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Risk-Adjusted Discount Rate and Its Components for Onshore Wind Farms at the Feasibility Stage

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Abstract: The concept of risk is well known in the energy sector. It is normally recognized when it comes to price and cost forecasting, annual production calculation, or evaluating project lifetime. Nevertheless, it should be pointed out that the quantitative evaluation of risk is usually difficult. The discount rate is the only parameter reflecting risk in the discounted cash flow analysis. Therefore, knowledge of the discount rate along with the major components affecting its level is of fundamental significance for making investment decisions, capital budgeting, and project management. By referring to the standard coal-fired power generation projects the authors of the paper tackle the analysis of the composition of discount rate for onshore wind farm technologies in the Polish conditions. The study was carried out on the basis of a typical (hypothetical) onshore wind farm project assessed at the feasibility stage. To enable comparisons and discussions, it was assumed that the best reference point for such purposes is the real risk-adjusted discount rate, RADR, after-tax, in all equity evaluations (the 'bare bones' assumption); that is because such a rate reflects the inherent characteristics of the project risk. The study methodology involves the a priori application of the discount rate level and subsequently—in an analytical way—calculation of its individual components. The starting point for the analysis of the RADR's composition was the definition of risk, understood as the product of uncertainty and consequences. Then, the risk factors were adopted and level of uncertainty assessed. Subsequently, using the classical sensitivity analysis of IRR, the consequences (as slopes of sensitivity lines) were calculated. Consequently, risk portions in percentage forms were received. Eventually, relative risks and risk components within cost of equity were assessed. Apart from the characteristics of the discount rate at the feasibility stage, in the discussion section the study was supplemented with an analogous analysis of the project's cost of equity at the operating stage.

Keywords: onshore wind; risk assessment; cash-flows; discount rate; cost of capital; cost of equity

Citation: Saługa, P.W.; Zamasz, K.; Dacko-Pikiewicz, Z.; Szczepańska-Woszczyna, K.; Malec, M. Risk-Adjusted Discount Rate and Its Components for Onshore Wind Farms at the Feasibility Stage. *Energies* **2021**, *14*, 6840. https://doi.org/10.3390/en14206840

Academic Editor: Ricardo J. Bessa

Received: 21 September 2021
Accepted: 17 October 2021
Published: 19 October 2021

1. Introduction

Due to the climate policy of highly developed countries around the world, including the European Union, investments in renewable energy sources are becoming an urgent necessity in Poland. In relation to the above, not only is there an emerging public awareness of off-shore farms as a potential zero-carbon source of electricity [1], but also a number of low-carbon investments were implemented in Poland in the last decade, including the onshore wind farms (currently approx. 60% of the total RES capacity) [2]. This is favoured by the fact that, from the point of view of the wind technology, the area of Poland is geographically relatively attractive and the most interesting regions are Pomerania (primarily West Pomerania, Wolin Island), as well as the belt of lowlands in central Poland: from Greater-Poland, through Masovia, up to Warmia (Ermland) and Masuria provinces [3]. Actually, in Poland are currently operating approx. 1200 wind energy installations with a total capacity of approx. 6.7 GW producing ~10% (15.7 TWh) of electricity [4]. The recent increase in the demand for electricity was covered primarily thanks to the existence of such farms [5].

In spite of the fact that the development of wind power was, in Poland, temporarily halted by the introduction of the so-called 'Distance Act' and by the growing popularity of small photovoltaic panels technology among Polish citizens [6], yet the unwavering interest in wind farms—primarily on account of the pressure of climate policy of the European Union and a drop in investment costs—have induced the government to mitigate the current legal regulations [7]. The number of wind projects allows for expecting a new flourish and intensified development of this technology [3].

Wind energy projects are generally long-term. The investment period ranges from 3 to 4 years, whereas the operational period stretches even up to 25 years [8] which means that investors often use indicators to try to calculate the future profitability of an investment, such as NPV, IRR, or DPP [9]. One can say that there is usually an agreement within energy sector on CAPEX, OPEX, production, capacity factors and, in consequence, resulting cash flow values. Nevertheless, projects of this type are usually encumbered with a significant risk, the expression of which are discount rates used by the investors to actualise the values of the future cash flows and establish investment criteria.

Every discount rate is selected as regards the risk of an individual project in reference to:

1. Industry expectations with respect to the project returns;
2. The risk factors associated with energy projects in general, and
3. The risk factors associated with the specificity of the project.

One of the basic approaches applied in the procedure encompassing determination of an adequate discount rate is searching for similar—in relation to the analysed project—'twin' investments. Due to this, a significant role in this process plays the investor's comprehensive knowledge about similar projects and assessment of their efficiencies [10]. This experience is invaluable due to the fact that—e.g., in the case of projects implemented in the energy sector—these components may fall within a relatively extensive range—from several to several dozen percent (nominal) [11–13]. Various studies [11,12,14–16] show that among low-carbon technologies, the most risky are the wave (floating) power plants, CCS, nuclear power plants, geothermal plants, tidal barrage, and tidal stream plants; on the other hand, the lowest risk projects are the CCGT generation technologies, hydro RORs, solar PVs, biomass plants, and onshore wind farms—the last ones are the subject of this paper.

We must emphasize that, however, among industry professionals and scholars appear different views on levels of the discount rate that should be used in the net present value evaluations.

There is a number publications on discount rates applied in the renewable energy sector, including onshore wind projects. Because the majority of those papers concentrate on distinct and specific issues, they generally cite amounts of discount rates and roughly describe ways of obtaining those percentages but often without any vital details.

Publications on the cost of capital (briefly reviewed below) feature then various forms and approaches to discount rates: nominal or real, pre- and after-tax, but often they not indicate that issues. Most of the papers focus on hurdle rates and the calculation of the weighted average cost of capital, WACC [11–13,17–19]. The information about the last ones would even be more interesting if they gave feedback about gearing/capital structure, but they did not.

The level of the discount rate in the economic evaluation of energy technologies should reflect the risk related to an individual project. However, the risk is recognised in the majority of publications is typically assigned to a company. Moreover, it is usually given as aggregated single value, thus it is rather impossible to figure out which uncertain project parameters primarily correspond to the discount rate selected. A question arises then: what is of the structure of that rate and, consequently, their risk components? No available publications regard this issue, so this is a research gap; an unexplored topic revealed during a literature search is also issue of discount rates at different stages of energy project development. Correspondingly, the purpose of the paper is to analyse this issue with respect to the cost of equity for onshore wind investments in the Polish conditions. According to that we propose methodology for the analysis of risk levels that estimates the constituent components of the cost of equity used in DCF calculations of onshore wind projects. We find it to be an important contribution to the issue of the economics of renewables.

2. Methods

To answer the question presented above, in reference to the specific technology (here: the onshore wind technology) it is necessary, first of all, to determine the level of the discount rate for a particular project development stage in a form convenient for further analyses and, secondly, the risk product related to the individual parameters influencing the efficiency of onshore wind investments [20]. The used methodology is analogous to the one applied in the work pertaining to the cost of equity in the coal power sector [21] based on the approach proposed by Smith in the base-metals industry [22].

The discount rate, most frequently analysed in publications, is the weighted-average cost of capital which, according to economic theory, is a suitable finance parameter [18,19,23–25]. Companies usually use a combination of equity and debt financing. The after-tax *WACC* is calculated according to the formula

$$WACC = CoE \times V_e + CoD \times (1 - tax) \times V_d \tag{1}$$

where: *CoE*—cost of equity ≡ risk-adjusted discount rate, RADR; V_e—proportion of equity in investment financing; *CoD*—cost of debt; *tax*—corporate tax rate; (1 − *tax*) means the tax shield; V_d—debt share in investment financing. Of course, in the pre-tax version, there is no (1 − *tax*) component in Formula (1).

The WACC rate, unfortunately, does not form a convenient basis for any comparisons due to the fact that is comprises the weighted debt rate. The range of debt financing is different in individual countries: for example, in the EU member states it ranges from 55% in Sweden and Romania to 85% in Ireland and Germany [26]; credit interest rates range from 1% in Germany to 11% in Greece. In Poland, the share of debt in investment financing is 65%, whereas the average credit interest rate ranges from 4% to 6.5% [27].

The interesting to us component of WACC is cost of equity (CoE), or risk-adjusted discount rate (RADR). CoE is the return that a company requires for an investment or project; it reflects the gratification the financial markets require in order to:

(1) own the asset and
(2) take on the risk of ownership

Cost of equity is higher than cost of debt, because equity capital is more expensive. Since cost of debt is an external factor, CoE is the only discount rate which can be profoundly analysed in terms of risk of a project.

Thus, when speaking about investments in wind farms, the nominal cost of equity in the European Union member states recently ranged between 4% in Germany to 15–20% in Latvia (Figure 1), whereas in Poland from 9% to 11%. According to Damodaran [28], the average cost of equity (and thus the level of risk) for the European companies from the sector defined as 'Green and Renewable Energy', where wind power has a significant share, is systematically dropping: from 10.27% in 2015 to 5.93% in 2020 (nominal). This cost for individual companies is calculated according to the CAPM formula

$$CoE = RADR = R_f + \left(R_m - R_f\right) \times \beta \tag{2}$$

where: *CoE*—cost of equity ≡ RADR—expected return from *i* assets, R_m—expected return from market, R_f—risk free rate, β—beta coefficient for asset *i*.

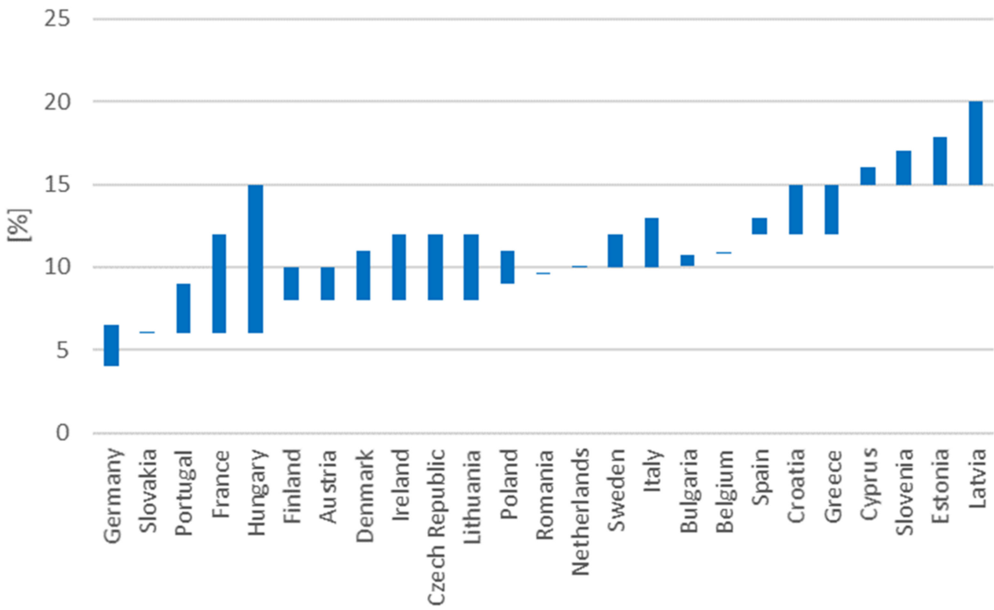

Figure 1. Cost of equity (2016) of an investment in wind energy in the European Union [26,27]. (Luxembourg and Malta—no data).

The risk-free rate, R_f, is calculated based of returns from risk-free securities (T-bills or/and T-bonds). The level of the rate changes along with the economic situation and monetary policy of individual EU member states.

The factor complicating the interest rate analyses of is inflation. Due to this, the authors of the paper decided to present these rates as real values.

Taking into account:

(1) the data referred to in the papers about discount rates [11–13,17,19–21,26,27,29–31],
(2) discussion with some renewable energy analysts,

the nominal cost of equity of onshore wind farm projects at the feasibility stage—in the Polish conditions—could be determined, on average, at the level of 10%.

All of the above-listed assumptions:

1. analysis of the investment at the feasibility stage;
2. 100% equity cash flows;
3. zero inflation,

allow for extracting a convenient substrate of the cost of equity ('bare bones') for all analyses and comparisons.

Bearing the above in mind, it is possible to analyse the structure of such rate and the range of individual uncertainties (risks) which are expressed in its components.

The risk-adjusted discount rate (CoE, RADR) comprises the following elements:

1. risk-free rate;
2. specific risk;
3. country risk;

In the case when the nominal discount rate is analysed, the result has to be increased by the rate of inflation, in line with Fisher's formula

$$R_n = [(1 + R_r)(1 + i)] - 1 \tag{3}$$

where: R_n—nominal interest rate, R_r—real interest rate, i—inflation.

The differences between the CoE/RADR rates presented in Figure 1 result from different specifics of individual EU member states with respect to adaptation of the wind technology and from various level of the risk-free rate in these countries.

It is worth underlying, that when adopting any financial-type parameters, it is necessary to take the future and not the past into account. However, the history may be a good point of reference for the future—in particular for long-term projects. Thus, when forecasting the risk-free rate in Poland for the upcoming decade, the relevant annual rates of return from 10-year bonds with annual average inflation rates according to Formula (3) were calculated. The long-term real risk-free rate, forecasted for the wind power plant lifetime and attained by averaging the results above, is on the level of 2.35%.

The expected real cost of equity of wind energy investments in Poland was calculated by reducing the nominal RADR in the amount of 10% by inflation (calculated as the long-term average) in line with Formula (3). The cost is on the level of 7.65% after-tax, which means that the real specific risk of onshore wind investments is on the level of 5.30%. Along with development of the project and information in-flow, the CoE/RADR (and thus the share of specific risk) will decrease: at the operating stage to the value of approx. 5.0–5.5% [32].

For the needs of the paper, a cash flow base case for a typical onshore wind farm project in Poland was developed, adopting the following premises:

1. installed capacity of the wind farm: 90 MW (45 wind turbines);
2. project lifetime: 25 years [5,29,32], where:
    - investment period: 3 years;
    - operating period: 22 years;
    - decommissioning: in the last (25th) year of the project life;
3. capital expenditures, CAPEX: 5.5 M PLN/MW [33,34]; distribution of CAPEX [17,24,35–37] as follow:
    - year 1–2% CAPEX;
    - year 2–18% CAPEX;
    - year 3–80% CAPEX;

    (CAPEX, after deducting the salvage (residual) value, were subjected to straight-line depreciation/amortization);
4. working capital: 6.03 M PLN (8.33% of annual revenues) [36]; spending—year '0', recovery—year 25;
5. operating expenditures, OPEX: 0.1445 M PLN/MW [17,24,36–38]; given the high share of fixed costs, OPEX were compared not to the unit of produced energy but to 1 MW of installed capacity;
6. decommissioning cost: 0.6 M PLN per turbine [39];
7. salvage value: 0.288 M PLN per turbine [39,40];
8. capacity factor, CF: 0.36 [16,41,42]; the factor was selected in relation to the advancement in wind technology with an assumption that in reference to the reduction of power generated by the wind plant along with time and technical wear and tear [5], it is going to decrease from the 15th to 19th year of the project lifetime by 0.1 annually (and from the 19th to the 25th year by 0.2 annually—to the final value of 0.23).

When comes to the electricity prices, it must be emphasised that in Poland the auction system supporting the renewable energy sources has been functioning since 2015. The participants who offer the lowest energy price and whose bids jointly do not exceed 100% of the value or the amount of energy specified in the auction notice and 80% of the quantity of electricity covered by all of the submitted bids win the auction. The support is granted for 15 years, whereas the auctioned amount is indexed year by year with the annual consumer price index. The electricity prices in the project in question were defined according to own forecasts, taking the results of auctions from 2018–2020 into account [43]. The price, in constant zlotys, for the entire operating period was adopted at the level of PLN 255.00 per MWh.

Among the parameters mentioned above, the following key risk parameters of the project were identified:

1. CAPEX;

2. capacity factor (CF);
3. electricity price;
4. annual operating expenditures (OPEX);
5. project lifetime.

To estimate the volumes of the risk components within the cost of equity, an analogous methodology for determining the components of the risk-adjusted discount rate, RADR, for projects implemented in the traditional coal-fired technology was used [44].

The starting point of the methodology is the concept that a measure of risk is the product of uncertainty and consequences

$$Risk = UnCrnty \times CnSqnce \tag{4}$$

Uncertainty ('*UnCrnty*') is the state of ignorance that may be reduced as a result of attaining a greater amount of information and number of data. Naturally, if the parameters with greater variability strongly affect the project's efficiency, it is said that they constitute significant risk factors. If, on the other hand, that influence is not great or the range of variability is narrow, then the risk related to such parameters is not high.

It is hard to precisely define the '*UnCrnty*' factor, yet in the statistical sense, it may be understood as the spread or variance of the probability distribution. *UnCrnty* can be then expressed as the range of error or the level of accuracy of a parameter. On the other hand, consequences ('*CnSqnce*') are the effects of impact of a parameter on the measure of a project's efficiency (here: internal rate of return, IRR—as this indicator is expressed as a percentage and may be directly referred to the cost of equity). *CnSqnce* may be measured by the tangent of the curve slope angle on the spider diagram in the classic sensitivity analysis. In case of strongly curved lines, it is possible to use the average tangent values of slopes of individual sections of the curve in the centre of the diagram.

The accuracy of assessment (*UnCrnty*) of key parameters was assumed as follows [32,34,45,46]:

1. CAPEX—±15%,
2. CF—±10%,
3. electricity price—±10%,
4. OPEX—±10%,
5. project lifetime—±5%.

3. Results

In the discounted cash flow spreadsheet, all calculations were made in constant Polish zlotys, PLNs, applying the real CoE/RADR in the amount of 7.65% (without country risk). It does not mean, of course, that 7.65% should be used for all onshore wind projects at the feasibility study—it was chosen just as a base.

Evaluation was made on all equity basis. The resultant net present value, NPV, in the base case amounts to 7.90 M PLNs, whereas the internal rate of return, IRR, is at 7.88%. Given that NPV > 0 and IRR > CoE/RADR, the project is feasible and thus should be implemented immediately.

Applying the proposed methodology, a sensitivity analysis was performed in line with the *Ceteris paribus* assumption to examine the change in the IRR in response to the changes of the key parameters adopted—in every case by ±10%, 20%, and 30%—and transferring the results to the spider diagram.

The results (Figure 2) indicate that the project's IRR is most sensitive to changes of electricity prices and the capacity factor, whereas it is least sensitive to the changes in operating expenditures. High sensitivity of the IRR to changes in the CAPEX is interesting (more in the direction of potential falls than increments) along with very high sensitivity of the IRR to the downside changes of the lifetime as compared to very small sensitivity to upside changes. This is caused, to a significant degree, by the loss of efficiency of the wind turbines—especially in later years of the project lifetime. Consequently, the operators should not be induced to extend the lifetime of a wind project, but they should definitely eschew its decommissioning ahead of time.

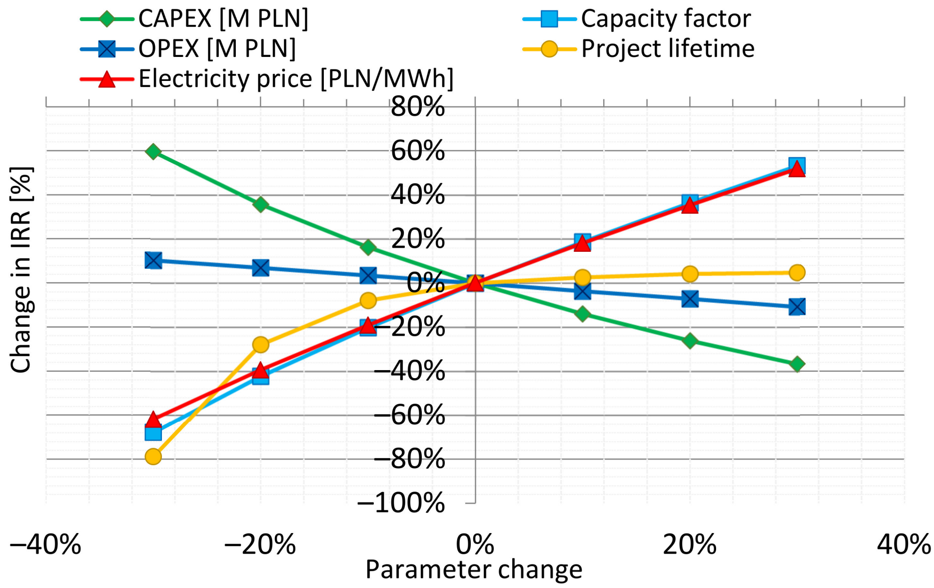

Figure 2. Sensitivity of IRR to key parameters of the typical wind project in Poland.

To calculate the *CnSqnce* values for individual variables, tangents of the slopes of sensitivity curves to the *x*-axis were calculated. Given the fact that the impact of individual risk factors is aggregate, all tangents of the slope of the sensitivity curves are adopted in the form of absolute values. By multiplying the values of *UnCrnty* and *CnSqnce* for every key variable, the value of risk was received and subsequently, by calculating the relative risk, the risk component in the cost of equity—i.e., the CoE/RADR—was received. The results of analysis of risk factors within the scope of the cost of equity are presented in Table 1 and in Figure 3.

Table 1. Analysis of risk components within a 7.65% real risk-adjusted discount rate of onshore wind projects in Polish conditions.

Risk Factor	***UnCrnty* (Assessment Accuracy)**	***CnSqnce* (Slope)**	**Risk Product**	**Relative Risk**	**Risk Component**
Risk-free rate (real)					**2.35%**
Capital expenditures, CAPEX (M PLNs)	15%	1.51	0.2269	0.323	1.71%
Capacity factor, CF	10%	1.94	0.1944	0.276	1.46%
Electricity price (PLN/MWh)	10%	1.86	0.1858	0.264	1.40%
Operating expenses, OPEX (M PLNs)	20%	0.35	0.0703	0.100	0.53%
Project lifetime	5%	0.52	0.0261	0.037	0.20%
Risk portion (SUM)			**0.7035**	**1.000**	**5.30%**
Cost of equity—risk-adjusted discount rate (real)					**7.65%**

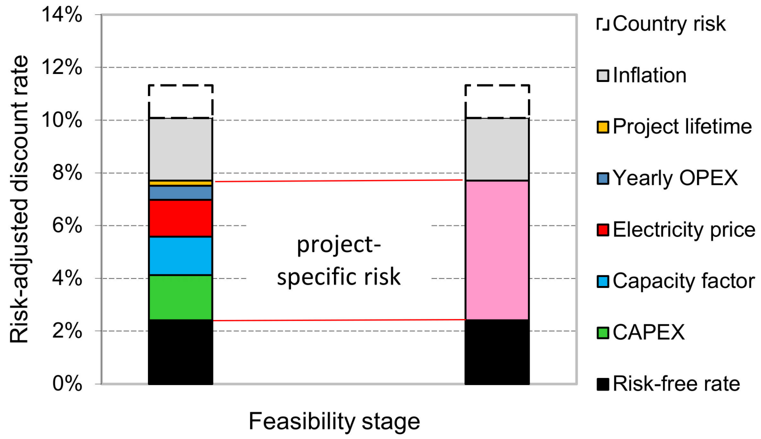

Figure 3. Key risk components of the risk-adjusted discount rate for Polish onshore wind projects at the feasibility stage.

With respect to the adopted assumptions the results show that the highest share within the specific risk of real cost of equity of onshore wind power projects in Poland (1.71%) have the capital expenditures, CAPEX, followed by—having a more or less equal share:

1. capacity factor, CF, (1.46%);
2. electricity price (1.40%).

The share of the remaining risk factors in the discount rate is slight: the component of operating expenses approximates 0.55% and the project lifetime is at 0.2%. When it comes to nominal values, the column would have to be increased by the rate of inflation, which would offer a nominal rate of 10.03%; a foreign investor would also increase such rate by the portion of the country risk (here: 1.2% [28]), which would eventually result in a nominal rate of 11.3%.

4. Discussion

The paper gives the answer as to what is the composition of risk within a 7.65% real discount rate of portions for Polish onshore wind projects at the feasibility stage. Crucial risk components are capital costs, capacity factor, and electricity price.

The obtained results provide useful information for decision-makers with respect to making decisions in the area of wind power: the greatest attention should be paid to the thought-through participation in the RES auctions and careful assessments of capital expenditures. It also implies that reducing CAPEX uncertainty investors might significantly change RADR structure, reducing risk within a discount rate mainly to combination of energy price and capacity factor risks.

As we mentioned above, risk-adjusted discount rate of 7.65% (real) is selected only as a base—it will vary over time, with risk-free rates and beta updates. It can be served, however, as a guide to make a ranking of different investment alternatives.

The concept that has been developed for the risk components analysis of a cost of equity at the feasibility study stage can be used for the evaluation of projects at other development stages—e.g., in reference to the results obtained, the analysis of the scope of the discount rate at the project's operating stage (5.5%) can be performed.

Discount rate in amount of 5.5% has been selected arbitrarily, taking into account discussion with energy companies—at this stage of the project development risk is significantly lower than at the feasibility stage. It can be assumed that at this level of project development the risk of capital expenses will resolve, whereas the assessment accuracy (*UnCrnty*) of the capacity factor, the price of electricity, the operating expenses, and the project lifetime will improve by half—the risk portions of these components will be reduced then as follows (Figure 4):

1. capacity factor—1.28%;

2. price of electricity—1.23%,
3. operating expenses—0.46%;
4. lifetime—0.17%;

altogether, with the risk-free rate, it amounts to 5.5%.

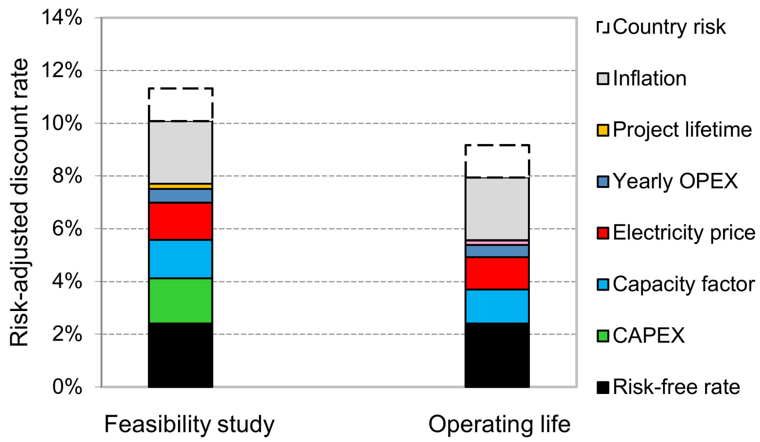

Figure 4. Key risk components of the risk-adjusted discount rate for Polish onshore wind projects at different development stages.

Then, the nominal rate will be 7.88% or, including the country risk—9.1%.

Similar analysis can be made for projects in scoping and pre-feasibility studies.

In reference to the analogous analyses carried out for traditional coal projects [23], it becomes clear that the risk factors within a similar CoE/RADR are distributed differently—in the case of traditional coal technology, the dominant component of specific risk within cost of equity was the electricity price (2.97%), which results from the fact that it is subject to market competition. Another significant portion is the price of CO_2 emission allowances (0.92%): the factor which does not occur in wind energy. The disparity of components of capital expenses is interesting: the risk portion (0.22%) related to this factor in reference to its weight in wind energy (1.71%) is slight, which is related to the amount, the technological advancement of capital assets and their significance for the efficiency of wind technology. Future research might involve gathering data that could help companies to estimate in detail the risk level of an individual project at various stages of a project. A very interesting challenge is also conducting similar studies for other renewable energy technologies.

5. Conclusions

Wind energy in Poland, in spite of the temporary inhibition of its development, has a significant growth potential, which may turn out to be invaluable when taking actions aimed at the transition to the modern low-carbon economy into account. One of the key issues that the investors have to face is the risk of the technology. Investors who put money into energy projects are expecting an adequately high interest rate, which would allow them to compensate for the minimum acceptable real rate of return from the market and the project's specific risk. That is reflected in the adopted discount rate, where the range of specific risk related to the technology used. The paper identifies key risk components within the cost of equity of onshore wind projects at the feasibility level.

In answering these questions, a decision was made to estimate the value of such a rate, and subsequently to present it in a form accessible for further research. It was decided that the analysis of the components of the discount rate is facilitated by the approach focusing exclusively on the cost of equity (risk-adjusted discount rate, RADR) after-tax. This rate reflects the real expectations of investors with respect to the project risk. It accounts for the risk-free discount rate, the project-specific risk and—depending on the purposes of the research—the inflation rate and the country risk. The analysis—assuming 100% equity in project financing—allows for concluding that the assessment refers to the inherent value of an energy project, not contaminated with the effects of benefits related to external financing.

To find out which onshore wind project parameters were the major factors of such risk, a relevant analysis of causes and effects was carried out, starting with the definition of risk understood as the product of uncertainty and consequences. Uncertainty was expressed as the assessment accuracy of key inputs, whereas consequence as the tangent of the slope of sensitivity curves of such variables (impact on changes in the IRR) on a spider diagram. Consequently, it was shown that the risk portions (real) in the cost of equity of onshore wind projects at the feasibility stage, in the amount of 7.65%, are as follows:

1. capital expenditures: 1.71%;
2. capacity factor: 1.46%;
3. electricity price: 1.40%;
4. operating costs: 0.53%;
5. project lifetime: 0.20%.

The analysis is supplemented by the assessment of risk portions within the rate characteristic for project's operating stage in the amount of 5.5%.

The research has some limits:

(1) results are rather indicative; *UnCrnty* and *CnSqnce* values should be determined for particular project individually;
(2) slopes of the sensitivity lines were averaged;
(3) variable assessment accuracies may be different for particular projects;
(4) identifying only a limited number of risk factors influencing a wind project;

Further work in this respect is of significant utility value—more extensive knowledge about the structure of cost of equity will allow for adequate commencement and more rational management of projects, as well as better understanding of cash flow evaluations and efficient risk control.

Author Contributions: Conceptualization, P.W.S., K.Z., Z.D.-P., K.S.-W. and M.M.; Methodology, P.W.S. and K.Z.; Software, P.W.S. and K.Z.; Validation, P.W.S., K.Z., Z.D.-P., K.S.-W. and M.M.; Investigation, P.W.S., K.Z., Z.D.-P., K.S.-W. and M.M.; Resources, P.W.S. and M.M.; Data curation, P.W.S. and M.M.; Writing—original draft preparation, P.W.S., Z.D.-P. and K.S.-W.; Writing—review and editing, P.W.S., K.Z. and M.M.; Visualization, P.W.S. and M.M.; Supervision, P.W.S., K.Z., Z.D.-P. and K.S.-W. All authors have read and agreed to the published version of the manuscript.

Funding: The project is funded under the program of the Minister of Science and Higher Education titled "Regional Initiative of Excellence" in 2019-2022, project number 018/RID/2018/19, the amount of funding PLN 10 788 423,16.

Acknowledgments: The work was carried out as part of the statutory activity of the Mineral and Energy Economy Research Institute, Polish Academy of Sciences and WSB University.

Conflicts of Interest: The authors declare no conflict of interest.

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