Exploiting Portfolio Effects in Diversified Project Bundles – A Quantitative Analysis of Potentials and Implications for Financial Engineering

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Abstract:

Wind farms represent long term and capital intensive real asset-investments under uncertainty which regularly require leverage through debt to meet the return expectations of equity-investors. These returns are i) uncertain and furthermore ii) volatile. Especially the financing phase will remain subject to uncertainties and the operating phase is exposed to asset-specific risks. Bundling wind farms into portfolios allows reducing both, uncertainty and risk. Depending on the selected farms taken into the portfolio, the inherent uncertainties will more or less set off against each other and parts of the volatility's covariance-risk will diversify. This reduces the portfolio's overall risk exposure at constant return expectations and therefore increases the debt capacity of the portfolio. The rise in debt capacity (at the same degree of risk) allows leveraging significantly the expected equity yields, hence exceeding by far the cumulated value of the single farms. In the P95-scenario, the debt capacity of the investigated portfolio based on 15 years of cash flows (CFs) increased by 17% compared to the sum of single solutions and the net present value (NVP) calculated at an equity discount rate of 12.5% rose by 19%.

To quantify the additional financial value generated through risk reduction, an existing financial model called 'Modern Portfolio Theory' or MPT (Markowitz, 1952) proves to be applicable because it's underlying assumptions are satisfyingly fulfilled. Using a standard model brings the additional advantages of a simple, fast, comprehensive and analytical quantification of the most important diversification effects without demanding further education. Thereby the trade off between precise theoretical methodology and concrete practical constraints and requirements takes a key role in qualifying the applicability of MPT on real assets. The extent of risk diversification faces practical and theoretical limitations. Explicitly, only the major contributors to overall uncertainty are assessed. The complex task of monitoring, controlling and optimizing all of the very different types of existing risks in wind farm portfolios is not covered.

Keywords: portfolio selection, non-recourse financing, risk and uncertainty, project default analysis

Diversification, Value Creation & Comparability

In order to make the process of creating additional financial value more transparent, the different levels of diversification and their contribution to the value generated are shown.

Methodologically, diversification can be categorized into:

1) "horizontal" diversification of technological, methodological and temporal uncertainty (uncertainties tend to diminish over time as operational data is available)
2) "horizontal" diversification of the governing wind regimes and their volatility (long term volatilities tend to be relatively stable over time)
3) "vertical" diversification of cash flows through goal-oriented contracting (revenues are mainly given, only costs can be optimized through contracting)

Further substantial sources of potential value creation through portfolio bundling are:

4) increased leverage through adequate (probability based) credit structuring
5) extended access to more major capital markets and improved lending conditions and
6) reduced transaction costs, time to execution and other substantial economies of scale

To prevent any dilution between the diversification effects and the latter factors and to make the portfolio-solution comparable to single solutions it is necessary to freeze the factors 4)-6) (ceteris paribus) and keep them constant in all scenarios. Therefore the actual financings have been neglected and all single farms are assumed to be optimally financed and structured. This fictional view guarantees a pure value based assessment and the comparability of the results.

Table 1: Overview of the Main Properties of the Wind Farms considered for the Portfolio Assessment

	Bougainville	Bütow-Zepkow	Merdelou	Quenstedt	Weenermoor	Portfolio
WT Type	6 E66-20.70 2 MW	22 DeWind D4	12 Nordex N60	8 Tacke TW 1.5s 1.5 MW	8 Enercon E66 1.5 MW	
Installed Power	12 MW	13.2 MW	15.6 MW	12 MW	12 MW	
Hub height	98 m	70 m	46 m	65 m	65 m	
Energy yield result	24.6 GWh	24.2 GWh	45.2 GWh	22.4 GWh	25.1 GWh	141.5 GWh
Related Overall Uncertainty	13%	16%	18%	15%	14%	12%
Yearly Variability of energy yield	11.4%	11.1%	10.9%	9.6%	10.5%	6.6%

Relevance of Diversification or Risk Reduction

Wind farm projects and portfolios in the wind energy industry are growing in size, number and volume, thereby increasing their absolute risk exposure in terms of millions of Euros at risk. This alone should provoke the need to manage and reduce 'actively' these risks for all involved parties (lenders, owners, developers) to avoid the potential negative implications on the economics.

Another currently relevant factor impacting the business case of a wind farm is the high worldwide demand in turbines that corresponds with their increasing prices.

Especially in Germany, the annual decrease in the tariffs of 2% is also disadvantageous for the project's profitability. If the production costs tend to increase while sales-prices tend to decrease then automatically margins will be shrinking. One the other hand there is competitive pressure to cope with the industry's growth rate. Portfolio-financing helps to activate inaccessible or hidden financial value and can potentially deliver the additional margin needed to compete.

Debt Capacity & Default Probability

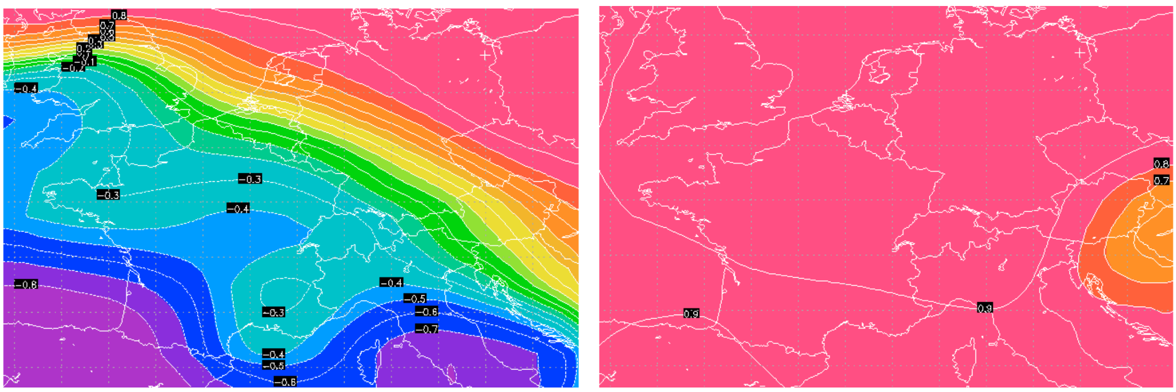
Investment decisions and loan extensions will due to 'Basel II' increasingly become more risk-sensitive and be based on probability measures like expected returns and the risk (standard deviation) associated to them. Less risky returns will consequently allow higher leverage because they have higher probable returns at the same level of risk and therefore promise also higher equity yields. Theoretically, probability based sizing of debt capacity is a straightforward matter if all probability distribution of each 'cash available for debt service' (CADS) can be defined for all payment-dates. Then, to every lender's individual risk-aversion (equal to one minus the accepted default probability) the adequate risk-premium can be derived using market data. Thus not only debt sizing but also transparent pricing is theoretically possible. Since wind farms have a comparatively simple business case the determination of the probability functions of CADS at each payment date is by far much easier than for most other types of assets. The main reason is the unbiased and independent nature of the main overall-uncertainty contributors namely technology (mainly responsible for uncertainty) and wind (mainly contributing volatility).

In the analyzed portfolio the probability distributions for 15 years of CADS (equal to typical credit tenors) were determined based on a very conservative accepted default probability (DP) of only 5% (equal to a P95-scenario) before possible cash reserves or more competitive letter of credits (LCs). The debt capacity was derived by discounting the P95-CADS of all 15 years with the corresponding debt interest rate. This view is equal to a P95 based funding at a dept service coverage ratio (DSCR) of 1.00. While the more common DSCR-based banking standard approach is different to the approach of defining an accepted default probability (DP) ex ante, the DP-approach is much more in accordance with the financial market theory and furthermore has the advantage to make the pricing and sizing procedure fully comparable. Repeating this method for all single wind farms and the portfolio as a whole returns the differential that can be achieved by financing a portfolio instead of single farms. Depending on varying equity return expectations such an increase in debt has massive effects on the NPV.

Mechanisms of Diversification

The essential message of Markowitz' 'Portfolio Selection' or 'Modern Portfolio Theory' (MPT) concludes that the overall risk exposure of any combination or portfolio of (n-many) different risky assets with normally distributed outcomes does not exclusively depend on the (n-many) single risks of the single assets. It is increasingly dominated by the (2[½(n^2–n)]-many) covariance-risks as the number of assets (n) in the portfolio increases. MPT exploits the comfortable statistical properties of the assumed normally distributed variables to derive the expected return and the associated risk of the resulting portfolio. Looking at the mid to long term profitability and stability, annual periods seem to be sufficient for default probability analysis purposes since cash

Figure 1: Evaluation of the wind speed correlation coefficient (R, monthly basis) in Central Europe. Left: year 2001, right: year 2003.



shortages within several years are buffered by mandatory cash reserves or LCs yielding additional interests to lenders and improving the equity owners net present value (NPV).

Expected Return of a Portfolio:
=Mean of Portf. =Sum of weight. single Exp. Returns
=Sum of weighted single Means

1.1 $E(R_{Portfolio}) = \mu_{Portfolio} = \sum w_i E(R_i) = \sum w_i \mu_i$
where: $\sum w_i = 1$; w_i = weight of i

Variance of a Portfolio:
=weighted single Variances + weighted Covariances

1.2 $\sigma^2_{Portfolio} = \sum w^2_i \sigma^2_i + \sum \sum w_i w_j \sigma_{i,j}$; $i \neq j$; $i, j \ni N$
where: $\sigma_{i,j} = \sigma_i \sigma_j \rho_{i,j}$
$= \sum \sum w_i w_j \sigma_{i,j} = \sum \sum w_i w_j \rho_{i,j} \sigma_i$
where: $\rho_{i,j} = \sigma_{i,j}/\sigma_i \sigma_j$

Economically both, the profitability and the stability of a portfolio are determined by:

a) the expected or most probable return (P50) of each single farm in the portfolio which is to a great extent - except costs - externally given by technology, wind (and also the tariff system)
b) the (overall-)risk associated to each single wind farm return defined as the possible deviation from the expected return also mainly given externally by the same factors
c) the correlations between each single farm's expected return to each other, defined as the inclination of the single farm returns to develop into the same direction which can be changed by altering the composition of the portfolio i.e. pooling other farms and
d) the weights of each single farm contributing to the portfolio which can only be changed very marginally because of external constraints like permissions or laws

These factors determine in their interplay the extent and its probability to undercut (risk) or overshoot (chance) the expected return of the whole portfolio.

The expected return of the entire wind farm portfolio (1.1) simply equals the sum of the expected returns of all single wind farms. The overall risk or standard deviation of the portfolio (1.2) comprises not only the sum of all the single farm risks but also the covariance risk that quantifies the risk that all the single farm returns develop into the same direction. With a growing number of farms in the portfolio, the portfolio's risk will depend less on the (cumulated) single variances of each single farm, it becomes dominated by the multiplicative covariance-risk. With regard to the mid- to long-term overall risk exposure of a portfolio, an accurate project selection will affect the profitability and economic stability of the portfolio. According to MPT, diversification can be optimized by combining such farms or assets which exhibit low or in the best case negative correlation or covariance.

Therefore, investment decisions for new projects do not only demand a risk-oriented evaluation of each new single wind farm project. They also require an evaluation of the entire wind farm portfolio's risk exposure and the impact on it, if a new project is added.

Portfolio Diversification in a Case Study

DEWI and ENERTRAG's financial department (ESF) investigated the effects that result from combining five existing and operating wind farms spread from the north of Germany down to the very south of France (Table 1). DEWI elaborated which farms of ENERTRAG's existing projects would suite a portfolio targeted to bring substantial improvements in the economics and identified five farms by assessing the potentials of uncertainty reduction and wind regime balancing. The different timing perspectives and their effects were taken into account as well. The first calculation of these desired effects were done on a data base equivalent to a preoperational stage of knowledge. The second calculation used existing operational data to verify the initial results.

ENERTRAG quantified the risk reduction induced by the legal and contractual agreements that affect the cost-structure and their correlation to sales and translated the engineering data inputs into financial terms and quantified the economic implications. The results are surprisingly positive, confirm the theoretical concepts, their applicability and estimations and strongly support and promote further engagement in this field.

Technical & Wind Assessment

The mechanisms leading to the portfolio effect were analyzed by the DEWI expert acting as technical and wind adviser. The main considered portfolio aspects are the following:

- **Independence of wind variations**. As the wind farms are spread over a large area in Central Europe, the degree of independence of the wind variations at the different sites was significant. The principal effect is shown in Fig. 1, where the correlation coefficient of the monthly wind conditions with a certain point in Germany is evaluated for two different exemplary periods. The correlation depends highly on the large scale meteorological conditions, e.g. in 2001 the wind conditions in Southern France where anti-correlated, whereas in 2003 the correlation over large parts of Central Europe was exceeding 90%. Hence, even if the operational data from wind farms are available, the correlation and dependence of the wind potential can only be assessed based on careful evaluation of long term data and the creation of a site specific energy yield index. In Table 2 the results of this assessment is shown. A correlation coefficient between the monthly energy yield between –1% and 85% is found. The variability of the monthly energy yield is between 30% for Merdelou (which is a complex terrain site with steady and high wind speeds) and 49% for Bougainville, in the mean 39%. The partial independence of the wind variation leads to a variability of the portfolio output reduced to 29%. The values for the yearly variability amount to 6.6%

Table 2: Correlation coefficient (R) and variability of the expected respectively actual monthly energy yield

	Bougainville	Bütow	Merdelou	Quenstedt	Weenermoor
Bougainville	100%				
Bütow	33%	100%			
Merdelou	42%	-1%	100%		
Quenstedt	58%	85%	8%	100%	
Weenermoor	49%	80%	1%	83%	100%
Monthly Energy Yield Variability	49%	41%	30%	38%	43%

for the portfolio and 10.8% for the sum of the projects.

- **Technical diversification**. The variety of different wind turbine types, technology and power curves in the considered portfolio (Table 3) leads to a distinct reduction of the portfolio uncertainty. The technical aspects and power curve uncertainties related to the site conditions were assessed for each wind farm and the overall portfolio uncertainty was derived considering the dependency of the different components.
- **Wind potential calculations**. Due to the fact that the wind potential calculations for each of the projects has uncertainties which are connected to the site specific properties (site measurement, calculation methods etc.), a certain independence of the uncertainties can be found also, which can be assessed with profound experience on base of the available wind studies. Generally the existence of different studies with different methodologies can further reduce this uncertainty component. A further important measure to reduce this uncertainty is the evaluation of available operational data, which was not performed for the presented work, as it focuses on the advantages for the *prior*-installation assessment was be shown. If however the operational data would have been taken into account, the uncertainties of each energy yield and hence also the overall portfolio uncertainty would further reduce.

The assessment of the uncertainty components and an extensive matrix of risk components and interdependencies between them was the main output of the wind and technical assessment, serving as base for the financial assessment.

Table 3: Overview of the Main Properties of the Wind Farms considered for the Portfolio Assessment

Wind Turbine Type	Power Curve	Site Specific Uncertainties overall	statistical (Kat. A)	systemat. (Kat. B)
Enercon E66-20.70	measured	6.6%	1.4%	6.4%
DeWind D4	theoretical	10.0%		10.0%
Nordex N60	measured	5.9%	0.4%	5.8%
Tacke TW 1.5s	measured	7.9%	1.8%	7.6%
Enercon E66-1.5	measured	5.0%	0.8%	4.9%

Assessment of Financial Implications

ESF - ENERTRAG Structured Finance took DEWI's annual results and integrated them into an annual cash flow model to derive from DEWI's annual probability distributions of annual energy production (AEP) the annual probability distributions of CADS which are necessary to enable a probability-based debt sizing. Looking at annual figures enables the strong simplification regarding the complex issue of seasonality or, time variability of risk parameters (introducing conditional heteroscedasticity). But due to standard credit conditions, lenders regularly demand quarterly and semi-annual periods (ERP/DtA). But still it is sufficient to prove that annual periods can serve the debt service since LCs or reserves are in place to bridge short term liquidity shortages. LCs or reserves can properly be sized by applying the proposed DP-approach instead of the more common, time-indifferent lump-sum-sizing.

The approach is straightforward. The timing and amount of annual energy production (AEP) determines the duration (and the level) of the tariff so that revenues can be depicted as a function of AEP. Than costs have to be assessed as bivariate variables (amount and timing) which is a highly individualized procedure. But generally costs (in the sense of cash out-flows) can be split up in fixed costs without volatility and variable costs exhibiting fluctuation. Major cost contributors are O&M, Land Leases and Insurance. In this case O&M was a direct function of net AEP and is therefore fully anti-correlated to AEP. This reduces significantly the volatility of CADS and also returns. Cumulated fixed costs have no or negligible effects on the absolute standard deviation of CADS. The residual variable costs (except taxes) will not correlate to AEP in the long run since wind develops independently from the bills of lawyers, consultants, services or others. But for a conservative estimate these marginal costs can be assumed to correlate fully to revenues (and to each other). Taxes are different. They will clearly correlate negatively analogous to O&M. In this case, a Monte Carlo Simulation of an operations-research model describing the cash-flows was used to generate a data base to derive necessary means, standard deviations and correlations for all variables in the cash-flows. For a conservative and simplifying estimate they can also be assumed to correlate fully to revenues.

Based on the means, standard deviation and correlations of the five most important cash flows (CFs) for each annual period, the probability distribution for each annual CADS was derived using a (5 Projects x 5 CFs) x (5 Projects x 5 CFs) correlation-matrix including:

+ Revenues (Tariff x AEP assessed by DEWI)
- O&M (anti-correlated by contract & volatile)
- Variable Costs (uncorrelated by assumption)
- Fix Costs (uncorrelated by definition)
- Taxes (negatively correlated & volatile

= annual CADS:

Note: annual means and standard deviations of CADS determine the debt capacity of each single project and also of the portfolio.

The diversification of cash flows generates only 3% of the total increase in debt capacity of 17% but it is statistically significant and adds to the total effect. Another important but neglected factor to reduce the standard-deviation in CADS and increase the debt capacity is liquidity management or the ability to manage the dates of payment. This has been neglected because it is difficult to quantify the implicitly necessary management skills.

Conclusion

Results – For the considered portfolio, the debt capacity was a 117% of the sum of debt capacities of all single farms. In other words: the well selected pooling of wind farms allowed an increase of debt by 10.6 million to 72.6 million in the portfolio compared to 62.0 million for the cumulated single solutions. The NPV increased by 19% from 17.9 million to 21.3 million based on an equity discount-rate of 12.5%. Higher discount rates tend to increase the NPV-differential.

Discussion – Portfolio-financing has often been discussed but quantifications are rarely found. Following the theoretical approach of Markowitz (1952), the risk reducing effects of portfolio bundling have been quantified from a preoperational perspective that is typical for the financing phase. The debt capacity and the value of equity was derived for i) the portfolio-solution and ii) the single solutions. It has been shown that:

a) the predicted risk reduction was in accordance with real observable production data
b) the technical and methodological diversification contributes a major part of risk reduction during the financing phase
c) the uncertainties will further diminish with evaluation of cumulating operational production data
d) in the financing phase, the wind regime diversification can be as important as the technical diversification depending on a suitable selection
e) the cost-structure of the projects can contribute to an decrease in the overall risk
f) the portfolio's overall risk-reduction allows major improvements for its debt capacity
g) the increase in leverage explicitly engineered to have no effect on the default probability helps to improve significantly the return on equity and its net present value.

Recommendations – about the farm selection process:

1) To achieve high diversification in the uncertainty it is advisable:
   a) to reduce technical uncertainty to bundle farms with different types of turbines to lower the correlation between power-curve uncertainty and important technical factors
   b) to reduce methodological uncertainty by combining different data bases and methodology
   c) to exploit the temporal dilution of uncertainty to combine Greenfield assets with existing but relatively new wind farms that are already in operation for some years.
2) To achieve high diversification in the volatility of the different wind regimes it is advisable:
   a) to quantify the correlations between different existing and possible new farm locations
   b) to select those locations or wind farms that exhibit low or negative correlations in AEP
3) To achieve high diversification in the cash flows it is advisable:
   a) to increase or maximize the proportion of variable costs that correlate negatively to sales (practically major costs like O&M should be fully dependent on revenues or net-AEP)
   b) to increase or maximize the proportion of fixed costs in the residual share of costs (practically major costs like land leases should be contractually defined as fixed costs)

Note: costs are understood as such causing cash out flows i.e. affecting the periodical liquidity

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