1. Introduction

According to the Global Wind Energy Council, the accumulated installed capacity of wind power worldwide today is of almost 160,000 MW [4]. This number has been increasing at a rate of almost 25% a year since 2004. Only in the European Union wind power installations accounted for 39% of the total of new installations of power generation capacity in 2009, meaning that no other energy generation source has grown more than wind energy [4]. However, there is a general consensus that to keep the expansion curve upwards (especially in difficult markets like in developing countries), new project finance alternatives must be explored. In this sense, the work presented in this article addresses the application of the Modern Portfolio Theory (MPT) as a wind farm project risk management strategy. The research was developed in cooperation between the department of Ecological Economics of the Business Administration and Economics faculty of the Carl von Ossietzky University of Oldenburg and the Technical Due Diligence department of DEWI GmbH.

The first part of this paper shortly reviews the principles of the Modern Portfolio Theory. In the second part, an approach developed to the quantification of the portfolio effect in wind farms will be briefly introduced, and its application illustrated within two different case studies.

2. The Modern Portfolio Theory and the Approach to Investments in Wind Farms

In the practice of assets management, the payoff of an investment is described by a set of outcomes, each associated with a probability of occurrence (frequency or return distribution). The two most frequently employed attributes of these distributions are: a measure of central tendency (the expected return), and a measure of risk or dispersion around the mean (the standard deviation).

The Modern Portfolio Theory says basically that the return of a portfolio of different assets is nothing else than the weighted sum of the return of the individual assets. The risk instead is more complex. The MPT defines risk as the standard deviation of the expected return of the investment in a certain asset. The risk of the investment in a portfolio of different assets depends on whether the return on the individual assets tends to move together or whether some assets give good returns when other gives bad returns. This is because different assets are exposed into a large extent to different kinds of risk – A combination of systematic and unsystematic risks.

The systematic risk, which together with the specific risk, determines the overall risk of an asset is the type of risk which is common to all kinds of assets. It is caused by general market influences. The unsystematic risk or specific risk is by nature diversifiable.

In the case of wind farms the unsystematic risks are distinguished between technical and commercial risks.

The technical risks are related to the energy production of the wind farm, being mainly connected to the uncertainty around the availability of the wind resource and the technical performance of the wind turbines and the wind farm itself. The commercial risks are linked to aspects like the applied tariff, supply contracts, grid connection requirements, legal aspects like licensing, land use rights, etc.

Commercial risks are strongly influenced by local characteristics and their assessment requires a qualitative approach designed according to the investor’s own perception of risk. Technical risks instead can be assessed following a quantitative approach.

The next sections describe a quantitative approach developed to assess the reduction of the overall uncertainty around the energy production of a portfolio of wind farms once their diversification aspects are taken into account. The analysis is complemented with an investigation of key project finance parameters like the Debt Service Coverage
Ratio (DSCR) and the ratio debt to equity finance of the single wind farms and the portfolio.

3. Portfolio Effect Quantification Approach

In general words, it can be said that the return of wind farms is a direct function of their Annual Energy Production (AEP) and that the risk is the overall uncertainty around this value. Similarly to the management of traditional assets, the set of AEP outcomes associated with a determined probability of occurrence is described in the so called “Probability of Exceedance” distribution. The mean value of the distribution is the predicted net AEP (P50) and the standard deviation the uncertainty of this prediction. The P90 value is the annual energy production which will be exceeded with a probability of 90%.

Shortly summarizing, the statistics behind the distribution say that the lower the standard deviation, the higher the P90. Since most of the financing deals are usually based on the P90, the focus of the present portfolio assessment approach is on the estimation of the standard deviation of a portfolio of different wind farms and the correspondent P90 value.

The portfolio’s risk (or portfolio’s variance) is described in the equation 2.1. Assuming a portfolio composed by two wind farms “j” and “k”, \( \sigma_{jk} \) is the covariance between the return of the wind farms.

\[
\sigma_r^2 = \sum_{j=1}^{N}(X_j\sigma_j^2) + \sum_{j=1}^{N} \sum_{k=1}^{N}(X_j X_k \sigma_{jk}) \quad (Eq. 2.1)
\]

The covariance is a measure of how the returns move together. Moreover, the dependence of the returns of the wind farms is expressed by the correlation coefficient. In this sense the key aspect of the quantification approach introduced here is the determination of the correlation coefficient between the long term wind availability and the technical performance of single wind farms. An overview of the quantification approach is presented in the figure 3.1.

4. Case Studies

4.1 Estimation of the Portfolio Effect

The portfolio effect quantification approach was tested within two different case studies. The first portfolio was composed by nine “fictitious” pre-operational wind farms located in five different countries: France (WFs “F1”, “F2” and “F3”), Sweden (WF “S1”), Poland (WF “P1” and “P2”), Turkey (WF “T1”), northeast and south of Brazil (WF “B1” and “B2”). The portfolio had a total of 356 wind turbines with a nominal power of ca. 697 MW. The second portfolio was composed by nine operational wind farms all located in Germany. The second portfolio had a total of 51 turbines and nominal power of ca. 75 MW. The objective was to address the risk diversification potential of different local wind regions, as well as the complementarity of the different technical performances.

In the first portfolio, the interdependence of the wind resource available at every wind farm site was quantified by the correlation coefficients obtained from the linear regression between the long-term predicted wind speeds of the single wind farms. In the second portfolio, due to a different energy yield assessment approach, which its description is out of the scope here, the long-term corrected local wind indexes were applied in the linear regression.

In the international portfolio the predicted long-term monthly wind speeds shown a considerable weak correlation. For example, the predicted long-term wind speeds for the site “B2”, located in the south of Brazil, correlates only 2% with the wind speeds of the Swedish wind farm. Differently, the long-term wind climate of the wind farms located in Germany had a high correlation. The comparison between the correlation results evidences the potential of geographical diversification - The
distant the wind farms, the lower the correlation coefficients. In the first portfolio, the correlations between the predicted wind climates lead to a reduction of the uncertainty around this value of about 35%. In the second portfolio, the reduction of this source of uncertainty was limited to 1.2%. Once other sources of uncertainties are considered like the uncertainty on the applied power curves and the farm efficiency calculations, the reduction of the overall uncertainty of the predicted annual energy production of the international portfolio was of about 12.4%.

Moreover, due to the availability of operational data from the wind farms considered in the second portfolio the uncertainties regarding their technical performance could be reduced in about 15%, leading to a reduction of the overall AEP estimation of ca 12.9% - a result similar to the first portfolio. The similarity of the results can be justified with a short view on the relation systematic to unsystematic risks. In the first portfolio the unsystematic risk (diversifiable risk) was limited to the local wind climate of the wind farms. The uncertainty on the applied power curves, which significantly contributes to the overall uncertainty of the AEP calculations, was treated as a systematic risk. In the German portfolio however, also the uncertainties connected to the technical performance of the wind turbines were taken into account. A higher part of the overall uncertainties was composed by unsystematic risks.

Although the reduction of the overall uncertainties is similar, the P90 value of the first portfolio (portfolio) is 3.3% higher than the simple sum of the P90 values of the single wind farms (sum of all). In the second portfolio this difference is of about 1.4%. The deviation is explained by the size of the portfolios. The graphs 4.1.1 and 4.1.2 show the portfolio results.

4.2 Financial Analysis

The second part of the case studies addressed the impact of the increase of the portfolio’s P90 in its financing performance. Key financing parameters like the Debt Service Cover Ratio (rate between the available project’s cashflow to the debt service), as well as the ratio between the debt to equity finance percentages were estimated with a general financial model developed in the context of the research.

Shortly speaking, the objective of an equity investor within a financial analysis is to reduce the necessary equity to finance the overall investment as much as possible. Therefore, the part of the overall investment costs financed with a debt has to be as high as possible. In this sense, the ratio equity to debt finance of all the single wind farms, as well as of two different portfolio variants is the reference for the comparisons.

The financial model ran with basic assumptions for the investment (1.2 million Euros/MW) and operational costs (2.5% of investment costs for the...
first five years, and 5% from the 6th operational year onwards), as well as an operational life of 20 years. For the income the local tariffs were considered. The portfolio’s tariff is the weighted tariff of the single wind farms. The energy production is the correspondent P90. The graph 4.2.1 shows the debt to equity finance ratio of the single wind farms and the portfolio of the first case study. As seen, once the portfolio effects are considered the part of the investment costs to be financed through a debt increases from about 65% (all farms) to a little above 67% (portfolio). The consequent reduction of equity is equivalent to 2.5% of the total investment costs. Further on, there was an increase in the predicted internal rate of return of about 10%.

Since the financial performance of the portfolio is directly connected to its energy production, the results of the financial analysis of the second portfolio were rather modest. The debt capacity of the portfolio was shortly increased from 57.1% to 58%. The equity reduction was equivalent to ca. 1% of the total investment costs and the predicted internal rate of return increased in about 5%.

In general, the financial analyses have shown that it is practically impossible to define a “rule of the thumb” linking the increase of the P90 value to the improvement of the DSCR or the debt to equity ratio of a portfolio of wind farms. The financing conditions of a portfolio are extremely dependent to the cost situation of the single wind farms. That is, the financing conditions of a portfolio will vary according to the individual situation of the projects included on it.

5. Conclusions

An alternative to the application of the principles of the Modern Portfolio Theory as a strategy to the reduction of the risks around the energy production of wind farms was presented in the last sections. The potential of geographical diversification to reduce the risks related to the availability of wind as a primary resource was demonstrated by the results of the first case study. Furthermore, the results of the second case study have shown that, once a sufficient historical of technical performance data is available, a reduction of the risks linked to the technical performance of the wind turbines can be achieved in a similarly way. Nevertheless, the existence of “non-diversifiable” risks still brings challenges to the financing of wind farms.

In this sense, it is important to point out that the financing performance of a portfolio of wind farms is extremely dependent to the individual performance of the single projects. In other words, a portfolio analysis is not a miracle. A “bad” project remains a “bad” project even when this project is bundled with a “good” one. For this reason, other risk management strategies, as for example, a well performed technical due diligence should be always taken into consideration.

6. Acknowledgements

This research was partially financed by the Reiner Lemoine Stiftung.

7. References