THE MODERN PORTFOLIO THEORY APPLIED TO WIND FARMS FINANCING

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Summary

The increase in the participation of wind energy in the global energy matrix observed in the last years raises the necessity to investigate alternatives to improve the economic performance of the projects. In this context, this PhD research, developed on a co-operation between the Micrositing and the Technical Due Diligence departments of the German Wind Energy Institut (DEWI GmbH) and the University of Oldenburg (faculty of Economics), will address the application of the Modern Portfolio Theory (MPT) to Wind Farms (WF). In a few words, the general objective is to investigate, by comparison with the performance of single projects, the eventual financial benefits of bundling several WF projects in a portfolio.

1. Introduction and Initial Assumptions

The Modern Portfolio Theory is traditionally a reference on the analysis of investments in financial assets like bonds, stocks, etc., which returns are always conditioned to a determined level of risk. From the economical point of view, a wind farm project is a real asset investment. Its return is uncertain and volatile [1]. In this sense, the initial understanding of this investigation is that the theoretical background of the MPT can also be applied on the analysis of investments in wind farms.

The theory proposes that the risk of financial investments can be reduced by allocating the resources in a portfolio of assets which returns are independent from each other (diversification). In the case of wind farms, the independence of the return is related to the fact that the income of one farm is directly connected to its energy production, which on the other hand, depends on aspects particular to every project, such as its geographical location (local wind regime), turbine type and energy potential calculations. Further on, the return of wind farms is a function of its fixed and operational costs, as well as taxes and the tariff paid by the project's off-taker. For these parameters, commercial issues (EPC contracts, O&M, etc.) as well as local aspects such as incentive politics for the promotion of renewable energies might significantly distinguish one project to the other.

The initial premise of our portfolio analysis is that the risk of the investment in a WF project is function of the overall uncertainty of the Annual Energy Production (AEP) of the plants. The goal is then to understand the different parameters contributing to the overall uncertainty and how do these parameters differ from one project to the other, so that a correlation between the uncertainty on the AEP of the projects can be established. As described in section 2, the lower the correlation between the uncertainties, the lower the portfolio's overall risk (eq. 2). The final step to conclude the investigation is to generate a portfolio's cash flow so that the individual economical performance of the projects can be compared to the portfolio one. The following research questions summarise the key issues that will be addressed along the work.

Research Questions:

- How much can the risk of the investment in wind farms be reduced by bundling projects in a portfolio?
- What are the main aspects of a WF project contributing to the portfolio effect (reduction of risk due to diversification)?
- What is the improvement on the overall financial performance of investments?

2. The Modern Portfolio Theory

The Modern Portfolio Theory (MPT), or "Markowitz Portfolio Selection", conceived in the context of financial assets, proposes that the expected return of a portfolio of assets (in our case wind farms) is the weighted sum (*W*) of the individual return of all single asset composing the portfolio (eq. 1). Further on, the theory states that the overall risk exposure of a portfolio of different risky assets with normally distributed outcomes does not exclusively depend on the risks of the single assets. Rather, it is increasingly dominated by the co-variance risks as the number of assets in the portfolio increases (eq. 2) [1]. Therefore, the strategy to improve the performance of investments is to build a portfolio of assets which returns are as low correlated as possible (fig.1).

To apply the MPT to WF projects means to establish a portfolio of farms, in which the individual production of the constituting plants are as much independent as possible. In other words, to combine plants located in regions with different wind regimes, operating under different conditions (turbine types, power curves, etc.).

Equation 1: Expected Return of a Portfolio

$$ER_{(Portfolio)} = \sum W_i E(R_i)$$

Equation 2: Overall risk of a Portfolio

$$\sigma^2_{Portfolio} = \sum W_i^2 \sigma_i^2 + \sum \sum W_i W_j \sigma_{ij}$$

where:

$\sigma^2_{Portfolio}$ is the variance of the portfolio;

σi, σj are respectively the variance of assets "i" and "j";

$\sigma i,j$ is the co-variance between the assets, and ρij is the correlation coefficient between farms "i" and "j".

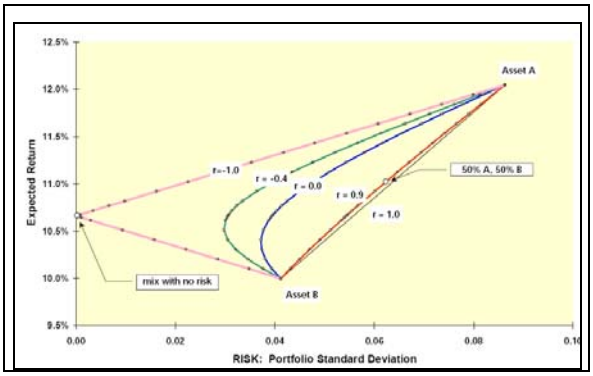

Fig. 1.: Example of a portfolio of two different financial assets (A and B). Unequal "Risk x Return" curves are generated for different correlation coefficients (r) [3].

3. Methodology of Investigation

The investigation is carried out based on case studies relying on data from wind farms in operation. The next diagram (fig.2) illustrates the research approach to be applied.

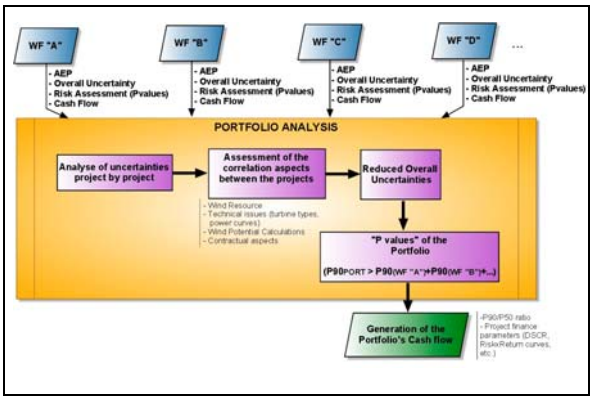

Fig.2.: Research approach of the portfolio analysis.

The input of the portfolio analysis is the information on the annual energy production, overall uncertainty, the P values and the cash flow of the single farms considered in the portfolio. The initial step is the detailed analysis of the uncertainties involved in the AEP in a project by project basis, so that independencies, or correlation aspects between the projects can be identified. From this analysis, a correlation coefficient (ρ_{PORT}) will be quantified. The expected return of the portfolio is solely the sum of expected returns of the single projects, and the risk, or uncertainty of the portfolio, will be determined according to the correlation coefficient (eq.2). With this parameters (expected return and uncertainty), P values (P75, P90, etc.) can be obtained, and consequently the cash flow.

The conclusions will be based on the comparison of project financing parameters (Debt Service Cover Ratio, IRR, NPV, etc.) between the single projects and the portfolio.

4. Preliminary Findings

Portfolio assessments developed in the past indicate that there are mainly three aspects with potential to correlate between different wind farms: the Wind resource, that here we call "geographical diversification", technical characteristics (wind turbine types and power curves) and wind potential calculations [1].

- *Geographical Diversification:* The geographical diversification is relatively simple to assess, and represents the degree of independence between the wind regime on the farm's sites. It is the factor that expresses the seasonal aspect of the farm's production. Depending on the farm location, the wind available for one project might complement the lack of wind in another one, so that the overall production of the portfolio is not so volatile as when the production of the farms is considered individually. In short words the geographical diversification can be summarised as: "if the wind is not blowing in Germany, then it may be blowing in Italy" [2].

- *Technical Diversification:* The technical diversification is resultant from the variety of wind turbine types, power curves and technologies utilised in the projects considered. By a deep understanding of the technical characteristics of the wind turbines, its suitability to the site, availability and the uncertainties involved in the determination of its power curves, it is possible to establish a correlation factor between the risks related to the technical aspects of the farms in the portfolio.

- *Wind Potential Calculations:* It is common practice by project developers to order yield assessments for the projects under investigation from different technical advisers. Although the assessments follow basically a similar approach results may vary quite considerable in some cases. A detailed analysis of the different studies can identify the independence of given assumptions as well as the resulting uncertainties, so that a certain correlation also for this aspect can be established.

5. References

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