



OPPORTUNITIES AND RISKS IN WIND ENERGY FINANCE: TESTING VOLATILITY FOR TURBINE MANUFACTURERS

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ABSTRACT

Opportunities and Risks in Wind Energy Finance: Testing Volatility For Turbine Manufacturers

This paper studies several risks involved in financing wind energy projects and alternatives for financing the projects. Since the projects have high initial costs, they need to be leveraged heavily typically in project finance transaction. The paper includes an empirical analysis of major wind turbine manufacturers which helps to better understand the industry dynamics. The data used in this study is Volatility Index of S&P 500, and major wind turbine manufacturers namely Vestas Wind Systems A/S closing value in the Copenhagen stock exchange, Xinjiang GoldWind Science & Technology Co., Ltd. closing value in the Hong Kong stock exchange, and GAMESA closing value in the Frankfurt stock exchange. The research period is between 8 October 2010 and 6 July 2015. The data is daily and the total number of data is 1193. The long term relationship between the variables is analyzed with Johansen's Cointegration methodology. This indicates that there is a long-run relationship between the stock exchange volatility and wind turbine manufacturing firms' performance. For the short run analysis a VECM is developed. Granger causality analysis is also provided. This suggests there is no causality in neither ways between VIX, and firms' stock market value namely VESTAS, GOLDWIND, and GAMESA. This shows that stock market volatility fail to represent the changes in wind turbine manufacturing firms' performance in the short run although there is a relationship in the long run. This indicates that wind turbine manufacturing industry shows its own dynamics in the short run as explained in this paper. Knowledge on specific opportunities and threats for the industry especially in the field of finance is required for successful performance of the companies.

Keywords: Wind Energy, Project Finance, Cointegration, Granger Causality

JEL: C32, G32, Q42.



1. INTRODUCTION

Wind energy investment can be commercial or individual to fulfill the needs for a small house or facility. Commercial scale investment is connected to the grid and may include PPA (power-purchase agreement). A PPA guarantees the investor to sell the electricity generated at a predetermined price. This agreement can be between the investor and the government for several years. This is also important for financing wind energy projects. Creditors would demand a stable cash flow and PPA assures the sales at a pre-determined risk. This is a substantial reduction for the risks in cash flow projections.

Wind energy has more initial costs when compared with the alternatives. Public subsidies and incentives therefore determine the growth for the industry. There is however increased interest for the development of wind energy. Europe has a target to achieve 20% renewable energy by 2020.

Typical wind energy projects start by obtaining a project license from energy authority. This project can be located on a government land or a private land. The investor needs to collect data on the wind site to correctly determine the location for wind turbines and which kind of turbines can be used. The design of the site determines the efficiency of the project. Several contracts including wind turbine purchase contract need to be finalized. At this stage the budget that is subject to project finance can be determined. Once finance is obtained, equipments are ordered and then constructed on the site. Once constructed, operations and maintenance stage starts.

For financing the project, a pro-forma cash flow statement has to be prepared. Typically a sensitivity analysis and a Monte Carlo Simulation has to be prepared. This analysis is required to control the risks for deviation in projected cash flow statement. The project revenue that consists of electricity sales and project costs including initial and operations costs are analyzed in stress tests.

A typical financial arrangement is a project finance where the project is non-recourse / limited recourse. Often a SPV (Special purpose Vehicle) is the project investors whose only function is the wind project. By financing SPV, the investor only risks the specific project, if it is unable to payback the loan. The loan has a long duration often more than 10 years to meet the cash flow requirements of the project. The loan often doesn't require payment until the project starts to generate revenues. The finance is also highly leveraged. More than 50% of the project can be financed by the project loan. Although there are alternatives such as project bonds, project loans are by far the most common.

There are varieties of risks to be considered. Wind energy production is one of the core risks that is optimized in micro-siting. Electricity price is also a risk; the price in the market is volatile. However if the company has a PPA, it is not affected from market volatility. Construction is also a risk to be controlled; one should avoid the damage of the equipment during transportation and construction. For the operations stage, routine maintenance is required as it may be suggested by turbine provider. Political risks or country risks are risks specific to a specific country such as terror or change in tariff. Economic risks are those that change the cash flow of the project such as change in commodity prices like steel that is effective in turbine prices. There are also financial risks that need to be considered. The loan is often in foreign currency which leads to exchange rate risks. Financial risks to be considered are wind characteristics, price of the turbines, installation costs, the cost of power line, and cost of finance.

The remainder of this paper is organized as follows. In Section 2, some of the relevant works in the literature is given. Then the methodology and research model is presented in Section 3. The data set, and empirical analysis are available in Section 4. In Section 5, some of the important findings of the analysis are discussed. Finally in Section 6, policy and financial implications of the study are given.

2. LITERATURE REVIEW

Dalbern et al. study the structure of the wind energy market in Brazil. The market is negotiated by the government of Brazil. The negotiations allow 5-years grace period which means first electricity delivery will be 5 years after the auction is completed. The contracts are designed for 20 years which is one of the important issues for easing financing. When the prices are low, the developers are tempted to delay investment to obtain better equipment prices and wind farm knowledge. Wind farm knowledge requires years of wind data and



effective micro-siting. Typical construction start is 3 years where some sites never materialize.

The timing and cash flow projections determine the DCF- Discounted Cash Flow for these projects. There are however difficulties involved one of which is that the cost and revenue projections cannot be materialized. Possible ways to treat the uncertainty are scenario and simulation analysis. Another approach roots from the fact that managers can act by taking viable decisions depending on their expertise. They have many real life options that they can use for the benefit of the project. So the price of this option can be determined similar to financial options. This is called Real Options analysis.

The bidders that consider option of abandoning the project at the cost of 5% performance bond may bid more aggressively in the auction. The study claims that 60% of the total projects may not be materialized. Increasing penalties can reduce projects abandoned but may also increase the cost for government for projects that are realized. (Dalber et al., 2014:303-311)

Wind energy is a capital intensive investment that the government lacks especially in tough economic environment. Institutional investor is often looking for shorter pay back periods than those in renewable energy infrastructure industry. Financial citizen participation might be a solution for renewable energy finance for most of the cases. Yildiz studies this phenomena especially focusing on energy cooperatives and closed end funds. The main reasons why cooperatives are so popular in energy industry are that it allows typically low amount of investment and that it allows the investor to take part in entrepreneur decision making process. Closed end funds target more investors for most of the cases. The reason they are popular in renewable energy finance is the limited liability like corporations where investors are only liable for the amount they invest in the fund. Private individuals may therefore contribute to the realization of infrastructure projects via business models and financing concepts.

Individuals may invest in companies on their own or jointly. This may be participation by equity with voting rights where a minimum of 50% voting rights is held by the citizens. This may be realized for small scale and large scale projects. There are also debt and mezzanine finance where the investors rely less on entrepreneur success. Typical debt finance instruments are savings bonds and corporate bonds. This involves temporary limited contractual obligation with guaranteed returns. Mezzanine finance is the profit participation rights provided by project development companies. The returns are not guaranteed and investors don't deal with entrepreneur issues. (Yildiz, 2014:1-9)

Renewable energy requires special methods for financing. Some incentives include subsidies, grants and tax rebates. Major financing methods for the industry are government finance, international finance (including Clean Development Mechanism - CDM), private sector finance, micro credit and community based finance. India has witnessed exponential growth in the wind industry. The reason to this success is fiscal and financial incentives and direct financing allowed for this industry. CDM is an international tool for financing climate friendly projects as part of Kyoto Protocol. This improves cash flow, cover the risk of delayed payment by utility or increase in tariff. This also has the benefit of covering operational and maintenance costs. Government finance is crucial for the wind industry. This involves combination of government subsidy with local development funds and end user fees. Foreign aid and investment are received either for demonstration of a product with a hidden agenda of technology push or commercialization stage where return is assured. Government of India took the lead for demonstration stage of wind power so foreign aid is not so significant. International funding mechanisms such as Global Environment Facility focused on financing demonstration projects. Private finance comes in the early stage of demand driven commercialization. In wind industry private financiers have been involved in large scale projects both by Indian project developers and through joint ventures. Once private sector is involved it invests on product customization. Micro credit and community based finance are not active for Indian wind industry when grid connected wind power projects are studied. Community does not benefit directly from the wind industry therefore there is no community involvement. (Chaurey et al., 2003:249-263)

Umamaheswaran & Seth study large scale renewable energy finance in India. Renewable energy is a good alternative to produce energy while meeting climate change requirements. The policy instruments such as feed-in tariffs, renewable obligations, and generation based incentives are important in the development of the industry. Conventionally 70% of the total funding is provided as debt in India, and the rest is equity. Clean energy is financed similar to other infrastructure loans in the market. This creates an asset liability management problem (ALM) for the banking industry where the duration of deposits is between 0-5 years where the renewable energy loans have longer duration. Obtaining international funding may be also costly because the counterparty risk is high for most companies having rating less than B+. Most of the loans are issued on-balance sheet however there



is the need to finance off-balance sheet with project finance arrangements. (Umamaheswaran&Seth , 2015:166-171)

Ming et al. study the case of China for renewable energy development and financing. For them some important barriers for the wind energy are single financing channels and blindness of project investment. The government centered renewable energy investment and finance help development in early stage, but it can't be adapted to sustainable development. The major sources of renewable energy finance for wind energy finance are corporate financing, project financing and financial lease. Project bonds and third party financial services providers are lacking. Many companies especially state-owned companies prefer corporate financing. The Hong-Kong stock exchange is an important platform to raise capital for renewable energy in China. Foreign companies prefer project financing typically in a Build Operate Transfer – BOT transaction. The renewable energy industry is also actively financed by financial leases roughly 30% for China. For loans 20% of capital is required where 80% can be obtained by bank loans. (Ming et al. , 2014:23-29)

Moldvay et al. study South African wind energy industry specifically the production of the wind turbines. The local production opportunities exist however this is especially for smaller scale. For larger scale long term commitment for the wind turbine facilities from the government is needed. The major problem is the cost of raw materials, specifically steel. Full turbine manufacturing model decreases the risk of currency fluctuations, increases direct employment and is expected to offer lower pricing. This model can create however lower efficiency turbines. (Moldvay et al., 2013:315-331)

3. RESEARCH MODEL

Empirical studies using financial data almost always involve nonstationary and trending variables. If two series have a long-run equilibrium relationship, they cannot drift apart indefinitely. The deviation from the equilibrium is stationary and it has a zero mean. The combination of two nonstationary series is testable and indeed stationary. According to Engle and Granger (1987), the two series are said to be cointegrated. There are two test statistics under the Johansen which are formulated as follows. (Lizardo& Kelly, 2011:1-5)

$$\Lambda \text{ trace } (r) = -T \sum \ln (1 - \Lambda)$$

$$\Lambda \text{ max } (r, r+1) = -T \ln (1 - \Lambda)$$

In order to test for direct causality between RealClearPolitics (RCP) polling averages and the InTrade (IT) prices, we perform Granger causality tests (Granger 1969) using eqs. 1 and 2 below:

$$V1_t = \gamma + \sum a V1_{t-i} + \sum b V2_{t-i} + \mu_t$$

$$V2_t = \phi + \sum \delta V1_{t-i} + \sum \lambda V2_{t-i} + \eta_t$$

In equations above, V1 and V2 are the time series sequences, γ and ϕ are the respective intercepts, μ_t and η_t are white noise error terms, and k is the maximum lag length used in each time series. The optimum lag length is identified using lag order selection criteria, which is based on Granger's definition of causality. If in equation 1 the b coefficients are jointly significantly different from zero, then we conclude that V2 Granger causes V1. Separately, if the δ coefficients in equation 2 are jointly significantly different from zero, then we conclude that V1 Granger causes V2. It is possible that V2 Granger causes V1, V1 Granger causes V2 or that Granger causality exists in both directions (i.e., two-way causality). (Duquette et al., 2014:360)

4. DATA ANALYSIS

The data used in this study is Volatility Index of S&P 500 (shortly named as "VIX" in this study), and major wind turbine manufacturers namely Vestas Wind Systems A/S closing value in the Copenhagen stock exchange (shortly named as "VESTAS" in this study), Xinjiang GoldWind Science & Technology Co., Ltd. closing value in the Hong Kong stock exchange (shortly named as "GOLDWIND" in this study), and GAMESA (GTQ1.F) closing value in the Frankfurt stock exchange (shortly named as "GAMESA" in this study.) The research period is between 8 October 2010 and 6 July 2015. The data is daily and the total number of data is 1193.

Table 1 below show the unit root test results. The variables are first checked whether they are stationary. The tests used for this purpose are Augmented Dickey Fuller (ADF) and Phillips Perron (PP).

**Table 1: Unit Root Tests**

	ADF Test Statistic	Critical Value		PP Test Statistic	Critical Value
VIX	-2,9917	-2,8638		-4,5648	-3,4136
VESTAS	1,2638	-1,9411		1,3480	-1,9411
GOLDWIND	-1,0018	-1,9411		-0,9998	-1,9411
GAMESA	2,2048	-1,9411		2,2796	-2,8645
D(VESTAS)	-35,9831	-1,9411		-35,9853	-1,9411
D(GOLDWIND)	-27,3233	-3,4136		-35,7637	-3,4136
D(GAMESA)	-35,2290	-1,9412		-35,2233	-1,9412

The variables are then modeled in Vector Autoregression (VAR) model. For the model to be reliable, it should have the correct lags. Table 2 below indicates the lag order selection criteria. VAR(1) model is selected as indicated by Schwarz information criterion(SC) and Hannan-Quinn information criterion (HQ).

Table 2 : Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-6820.046	NA	1.203628	11.53685	11.55401	11.54332
1	-5193.154	3240.030	0.079020	8.813448	8.899260*	8.845796*
2	-5162.905	60.03934	0.077139	8.789357	8.943820	8.847583
3	-5155.455	14.73652	0.078262	8.803812	9.026924	8.887915
4	-5135.040	40.24285	0.077680	8.796348	9.088110	8.906330
5	-5123.852	21.97786	0.078316	8.804484	9.164896	8.940344
6	-5101.852	43.07029	0.077526	8.794340	9.223403	8.956078
7	-5080.654	41.35707*	0.076849*	8.785552*	9.283264	8.973168
8	-5069.534	21.61957	0.077487	8.793802	9.360165	9.007297

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

VAR(1) model with substituted coefficients is given below. The dependent variables in the econometric model are VIX, VESTAS (differenced), GOLDWIND (differenced), and GAMESA (differenced). In all equations, the dependent variables are modelled with multiple independent variables including first lags of the dependent variable itself and other variables.

$$VIX = 0.964389839356 \cdot VIX(-1) + 0.0012408809741 \cdot D(VESTAS(-1)) - 0.193464466851 \cdot D(GOLDWIND(-1)) - 0.241178941158 \cdot D(GAMESA(-1)) + 0.619915534839$$

$$D(VESTAS) = -0.0267634955191 \cdot VIX(-1) - 0.0957329619623 \cdot D(VESTAS(-1)) - 0.855523752593 \cdot D(GOLDWIND(-1)) + 3.61353618478 \cdot D(GAMESA(-1)) + 0.605260054034$$

$$D(GOLDWIND) = -0.00105472910769 \cdot VIX(-1) + 0.00553977721222 \cdot D(VESTAS(-1)) - 0.0390393648527 \cdot D(GOLDWIND(-1)) + 0.192804525111 \cdot D(GAMESA(-1)) + 0.0136113889939$$



$$D(\text{GAMESA}) = -0.000781540776056 * VIX(-1) + 0.00331553538684 * D(\text{VESTAS}(-1)) - 0.0518420877143 * D(\text{GOLDWIND}(-1)) - 0.0586814440294 * D(\text{GAMESA}(-1)) + 0.0218525389047$$

The model is then checked for stability by examining Autoregressive roots. The stability check test for the VAR (1) model is given in Table 3.

Table 3: Stability check for VAR model

Root	Modulus
0.964806	0.964806
-0.189158	0.189158
-0.002356 - 0.116730i	0.116754
-0.002356 + 0.116730i	0.116754

No root lies outside the unit circle.
VAR satisfies the stability condition.

The VAR model is often used to check for long run relationships. This can be done by Cointegration Analysis following Johansen's methodology. Table 4 below shows the Cointegration results.

Table 4: Cointegration Results

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.415713	1650.935	47.85613	1.0000
At most 1 *	0.366113	1012.010	29.79707	0.0001
At most 2 *	0.317636	469.9637	15.49471	0.0001
At most 3 *	0.012983	15.53789	3.841466	0.0001

Trace test indicates 4 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

** MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.415713	638.9244	27.58434	0.0001
At most 1 *	0.366113	542.0465	21.13162	0.0001
At most 2 *	0.317636	454.4258	14.26460	0.0001
At most 3 *	0.012983	15.53789	3.841466	0.0001

Max-eigenvalue test indicates 4 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

** MacKinnon-Haug-Michelis (1999) p-values

The variables are also tested for short term relationship using Vector error correction model. (VECM) The model with substituted coefficients is given below.

$$D(VIX) = 9.68125368262e-07 * (VIX(-1) + 70.6396954878 * D(\text{VESTAS}(-1)) + 622.129505272 * D(\text{GOLDWIND}(-1)) - 2318.89153323 * D(\text{GAMESA}(-1)) - 7.8644388496) - 0.162546498489 * D(VIX(-1)) - 0.0013409584866 * D(\text{VESTAS}(-1), 2) - 0.0454447771724 * D(\text{GOLDWIND}(-1), 2) - 0.0775222581507 * D(\text{GAMESA}(-1), 2) - 0.00195030859183$$



$$D(VESTAS,2) = -0.00608125952087 * (VIX(-1) + 70.6396954878 * D(VESTAS(-1)) + 622.129505272 * D(GOLDWIND(-1)) - 2318.89153323 * D(GAMESA(-1)) - 7.8644388496) + 0.0592598099305 * D(VIX(-1)) - 0.337060680091 * D(VESTAS(-1),2) + 0.54746452514 * D(GOLDWIND(-1),2) - 6.35954045345 * D(GAMESA(-1),2) - 0.00617994720717$$

$$D(GOLDWIND,2) = -0.000400405801404 * (VIX(-1) + 70.6396954878 * D(VESTAS(-1)) + 622.129505272 * D(GOLDWIND(-1)) - 2318.89153323 * D(GAMESA(-1)) - 7.8644388496) - 0.00390071558576 * D(VIX(-1)) + 0.0204048437999 * D(VESTAS(-1),2) - 0.361266981002 * D(GOLDWIND(-1),2) - 0.306412388564 * D(GAMESA(-1),2) - 0.0013530957606$$

$$D(GAMESA,2) = 0.000251551722443 * (VIX(-1) + 70.6396954878 * D(VESTAS(-1)) + 622.129505272 * D(GOLDWIND(-1)) - 2318.89153323 * D(GAMESA(-1)) - 7.8644388496) - 0.00131477862607 * D(VIX(-1)) - 0.00683147957794 * D(VESTAS(-1),2) - 0.147204417692 * D(GOLDWIND(-1),2) - 0.203341963861 * D(GAMESA(-1),2) - 0.000252742486798$$

Since VECM is developed, short run relationship can be analyzed using Granger causality. The results are given in Table 5.

Table 5: Granger Causality Results

Dependentvariable: D(VIX)			
Excluded	Chi-sq	df	Prob.
D(VESTAS,2)	0.022419	1	0.8810
D(GOLDWIN D,2)	0.153592	1	0.6951
D(GAMESA,2)	0.078073	1	0.7799
All	0.448135	3	0.9301

Dependentvariable: D(VESTAS,2)			
Excluded	Chi-sq	df	Prob.
D(VIX)	0.361535	1	0.5477
D(GOLDWIN D,2)	1.890429	1	0.1692
D(GAMESA,2)	44.56014	1	0.0000
All	45.05445	3	0.0000

Dependentvariable: D(GOLDWIND,2)			
Excluded	Chi-sq	df	Prob.
D(VIX)	0.365766	1	0.5453
D(VESTAS,2)	102.7982	1	0.0000
D(GAMESA,2)	24.15419	1	0.0000
All	105.4555	3	0.0000

Dependentvariable: D(GAMESA,2)			
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Excluded	Chi-sq	df	Prob.
D(VIX)	0.133462	1	0.7149
D(VESTAS,2)	37.00712	1	0.0000
D(GOLDWIN D,2)	102.4972	1	0.0000
All	117.0522	3	0.0000

5. DISCUSSION

The purpose of this paper is to investigate the relationship between the VIX and the stock market performance of the turbine manufacturers. The variables are checked to see whether they are stationary with ADF and PP methodology. Accordingly, VIX is stationary in level – I (0) and the stock market performance of turbine manufacturers, VESTAS; GOLDWIND and GAMESA are stationary when differenced I(1).

The variables are then checked for the optimal lags for VAR model. For the principle of parsimony, least lags are preferred. VAR(1) is chosen as suggested by Schwarz information criterion(SC) and Hannan-Quinn information criterion (HQ). The model is also checked for stability with autoregressive roots where no roots lie outside the unit circle. This indicates that the model is stable.

The long term relationship between the variables is analyzed with Johansen's Cointegration methodology. Accordingly, 4 cointegrating vectors are found with both Trace and max-eigenvalue. This indicates that there is a long-run relationship between the stock exchange volatility and wind turbine manufacturing firms' performance.

For the short run analysis a VECM is developed. Granger causality analysis is also provided. This suggests there is no causality in neither ways between VIX , and firms' stock market value namely VESTAS, GOLDWIND, and GAMESA. This suggests that stock market volatility fail to represent the changes in wind turbine manufacturing firms' performance in the short run although there is a relationship on the long run. This indicates that wind turbine manufacturing industry shows its own dynamics in the short run as explained in this paper. Knowledge on specific opportunities and threats for the industry especially in the field of finance is required for successful performance of the companies.

6. CONCLUSION

A project based evaluation is needed to finance wind energy. Cash flows of the project is analyzed against possible risks. One of the most important factors in the cash flow is revenues. Electricity is a non-storable commodity whose value may change in an hourly basis in the free market. This kind of volatility in the price of the output of the project creates almost a non-tolerable risk for bankability of the project. For hedging against volatility long term agreement is required called PPA (Power Purchase Agreement). This can be an offtake agreement between the government and special purpose energy company that guarantees the electricity price for several years. This is a very important reduction in the risks which is demanded for financing projects.

Project cash flow includes initial investment, operations and maintenance costs, as well as project revenues. All of these need to be predicted for a cash flow analysis. But they are subject to volatility as they realize. Sensitivity and Monte Carlo analysis are needed to test for different scenarios of changes in the values of the variables. The managers also add value to projects by contributing to important decisions. This can be treated as options in Real Options valuation.

A special purpose vehicle (SPV) is needed to finance wind energy project. This is to limit the risks for the project sponsor. If the sponsor isn't SPV, investor risks all of its assets. SPV risks only energy project shares and assets such as wind turbines.

There are many different kinds of risks in the wind energy projects. The amount of energy produced in the site should be optimized. This is done by obtaining wind data and simulating the locations of wind turbines in a process called micro-siting. There can be material loss or injuries during the transportation and construction.



Road surveys and supervision may limit those risks. Insurance contracts may also be used at this stage. Another way of transferring the risks is involving experienced contractors. Operations stage risks are also available, in which routine and additional maintenance is needed. Some turbine companies may offer service at this stage.

In addition to project finance, private individuals are also interested to invest in wind energy. This can be used to provide some funding that may reduce the cost of funding for the project. Individuals may invest solely or as a group. Sometimes individuals take part in some funds which then invest in these projects. There is also additional debt such as corporate bonds or project bonds or mezzanine finance alternatives in wind energy. Leasing and exchange based solutions are also available in most developed markets. Ex-im banking is very active in the industry due to the international nature of the projects. CDM (Clean Development Mechanism) is an additional funding for climate friendly wind industry as supported by the Kyoto Protocol.

According to the findings of this paper wind energy projects are affected by stock market volatility in the long – run. This result is not surprising due to the fact that the projects are financed by long term obligations such as project finance. However the affect of short run volatility on wind turbine manufacturing firms is statistically insignificant. Therefore wind turbine manufacturing firms should seek low cost funding especially when there is low volatility, to lower their cost of capital.

This paper studies several risks involved in financing wind energy projects and alternatives for financing the projects. Since the projects have high initial costs, they need to be leveraged heavily typically in project finance transaction. The paper includes an empirical analysis of major wind turbine manufacturers which helps to better understand the industry dynamics. The investors in this field would benefit from the several risks and tools of finance described in this paper.

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