...	1,245.45	N(2,493.52, 10%)
Losses monetarily	286.20	286.18	286.26	...	143.05	N(286.20, 15%)
Total revenues	**2,207.32**	**2,205.12**	**2,205.34**	**...**	**1,102.40**	
Corporate tax	122.08	73.46	30.96	...	211.26	
Debt service	0.00	1,162.60	1,954.10	...	0.00	
FCFE	**1,453.85**	**330.28**	**−424.90**	**...**	**−268.77**	

[a]Normal N(μ, σ in %); triangular T(mode, min in %, max in %); uniform U(min, max)

the expected annual electricity production equals to 25,964.85 MWh. This results in annual revenues of €2,207.32 T. The wind park is depreciated linearly over a period of 16 years and profits are subject to a corporate tax rate of 30%. The project's expected periodical free cash flows to equity (FCFE) are shown in Table 1. Individual risks in the case study are modeled using probability distributions in combination with MCS and 50,000 iterations as outlined in Table 1. The distribution types and shapes were selected based on recommendations by [11].

3 DNPV Analysis

Equation 1 outlines the concept for calculating the DNPV [2, 7] with V representing revenues, I expenditures and R SIPs. In line with [2], we understand SIPs as the fair insurance premiums, which compensate for expected losses resulting from unfavorable deviations of revenues and expenditures with respect to their expected values. In the numerator, for each period t, the respective SIPs reduce the expected revenues and increase the expected expenditures. To account for the time value of money, the resulting risk-adjusted cash flows are discounted at the risk-free rate r_f. This is legitimate given that the SIPs render the associated cash flows riskless [7].

$$DNPV = \sum_t \sum_{i,j} \frac{(\tilde{V}_{t,i} - \tilde{R}_{t,i}) - (\tilde{I}_{t,j} + \tilde{R}_{t,j})}{(1 + r_f)^t} \tag{1}$$

For the computation of SIPs, [2] distinguish between heuristic methods, stochastic processes, and the use of time-invariant probability distributions. Henceforth, we focus on the latter. When calculating SIPs based on probability distributions, differentiation between SIPs for expenditures and revenues is required. Equation 2 is to be used in the case of revenue risks [2, 7] where $\tilde{V}_{t,i}$ represents the expected revenues, $L_{t,i}$ the expected revenue shortfall relative to $\tilde{V}_{t,i}$ and $Pr\left[\tilde{V}_{t,i} > V_{t,i}\right]$ the probability of revenues falling below their expected value. To calculate SIPs for expenditure risks, Eq. 3 is to be used analogously [2, 7], with $\tilde{I}_{t,j}$ representing the expected expenditures, $L_{t,j}$ the expected excess expenditures relative to $\tilde{I}_{t,j}$ and $Pr\left[I_{t,j} > \tilde{I}_{t,j}\right]$ the probability of incurring excess expenditures.

$$\tilde{R}_{t,i} = (\tilde{V}_{t,i} - \tilde{V}^{-}_{t,i}) \cdot Pr\left[\tilde{V}_{t,i} > V_{t,i}\right] = L_{t,i} \cdot Pr\left[\tilde{V}_{t,i} > V_{t,i}\right] \tag{2}$$

$$\tilde{R}_{t,j} = (\tilde{I}^{+}_{t,j} - \tilde{I}_{t,j}) \cdot Pr\left[I_{t,j} > \tilde{I}_{t,j}\right] = L_{t,j} \cdot Pr\left[I_{t,j} > \tilde{I}_{t,j}\right] \tag{3}$$

To illustrate the calculation of SIPs, Fig. 1 shows the complete and truncated distributions for maintenance and repair (MR) and revenues before losses (RBL), including the characteristic inputs for the calculation of the corresponding SIPs.

Table 2 displays a breakdown of the total cost of risk represented by the SIPs for the parameters subject to risk. It gives an idea of how the DNPV integrates with risk

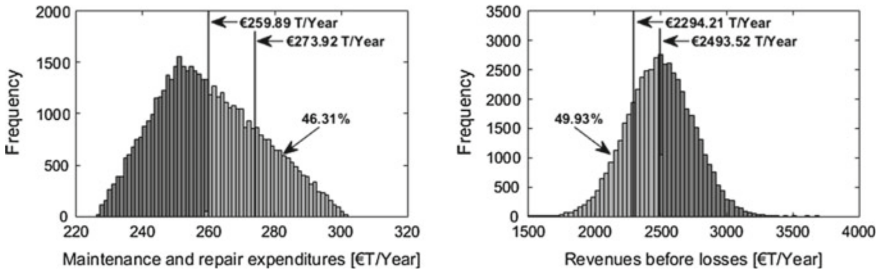

Fig. 1 SIP calculation for MR and RBL in year one. Applying Eq. 3 to the MR distributions results in an SIP of €6.50 T = (€273.92 T – €259.89 T) · 46.31%, whereas applying Eq. 2 to the RBL distribution gives an SIP of €99.52 T = (€2,493.52 T – €2,294.21 T) · 49.93%

Table 2 Decoupled FCFE and cost of risk described by SIPs in €T

Parameter	Year 1	Year 2	Year 3	...	Year 20	PV
Maintenance and repair	6.49	6.56	6.62	...	3.91	126.07
Land lease	4.97	5.02	5.07	...	2.99	96.38
Direct marketing	3.32	3.36	3.39	...	2.00	64.50
Other OPEX	7.74	7.82	7.90	...	4.67	150.26
Total OPEX	**22.52**	**22.76**	**22.98**	**...**	**13.57**	**437.21**
Decommissioning	**0.00**	**0.00**	**0.00**	**...**	**129.97**	**106.82**
Revenues before losses	99.52	99.34	99.27	...	49.71	1,762.30
Losses monetarily	16.18	16.18	16.16	...	8.09	286.83
Total revenues	**115.70**	**115.52**	**115.43**	**...**	**57.80**	**2,049.13**
Total SIPs	**138.22**	**138.28**	**138.41**	**...**	**201.34**	**2,593.16**
FCFE	**1,453.85**	**330.28**	**−424.90**	**...**	**−268.77**	**1,727.40 (= NPV)**
Decoupled FCFE	**1,315.63**	**192.00**	**−563.31**	**...**	**−470.11**	**3,363.50 (= DNPV)**

management by being able to quantify risks individually. For instance, total revenue risk results from adding the SIPs for RBL and the losses associated with the annual energy production, both expressed in monetary terms. RBL are the theoretical energy production if no park losses were to occur. The risk associated with RBL pertains to resource risk as well as the risk of inaccuracies in the wind data and modeling of the wind resource. Table 2 shows that revenue risk is the dominating risk category for the investment representing 79% of the total SIPs' present value (PV). OPEX risk is the second most important risk, but only a fraction of revenue risk with 16.9% of the total SIPs' PV. Although decommissioning risk outstrips OPEX risk in the final period, it is almost insignificant with 4.1%.

Deducting the SIPs from the FCFE yields the decoupled FCFE. Discounting these at the risk-free rate of 1% returns a DNPV of €3,363.50 T. To get the NPV of

€1,727.40 T, the FCFE are discounted at 8%, which is the required return assumed for the investors. Although the FCFE are more favorable than the decoupled FCFE, the DNPV exceeds the NPV, as the decoupled FCFE already price in risk. Due to this, the effect of discounting the FCFE in the NPV approach is significantly higher than the effect of discounting the decoupled FCFE in the DNPV approach.

The investors in the case study are well advised to proceed with the investment as long as they pay less than 70% of the NPV for the stake under negotiation. In this case, they are expected to earn a premium under the NPV and the DNPV paradigm. Thus, risk and the time value of money are expected to be covered according to both valuation approaches. However, based on the DNPV, investing even at a price higher than 70% of the NPV can be considered reasonable, whereas 70% of the DNPV can be considered the upper bound for a fair price. Exceeding this value means no longer being fairly compensated for the time value of money and potential losses associated with the investment. This case study demonstrates how the DNPV provides a new perspective on investment decisions by framing and modeling individual risks as costs to an investment. This facilitates a more thorough analysis of the risk structure of investments as well as their risk-return profile. Thus, the DNPV can broaden the foundation for investment decisions and thereby enhance their quality.

4 Limitations and Outlook

Decisions about wind energy investments require an adequate understanding of their risk-return profile. We applied the DNPV to the presented wind energy project to demonstrate its applicability. SIPs allow for a decoupling of the time value of money and risk and facilitate the pricing of risk. Further research has to explore how to assure the accuracy of SIPs, as project valuations require forecasting SIPs years into the future. In this respect, wind energy projects are ideal, since they are built in series, which facilitates data collection. Assets not sharing these characteristics appear to be less suitable for applying the DNPV. Espinoza [7] proposed the use of stochastic processes to calculate SIPs. Yet, the modeling of risks that are expected to behave dynamically still requires further research. In this regard the DNPV may profit from the experience with stochastic processes in the context of commodity price models used to evaluate long-term investments in the mining sector.

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