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Weather Derivative Solutions
for Wind Farms Financing in Mexico

Feasibility Study

May 2008

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Executive Summary

Context:

The Renewable Energy and Finance Unit of the Division of Technology, Industry and Economics (DTIE) of the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF) have worked on a long standing relationship to identify promising new financial risk mitigation solutions for renewable energy projects in developing and emerging economies.

Within the framework of the request for proposal regarding the UNEP/GEF "Assessment of Financial Risk Management Instruments for Renewable Energy Projects", Marsh Finances and Paris Re have undertaken this feasibility study for the implementation of a **Wind Power Derivative in Mexico**.

Weather derivatives are closely linked to renewable energy projects: these financial instruments were developed to protect companies against the climate volatility and are applicable to Renewable Energy projects such as biomass, wave, tidal, hydropower…this is particularly the case for wind farms where the question of a **"lack of wind"** hedging is arising.

Mexico was chosen as an application country for this study among a short list of possible countries (mainly in Latin America and Africa). Main criteria used for the selection of applicable countries included: eligibility to GEF scope, wind potential to develop a wind farm portfolio, emerging development of renewable energy, political willingness and involvement.

Objectives:

A weather derivative solution, well structured and optimized, could be of interest for the acceleration of renewable energy project expansion in developing countries. The confidence of investors and particularly lenders into the ability of hedging a portion of the fuel supply risk at an efficient price could leverage the **financing conditions** of sustainable energy projects.

This feasibility study would mainly lead to:

- Help project developers to understand the benefits of an embedded weather derivative in the financial structure

- Attract weather markets and develop their willingness to provide competitive products and underwriting capacity in developing countries

- Develop lenders offering and investor's appetite, by allowing them to share the weather risk with a specialized risk taker.

Methodology:

In order to be able to provide very practical and realistic feasibility conditions, this study focused on one specific actual project: La Venta III, which is to be the first Independent Private Producer (IPP) project, owned, financed, commissioned and operated by a private party, and selling produced energy to the national grid operated by the CFE (Comisión Federal de Electricidad).

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The feasibility conditions analyzed for this project should provide a feasibility framework for similar weather derivatives for renewable energy projects in developing countries. The framework of the study has been separated in three main aspects:

Legal aspect

This part of the study defines the nature of contract which is best adapted to local regulations. Weather derivatives can take the legal form of an insurance policy, a reinsurance treaty or a financial contract. Choosing one legal form or another depends on the local legal system and has tax and accounting consequences.

Technical aspect

The technical feasibility study is a major issue in the implementation of a weather derivative. As an index-based cover, the mechanism of the wind derivative exclusively depends on the definition of the Wind Index that triggers the cover. A wind derivative uses measured wind speed as an underlying index. A reliable, independent and accessible source of weather data is therefore essential to structure, price and settle a wind cover.

Financial aspect

This hedging solution can be integrated at different levels into the project financial structure with a different cost (premium) and benefit (limitation of the volatility in debt service payments to the bank and increase in equity's return). An efficient hedging product is one that provides security to the project stakeholders at a reasonable cost.

Financial benefits have been studied for each type of project stakeholders: the project developers aim at smoothing and securing the operating cash-flows; the lender aims at securing debt payment; the equity shareholders aim at improving return on equity i.e. by reducing their initial investment or by increasing the return on investment.

In order to estimate the potential benefit of the cover in terms of "bankability" of the project, and in order to take into account market realities such as market needs specific to the Mexican RE sector, any market distortions, regulatory barriers, investment climate and other environmental factors and risks, **a preliminary consultation was conducted with professionals involved in the promotion of wind energy in Mexico** (banks, specialized independent consultants, wind energy specialist promoting the development of this energy in Mexico).Those project stakeholders have mainly evolved around La Venta III project issued by the Mexican government.

Main Results:

From a contractual point of view:

Mexican law would not allow selling or buying weather derivatives as a financial contract. One single exception is financial reinsurance. Therefore the wind farm investor would not be allowed to sign a direct financial contract. However, an insurance contract between the wind project and a local insurer would be permitted.

The wind hedging product can therefore be structured as follows:

1. Insurance contract between the wind project and a local insurer;
2. Reinsurance or financial reinsurance set between the local insurer and the weather market acting as re-insurer. In the case of a financial reinsurance contract, the transaction must be validated by the Mexican regulatory authorities.

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Regarding the availability of wind data:

The study of the public stations available in the La Ventosa region shows that public data sources are not fully satisfactory to implement the wind derivative in La Venta. It is therefore not possible to find an appropriate level of correlation between reanalysis data and La Venta III. Reanalysis data are modeled historical data based on various meteorological sources (in comparison to measured historical data provided by weather stations).

The recommended solution would therefore be to use a dedicated wind mast as a data source, such as an existing private station like La Venta I/II station or a wind mast on La Venta III future wind farm. In order to be considered as an independent source, this dedicated station should be monitored by an independent third party, such as the the Instituto de Investigaciones Electricas which is a Mexican public institution dedicated to research and studies for the energy sector in Mexico.

Regarding the financial benefits of the cover:

The three structures presented below could be applicable for a large scale wind farm. These structures have been tested and their efficiency compared.
- Standard wind derivative
- Wind reserve
- Wind swap

The wind reserve and the wind swap have been developed by Marsh Finances for this study, based on a wind derivative, and calibrated specifically as credit enhancing instruments (wind risk is replaced by the weather counterparty credit risk). These products have been developed according to Marsh Finances experience of weather derivatives markets and wind projects issues.

1. Standard wind derivatives are already available today for wind projects to protect their wind risk exposition but they generally remain very expensive hedging instruments.

2. The wind swap is a product with a low premium. However, when the wind conditions are favorable, the project has to give back part of upside to the weather market (under a similar mechanism as standard collar type financial products). Even though the premium is attractive, this solution might be less adapted because the investor has to give away part of its upside revenues.

3. Among the three structures that have been presented in the consultation, the wind reserve received the most attention, with the following key points mentioned by the parties consulted:

   o the wind reserve has a low premium compared to the standard wind derivative

   o it does not impose giving away part of the upside to the weather market in favorable conditions

   o With the wind reserve, part of the cash remains in the reserve account as a buffer for a maximum of 12 months and therefore does not reduce equity return

   o Moreover, banks that have been consulted for this study are keen to increase the debt leverage when a wind derivative is in place.

Marsh Finances/Paris Re team:

Marsh Finances and Paris Re have constituted an outstanding and unique team to study the potentiality of the implementation of this Financial Risk Management Instrument

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Marsh Finances is a financial subsidiary of Marsh, one of the biggest insurance broker companies, and has risk management expertise in project finance and renewable energy; Marsh Finances has a long standing experience of weather derivative markets as an insurance broking and have participated to several studies related to the climate change issue in close relationship with the UNEP:

- Survey of insurance availability for renewable energy projects (March 2006)

- Assessment of financial risk management instruments in large scale projects (July 2007)

Paris Re is a worldwide leader/pioneer of weather cover and has a proven experience in providing protection capacity for renewable energy projects. Paris Re has led and underwritten the first weather derivative in relation with a governmental agency (WFP) to cover the consequences of extreme drought in Ethiopia

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1. Scope of the study

This feasibility study has been monitored and financed by the Renewable Energy and Finance Unit of the Division of Technology, Industry and Economics (DTIE) of the United Nations Environment Programme (UNEP), within the framework of the ongoing UNEP/GEF "Assessment of Financial Risk Management Instruments for Renewable Energy Projects". This UNEP/GEF project aims at identifying promising new financial risk mitigation solutions for renewable energy projects in developing and emerging economies, in order to encourage private investments in such projects.

This study conducted by Marsh with the help of Paris Re determines the feasibility conditions for the implementation of wind risk hedging instruments for wind farms in Mexico. In order to be as realistic and practical as possible, the analysis has been applied to a specific project, la Venta III. This study provides a replicable framework for the implementation of wind derivatives for other similar projects and can possibly be used as a benchmark methodology in other countries.

Potential clients for wind derivatives include wind projects sponsors and lenders, interested in covering wind risk for a wind farm or portfolio of wind farms. In Mexico, the Comision Federal de Electricidad, as well as private industrials sponsoring self-supply projects can protect their wind risk exposure with a wind derivative.

1.1 Wind risk hedging instruments

1.1.1 Wind risk

Wind flow across a given site generally exhibits some variations, which translates directly into production variability and cash flow variability. It has been estimated that due to low wind speeds and depending on their location, wind farms are at risk of a 15 to 25 percent loss of revenue per year compared to that of an average year.

Lenders typically consider three main categories of risk when financing a wind energy project: completion risk, operating risk and revenue risk. The two components of revenue risk are the power purchase price (price risk) and the available wind resource (volume risk). When power purchase agreements are structured to provide revenues to the project company on a fixed or scheduled price on a long term basis (as in Mexico), the only uncertainty remaining is the volume risk.

Wind risk is part of volume risk. However, volume risk involves other uncertainties independent from the wind conditions and therefore not covered by a wind derivative. These uncertainties are, for example: turbine unavailability periods, electricity grid default, energy losses due to machinery breakdown or default, etc...

Developers and operators of wind farms take into account the element of wind risk in their financial planning and risk management strategy, in order to secure project finance from institutional and other lenders. A wind production hedge provides substantial benefits by reducing the volatility of these cash-flows and strengthening the financing structure of the wind farm project.

1.1.2 Wind derivatives

Objective of wind derivatives

Derivatives are financial instruments used to transfer the risk of variability of an underlying asset to a third party. The derivatives pay-off is a function of the underlying asset value. Indemnities paid by a derivative do not depend on real losses (as with traditional insurance) but depend on the level of an index. This type of product is entirely parametric (i.e. based on the level of wind power production) with a predetermined trigger event, which allows for a very quick indemnification.

Assets which can be covered by derivatives include commodities price, exchange rates, or any index such as inflation, Consumer Price Index.

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Weather derivatives are a specific category of derivatives, with a weather index as underlying asset: temperature, rainfall, wind speed, etc.

Wind derivative are used to transfer the risk of wind speeds variation to a third party. The objective is to guarantee the availability of a given level of production which is a function of wind speeds estimated from the meteorological mast measurements. A wind production hedge can provide substantial benefits by reducing the volatility of the debt service coverage ratios (DSCR), lower the debt service reserve account (DSRA) and strengthening the financing structure. The solution can be structured for a single wind farm and/or for a portfolio of wind farms, even for wind farm project(s) already in operation.

Mechanism of wind derivatives for wind farms

Definition of the wind index

Wind derivatives are parametric index-based covers. This means that their mechanism of indemnification depends exclusively on the value of an index, and not on real losses suffered.
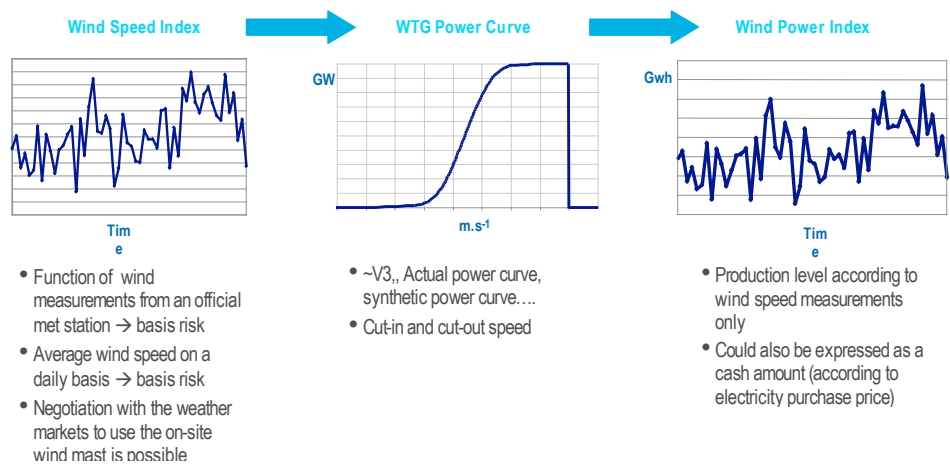
The index used for a wind derivative is a function of wind speed measurements, usually expressed in amount of energy production. Necessary conditions for the index to be acceptable are:

- independence : the value of the index cannot be modified by any of the parties,
- reliability : the data source will provide measurements during the whole cover period so that the index can be calculated,
- strong correlation with the wind farm exposure: the index must trigger the cover when the wind farm suffers from low production due to low wind speeds (Basis risk refers tot the potential deviation of the wind index from real on-site production)

The wind index is therefore usually based on an independent wind measurement station as close as possible to the wind farm.
The technical feasibility study is a major issue for the implementation of the wind derivative: it determines the weather station to be used as a reference and the calculation of the Wind Index based on the station data.

The following graph represents the processing of wind speeds measurements into wind power index, via the power curve.

Wind Speed Index → **WTG Power Curve** → **Wind Power Index**

- Function of wind measurements from an official met station → basis risk
- Average wind speed on a daily basis → basis risk
- Negotiation with the weather markets to use the on-site wind mast is possible

- ~V3,, Actual power curve, synthetic power curve….
- Cut-in and cut-out speed

- Production level according to wind speed measurements only
- Could also be expressed as a cash amount (according to electricity purchase price)

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Definition of the wind derivative parameters

Three parameters determine the functioning of the wind derivative:
- The Strike: level of Wind Index (expressed in MWh) which triggers the cover
- The Tick: amount indemnified per MWh below the Strike (it usually corresponds to the electricity price per MWh)
- The Capacity: maximum amount paid by the derivative

These parameters are fixed in advance in the contract: they determine the conditions for the trigger of the cover and the indemnity to be paid then.
- With a higher Strike(closer to the average expected production), the cover will be triggered more often
- With a higher Tick, and when the cover is triggered, the indemnity will be higher
- With a higher Capacity, the indemnity paid by the cover is higher if wind conditions are particularly unfavorable (i.e. if the Limit is reached)

The following chart is an explanatory example for a monthly protection.

Figure 1 - Monthly wind derivative mechanism
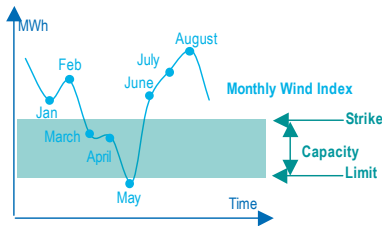
The cover is triggered in March, April and May.

In May, the Wind Index is below the limit: the indemnity equals the Capacity.

Calibration of the wind derivative parameters

The calibration of the parameters is specific to the wind speeds profile on the site. If wind speeds are very volatile, the risk involves more uncertainty and therefore the Premium is usually higher for a given level of protection.

For a given site, the parameters (Strike, Tick and Capacity) can, in theory, be set at any level. However, they need to be calibrated in accordance with a sustainable level of premium.
- With a higher Strike, the risk for the cover to be triggered is higher and therefore the Premium will increase
- With a higher Tick, the indemnity paid when the cover is triggered is higher and therefore the Premium will increase
- With a higher Capacity, the maximum risk covered is higher and therefore the Premium will increase

Therefore, the parameters are set in function of a trade-off between the Premium level and the level of coverage required.

The wind derivative is a revenue protection structure. It is equivalent to the project buying a put option to the risk taker, with the following payout profile:

Figure 2 - Wind derivative payoff profile
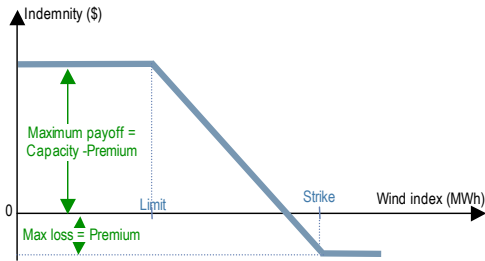
A typical wind hedge is a multi year contract. The period of cover may vary between 3 and 5 years.

Structuring wind derivatives

The structuring of a Wind Power Derivative is based on the wind availability study performed during the project planning period. For this study, on-site wind data as well as data from nearby official weather stations is collected and analyzed to determine wind speeds and directions, in the short-term and the long-term. This study is essential for the determination of the derivative data source and wind index.
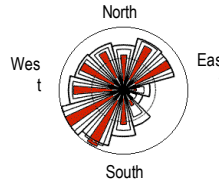
Figure 3 - Wind speed distribution probability
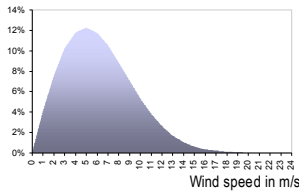
Figure 4 - Wind rose

Depending on the wind availability study results, the data source for the weather derivative can be selected. The wind data is then combined with the wind turbines power curves in order to express the index as a level of electricity production.

Wind derivative are traded structured on a case by case basis and traded over the counter. The trigger level (Strike) of the coverage is determined according to the level of coverage required by the project sponsor and the level of premium required by the risk taker.

A Wind Power Derivative is designed as a financial product via the emission of a standardized contract or an insurance policy.

Other weather derivatives

Weather derivatives have been used extensively in several sectors of the economy such as the tourism, oil and energy sectors. They are essentially financial instruments used by companies to offset financial risks and uncertainty caused by weather volatility: temperature, rain, snow or wind.

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Trading weather derivatives

Standard climate derivatives are traded on organized financial markets (Chicago Mercantile Exchange). Most of these standard climate derivative products are indexed on US temperatures and are designed for the energy sector to hedge against warm winters or cool summers. However, most climate derivatives are traded on a stand-alone basis ("over the counter").

For a product to become a standard and traded product on an organized market there is a need for a very large number of transactions covering similar risk and exposure. To the best of our knowledge, there are no standard wind derivatives – wind derivatives are only traded over the counter. Today, actors from both the insurance/reinsurance and the capital markets are eager to underwrite such financial products. Moreover, Mexican wind expositions are particularly not common in climate insurer's portfolio and therefore wind derivatives in Mexico constitute an attractive diversification opportunity for climate insurers.

[To give more information to the readers so that they can differentiate between the different weather financial risk management instruments, could you please explain the difference with weather insurance and weather futures? (e.g. how weather insurance is used as property insurance, how one covers low-risk, high-probability events and OTC w derivatives high-risk, low-probability events, OTC and secondary markets trading etc).]

1.2 Applying wind power derivatives for wind farms financing in Mexico

The direct benefit from a weather derivative is the smoothing of the volatility of production. With a wind derivative, the lowest production levels are hedged. Moreover, with such cover, a minimum level of revenues can be guaranteed. This increases lenders' confidence in the project's ability to pay debt service and can support the negotiation for improved financing conditions.

Due to the uncertainty on wind production, when considering the project's default risk, bankers usually base the calculation on a conservative production level (typically P90 production, which refers to a production level which has 90% probability to be exceeded and only 10% probability not to be reached). If the wind risk can be mitigated by the way of a weather derivative then the debt can be sized on a less conservative wind production. This enables gearing and equity returns to be maximized.

In some countries, with more attractive incentive regimes for wind energy, the best sites have been cherry picked and sponsors are now faced with trying to make marginal sites more viable: this approach to mitigation can also help the viability of those sites.

In preparation of the feasibility study, several countries/regions have been short listed based on 4 criteria:
-    Eligibility to receive GEF funding
-    Local commercial presence of MARSH and subscription capability of Paris Re
-    Operating wind capacities in 2007 according to the Windpower Monthly Indicator © above 1 MW[1]
-    Availability of wind resources according to the World of Wind Atlases

Mexico was identified as an interesting country to implement wind derivatives for wind farms: the wind potential in Mexico is considered very high whereas the installed capacity remains comparatively low. Wind derivatives will not solve all the issues involved in the development of wind energy in Mexico, but they can address efficiently wind risk which is the most severe risk likely to impact wind farms revenues.

1.2.1 National context

Overview of the electricity sector

The state utility Comisión Federal de Electricidiad, CFE, owns 85% of the generated electrical capacity in Mexico.

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[1] from the table published on http://www.windpower-monthly.com/WPM:WINDICATOR

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The installed capacity in Mexico is of 52GW (2006) from which 73% are fossil fuel based plants. Large hydro-electricity is the most developed renewable energy source and provides around 20% of total generation. The hydro-electric resource is already almost fully exploited.

The private sector has a limited participation in the electricity market with investments limited to electricity generation. Private power in various forms accounts for about 30% of Mexican electricity generation, through Independent Power Producers (IPP) and self-supply schemes.

Wind energy installed capacity

As of 2008, there are 3 wind projects operating in Mexico:
- La Venta I (7 turbines of 225kW), Oaxaca, operated by CFE since 1994
- Guerrero Negro, Baja California Sur, (1 turbine of 600kW) operated by CFE since 1998
- La Venta II (98 turbines of 850 kW, i.e. 83,3 MW) operated by CFE since 2007

Figure 5 - CFE capacity installed or under construction in Mexico as of 2006
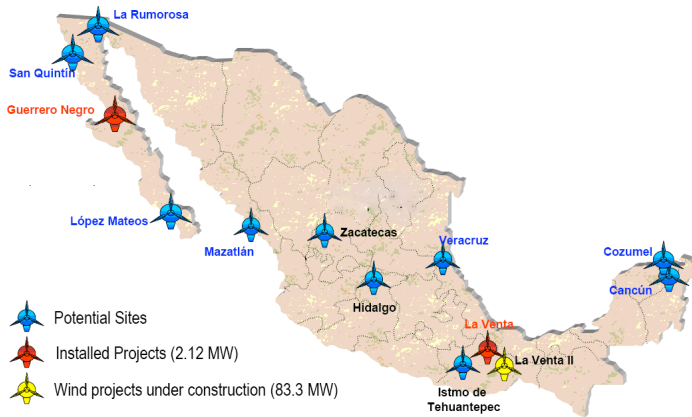
The state utility CFE plans to increase installed capacity by 1250 MW, with 589 MW for CFE sponsored project and 661 MW for private projects.

Wind energy potential

The on-shore wind energy potential in Mexico is estimated to be 5 000 MW[2]. In particular, an abundant wind resource of 3000 MW equivalent has been located in the "La Ventosa" region in the Isthmus of Tehuantepec located in the southern state of Oaxaca. Average annual wind speeds in this region range from 7 to 10 m/s measured at 30 m above ground.

The following map represents the CFE (Comisión Federal de Electricidiad) capacity installed or under construction in Mexico as of 2006

Since 2006, La Venta II has been completed and is under operation since 2007. CFE has agreed several other 20-year power purchase agreements with private investors for a further five wind farms (La Venta III and Oaxaca I-IV),

There are also other private self-supply projects planned for construction by the following private companies:

- Electricidad del Valle de México,
- Eoliatec del Istmo,

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[2] Source: Comisión Federal de Electricidad (CFE)

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- Bii Nee Stipa Energía Eólica,
- Fuerza Eólica del Istmo, Eurus, part of Cemex
- Parques Ecológicos de México, part of Iberdrola,
- Baja Wind, a company subsidiary of Sempra Energy,

Barriers to development of renewable energy

The Division of The Global Environment Facility (GEF) at the United Nations Development Programme (GEF-UNDP) approved in 2001 a project called "Action Plan for Removing Barriers to the Full Scale Implementation of Wind Power in Mexico".

This project identifies a number of significant barriers to the development of a wind power market in Mexico

- Institutional, legal, and policy frameworks

    CFE is legislated to buy the cheapest electricity available, without considering external costs, and to give preference to firms' capacity for new power installations, in order to ensure the reliability and stability of the national grid. There is no special regulation for renewable energy.

- Economics of wind power

    In Mexico, as in most countries, most wind power plants cannot compete with conventional power on the basis of costs per kWh alone. However, with moderate incentives, wind can become a competitive form of electricity generation in Mexico, because the average price of electricity is slightly inferior to the minimum buy-back price necessary for commercial wind power projects to become profitable (65 $/MWh according to the American Wind Energy Association for private owned wind projects[3]). The GEF, intends to develop a number of large scale renewable projects through a 70 million US$ donation through its Large-Scale Renewable Energies Project (PERGE), implemented by the World Bank. This funding would be used to provide an incentive to the electricity produced during the first five years of each project. La Venta III will be the first one of these projects, with 101 MW, set to become operational in 2009. Oaxaca I-IV are expected to come online in 2010 with 406 MW.

- Financial limitations

    Due to the lack of experience in commercial wind power development in Mexico, potential project developers and sponsors are less confident in the financial viability and profitability of the wind power market in Mexico.

- Market structure and human resources

    Even though several turbine manufacturers are operating in Mexico, there is still a significant lack of personnel trained in terms of both the development and implementation of wind power projects, and in the operation and maintenance of wind energy technologies

- Technical and information barriers

    Except for a few sites, the wind resource data available for Mexico is inadequate for pre-investment studies. Since 2001, the availability and reliability of data have been improved. Within our study, 48 meteorological stations have been located in Mexico. Moreover, institutions like the NOAA CIRES Climate Diagnostics Center in USA are providing worldwide wind measurement. This source can be used efficiently whenever reliable local data is not available.

Political engagement in the development of RE

From a political point of view, Mexico has a critical need to diversify its energy portfolio. Natural gas production has once been a major resource for the country, but is not any more able to meet the increasing electricity demand. Gas prices are also increasingly volatile. This situation has encouraged governmental agencies such as the Secretaría de Energía (SENER) and the Comisión Federal de Electricidad (CFE) to promote the development of domestic sources of renewable energy to complement fossil fuels in power production.

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[3] Source : American Wind Energy Association, http://www.awea.org/faq/cost.html

From an environmental point of view, the use of renewable energy production can decrease importation and consumption of natural gas, coal and oil. The consequent reduction in carbon emissions can be included in Kyoto schemes – Mexico ratified the Kyoto Protocol on September 7, 2000.

From an economical point of view, renewable energy projects activate local economy and can initiate a new dynamic industry. A study conducted by the Mexican Electrical Research Institute (Instituto de Investigaciones Eléctricas- IIE) has assessed in a study the benefits of a national wind energy program. It shows that an installed capacity of 5000 MW would generate 30,000 direct and 30,000 indirect jobs, both permanent and temporary[4].

Important policy initiatives aim at reducing development barriers for renewable energy:

- Accelerated Depreciation (2005)

  Investors can deduct 100% of the investment in renewable energy equipment after one year of operation. Following the tax deduction declaration, the equipment has to operate for at least five years.

- Renewable Energy Law (2005)

  The State Utility, CFE, is applying a least-cost principle for acquiring energy from third parties which makes it difficult for renewable energy projects to compete with conventional energy projects, where the initial cost for CFE is inferior. The aim of the new Renewable Energy Law is to define methodologies that include various parameters in addition to costs in the calculation of the CFE base-price, such as supply diversification, environmental benefits and carbon revenues.

- Creation of the "Fondo Verde"

  This domestically financed financial mechanism is to provide incentives for Grid-Connected RE.

The "Large Scale Renewable Energy Development Project" conducted by the GEF since 2004 supports the Mexican government in the promotion of Renewable Energy. The objective is
- To support the construction of the 101 MW IPP wind farm (La Venta III) by granting an electricity tariff support of 1,1$cts /kWh to be added to the CFE purchase price. This incentive could over time be assumed by the Green Fund implemented by the World Bank and the Global Environment Facility (GEF);
- To build an institutional capacity to value and manage such resources on a replicable basis.

Opportunities for the implementation of wind risk hedging in Mexico

The Mexican sovereign credit rating (Baa1) indicates a moderate political risk. Mexico has a well-regulated financial system, including a competent fiscal and monetary policy, an independent central bank, and a competitive and floating exchange rate. CFE's IPP program has been successful in attracting foreign investment in the Mexican power sector.

The Renewable Energy sector is developing, with 100MW installed capacity in 2007 and 500MW expected to be installed by 2014[5] (these figures refer to public energy production and do not include private self-supply production). It is promoted by international institutions such as UNEP, UNDP, the World Bank/GEF projects and followed with strong interest from international manufacturers and operators (Iberdrola, General Electric, Endesa, EDF, Gamesa Eolica, etc.). There is significant potential for the development of wind energy thanks to high wind resources, especially in Oaxaca and Baja California states.

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[4] Borja, M. et. al., Energía Eólica: centrales eoloeléctricas, IIE,
[5] Source : SENER Prospectiva del sector eléctrico 2005-2014
http://www.sener.gob.mx/webSener/res/PE_y_DT/pub/Electrico_2005_2014.pdf

Figure 6 - Wind resource map of North Baja California published by the US National Renewable Energy Laboratory[6]
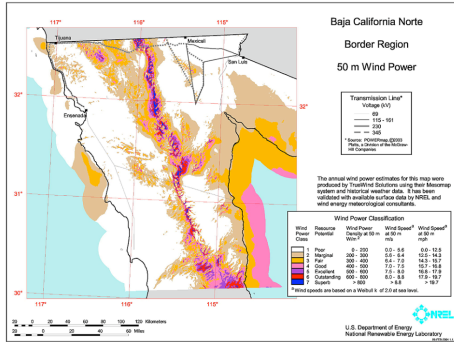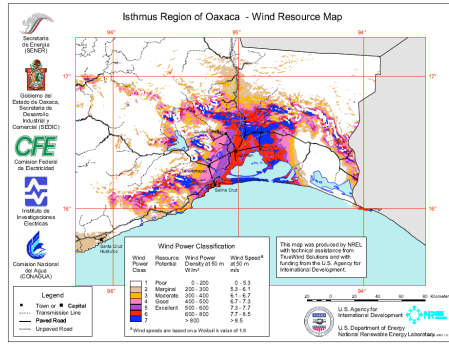
Figure 7 - Wind resource map of Oaxaca published by the US National Renewable Energy Laboratory

Within this context, the purpose of risk mitigation instruments is to improve sponsors' understanding of business risk and opportunities associated with wind energy.

Wind availability is a key risk and key performance driver of Wind Energy Projects. Due to low wind speeds, wind farms can be at risk of a 15 to 25 percent loss of revenue per year, potentially contributing to the inability to meet bank liabilities. Developers and operators of wind farms are therefore taking into account the element of wind risk in their financial planning and risk management strategy, in order to secure project finance from institutional and other lenders.

The implementation of wind hedging structure will allow developers and operators to secure their revenues in case of low wind speeds. This will increase international and national financial institutions' confidence in the viability and profitability of wind power projects and encourage more favorable financing conditions.

Weather Derivative market – appetite for Latin America and Mexico

The weather derivative market is dominated by the energy sector. Around 80% of the capacity is dedicated to hedging utilities against a warm winter and/or a cool summer in the US, Europe and Japan. A wind exposure in Mexico is therefore interesting for weather market players because it brings diversification both on the underlying "weather asset" (wind speed instead of temperature) and geographically. Global capacity for wind in Mexico in the weather market could be expected around 200 millions USD, according to the weather market.

1.3 Prototype project = La Venta III

In order to be able to provide very practical and realistic feasibility conditions, we have focused our study on one specific project La Venta III which is to be the first Independent Private Producer (IPP) project, owned, financed, commissioned and operated by a private party, and selling produced energy to the national grid operated by CFE.

The feasibility conditions studied for this project will provide a feasibility framework for a similar weather derivative for renewable energy projects in developing countries. However, as weather derivatives are not traded on a standard basis but over the counter (OTC), a refined study would need to be conducted to calibrate the optimal implementation scheme for a different project.

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[6] Other wind resource maps for Mexico are available at http://www.nrel.gov/wind/international_wind_resources.html#mexico

1.3.1 La Venta III project status

During the last quarter of 2006, the CFE made a call for bids for La Venta III, a new 101 MW project located in the La Ventosa region under the independent power producer contract, the winner will supply electricity to CFE for 20 years. The World Bank approved a US$25mn grant from the Global Environment Facility to help support La Venta III.

CFE received two bids from Iberdrola and Elecnor. Iberdrola submitted a qualified technical bid for the project, but the amount required for the project's engineering, supply and construction, was above the maximum bid allowed by the CFE. The other bid received from a Spanish consortium of Elecnor and Enerfín Sociedad de Energía was not selected for technical reasons.

Other firms were interested in the opportunity, but could not participate in the call for bids because they were not able to acquire adequate turbines in time for the development of the project. Such firms include:
- The Mexican construction company Cyasa, which carried out electromechanical construction works for the project La Venta II, and represented the Costa Rican division of the Italian power firm Enel
- Unión Fenosa, Spanish energy operator with 1550 MW installed capacity in Mexico

In November 2007, CFE decided not to award the contract for La Venta III. It is expected that CFE will launch a new call for tender. Over the next three years, CFE has planned US$3-billion-worth of investment in wind projects with a generating capacity of almost 2,000MW.

1.3.2 La Venta III financial assumptions

The financial assumptions considered in this feasibility study are based on the financial analysis of La Venta III done by the GEF, as part of the Project Document entitled "Action Plan for Removing Barriers to the Full-scale Implementation of Wind Power"[7]. Some of these assumptions have been adjusted for the purpose of this study.

A similar analysis with accurate figures would have to be conducted to confirm the economic feasibility of a wind derivative for a different wind project.

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[7] Project Appraisal Document, June 2006, available on GEF website
http://www.gefonline.org/projectDetails.cfm?projID=1900

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Example : Initial Investment and cost structure for La Venta III

La Venta III consists of 120 *Gamesa* 850 kW turbines with a total production capacity reaching 102MW.

The initial investment amount is constituted by :

- Equipment : 1m$ per installed MW = 102m$ for the wind farm
- Civil work and other installation costs : 28m$
- Reserve accounts up-front funding : 4,5m$

The project investment amount is financed from

- 40% equity investment (52,4m$ + 3,5m$ reserves = 56 m$)
- 60% debt (79m$)

The debt amount is divided into two separate portions :

- 70% Senior debt (55m$) for 8 years and 6,2% interest rate
- 30% Junior debt (24m$) for 15 years and 6,9% interest rate

Reserve accounts include :

- an Operation & Maintenance reserve amount :1m$
- two Debt Service Reserve Account for each portion : 3 months debt service reserve (2,2 m$) for the senior debt and 6 months debt service reserve for the junior debt (1,2m$)

The debt reserves are funded by the equity. The O&M reserve cost is included into the initial financed amount and shared proportionally between equity end debt.

Figure 8 - La Venta III, Investment and financing structure
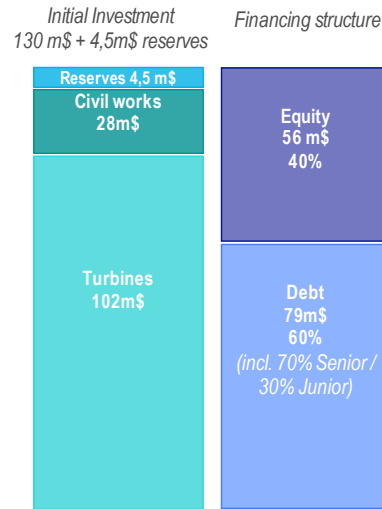
Example : Cash flow structure

Wind speed profile in La Venta III

According to our study of wind regimes in La Venta III, and with 102MW installed capacity, the wind farm is expected to run with a 47% capacity factor (including 15% losses and 3% turbine unavailability on average) and provide on average 414GWh per year (i.e 290MWh per turbine). This is based on the power curve for Gamesa 850kW turbines with a cut-in[8] wind speed of 3m/s and a cut-out[9] wind speed of 21m/s.

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[8] Cut-in wind speed is the lowest wind speed for which the wind turbines provide electricity
[9] Cut-out wind speed is the highest wind speed for which the wind turbines provide electricity. Above the cut-out wind speed, the turbines are stopped in order to prevent damages.

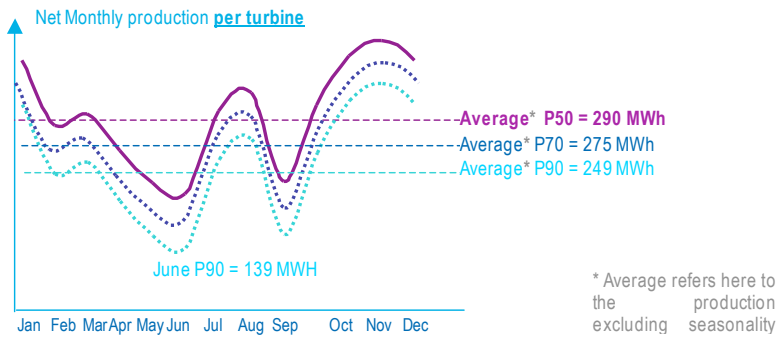*Figure 9 - La Venta III, Net Monthly production per turbine*
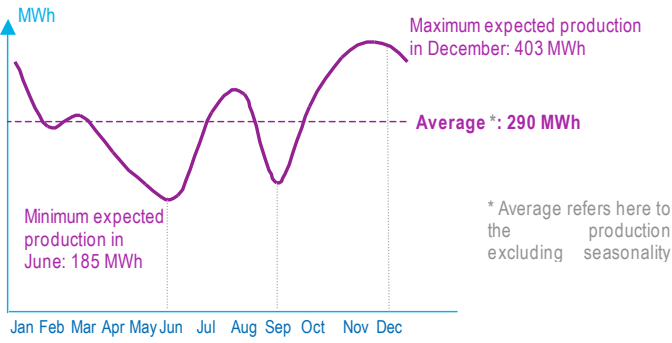
The production is at its lowest level in June and September and the seasonality cycle is of 12 months from November to October of the next year.

Potential variation from the average monthly production is represented by the standard deviation, which varies between 36 and 49 MWh. Distributions of monthly production are described in the table below.

	January	February	March	April	May	June	July	August	September	October	November	December
Average (MWh)	376	284	299	246	202	185	305	330	203	311	382	403
Standard deviation (MWh)	37	37	37	36	37	37	39	37	36	39	36	36

The wind profile is commonly expressed with reference to exceedance probabilities. PXX refers to the production level which has XX% probability to be exceeded. For example, P90 is a conservative measure of the expected electricity production: there is statistically 90% probability (one chance out of ten) that the project generates less than P90.

Figure 10 – La Venta III, Net monthly production per turbine with exceedance probabilities

Net Monthly production **per turbine**

Average* **P50 = 290 MWh**
Average* P70 = 275 MWh
Average* P90 = 249 MWh

June P90 = 139 MWH

* Average refers here to the production excluding seasonality

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

The complete production profile in La Venta III is provided in the graph below. This graph shows the reverse cumulative probability distribution of net monthly production in June (lowest month in the seasonality pattern), in December (highest month in the seasonality pattern) and of the monthly average production excluding seasonality effects.

On these three curves, it is possible to read the probability of exceedance for any confidence level.

- The curve on the left refers to the production for the month of June (less windy period)
- The curve on the right refers to the production for the month of December (most windy period)
- The middle curve refers to the production excluding seasonality effects i.e. the overall annual production divided by 12

Figure 11 - La Venta III; Probability curves of Net production per turbine

Monthly average (excl. seasonality effects)

June

December

P100
P90
P80
P70
P60
P50
P40
P30
P20
P10
P0

June P90
139 MWh

Average P90
247 MWh

December P90
357 MWh

June P70
166 MWh

Average P70
274 MWh

December P70
384 MWh

June P50
185 MWh

Average P50
294 MWh

December P50
404 MWh

0 MWh   100 MWh   200 MWh   300 MWh   400 MWh   500 MWh   600 MWh

Net production per turbine

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Monthly revenues & costs

Figure 12 - La Venta III, Monthly cashflow structure

Average net production of 290MWh/ turbine / month
i.e. 35 GWh net monthly for the wind farm
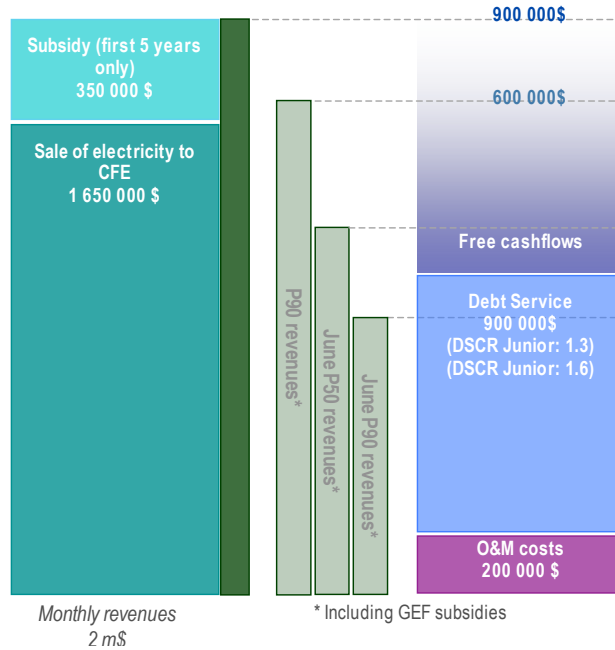
Revenues generated from the production of electricity include:
- Average <u>monthly</u> generation 290MWh with a Power Purchase Agreement at 47$/MWh
- Additional subsidy on electricity production from the World Bank, applicable only the first five years: 11$/MWh

Operating costs include the following:
- <u>Annual</u> fixed O&M: 12,063 $/kW
- <u>Annual</u> variable O&M: 0,0011$/kWh
- <u>Annual</u> Site owner royalty: 1,5% of operating revenues
- <u>Annual</u> insurance costs: 0,1% of equipment

Operating costs payments are paid monthly, and expected to inflate by 3% per year.

Figure 13 - La Venta III, Distribution of O&M costs
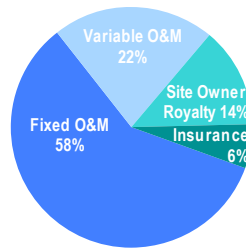
Operating cash flows are in priority used to service debt (interest and principal). Remaining cash flows are distributed to the equity shareholders in the form of cash dividends. The debt service is a constant annuity (principal + interest = constant). The project is engaged to "Timely payment of interest and Ultimate payment of principal".

2. Legal feasibility study

2.1 Objective: Define which type of contract is best adapted to local regulation

2.1.1 Two types of contracts: Financial / Insurance

Financial product

As a Financial derivative, the weather derivative is subject to the Master Agreement and an optional schedule if needed of the International Swaps and Derivatives Association, Inc. ("ISDA"), which will issue a legal document to approve the derivative structure.

Insurance product

As a reinsurance contract, the weather cover is actually proposed by a local insurer ("fronting company") who will seek coverage from a reinsurance company.

2.1.2 Choice of best adapted contract

Local laws might approve either of the structures. Sometimes, the legal status of the counterparty does not allow him to sign a weather derivative. The counterparty for the weather cover can be:
-    The investor
-    A Financial Institution financing the project
-    A local insurer, if the weather cover is based on an insurance policy

If the counterparty for the weather cover cannot legally contract a Derivative, the insurance option is selected.

If both Financial and Insurance structures are possible, tax and accounting issues are other criteria to determine the optimal scheme.

2.2 Feasibility for La Venta III

Mexican law does not allow selling or buying weather derivatives as a financial contract. One single exception is financial reinsurance. Therefore the wind farm investor is not allowed to sign a direct financial contract. However, an insurance contract between the wind project and a local insurer is permitted.

The wind hedging product can therefore be structured as follows:
-    Insurance contract between the wind project and a local insurer is permitted;
-    Reinsurance or financial reinsurance set between the local insurer and Paris Re as re-insurer. In the case of a financial reinsurance contract, the transaction must be validated by the regulatory body.

The local insurer might charge fronting fees. Maybe these costs can be decreased/cancelled if the wind hedging is incorporated for example into a Property Damage policy package.

The insurance company may choose between a reinsurance treaty and a financial contract (el reaseguro financiero) to cede its exposure to the weather market. Paris Re has already the experience of weather based insurance contracts in Mexico for the agriculture sector.

If the insurance company decides to transfer risk via a financial contract there are some regulatory issues that it has to fulfill such as asking the regulatory body the permission to present a medium-term plan.

Figure 14 - Suggested legal scheme for the implementation of a wind derivative in Mexico
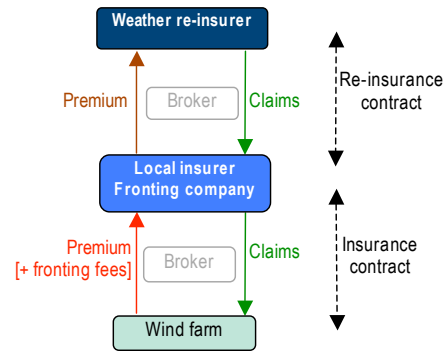
Paris Re and Marsh are willing to act as the weather reinsurer and broker on the Mexican market and encourage the pooling of local insurers' wind exposures into a reinsurance facility.

3. Technical feasibility study

The technical feasibility study is a major issue in the implementation of a weather derivative. As an index-based cover, the mechanism of the wind derivative exclusively depends on the definition of the Wind Index that triggers the cover.

3.1 Objective: Select a reliable wind data source and build the wind index representing the wind farm exposition to wind risk

The objective of the technical feasibility study is to check all the technical aspects necessary for defining a weather derivative contract. The payment structure of a weather derivative is based on an index. A wind derivative uses the average daily wind speed as an underlying index. A reliable and independent source of weather data is necessary for pricing the cover and for settling it.

3.1.1 Wind index

The Wind Index is a mathematical function based on weather data and used as a proxy of the power generation.

Three indexes are usually used for wind farms:

a. Wind Index = Average of the daily average wind speeds for the period of cover

This is the "vanilla" index for wind farms.

A very simple transformation can be applied to the series of measured wind speeds in order to provide a better correlation with the power generation. For example, wind speeds above a given threshold (typically corresponding to the turbine cut-out wind speed) are capped, thus reflecting that the turbines are stopped and do not produce when the wind speed is too high.

The resulting index for La Venta III, although looking very basic, correlates above 90% with actual power generation.

b. Wind Index = Total generation of power for the whole period (Wind Power Index).

The daily Power index is obtained using the power curve and the average daily wind speed.

c. The third index uses one of the first two and is obtained by comparing the index of the period of cover with the average index for the previous 10 years for example. The final index is therefore the ratio of the index of the current period to the 10 years average. This index is very useful for multi-year covers as its price is automatically updated.

3.1.2 Data sources

The wind derivative is an index-based cover. It is therefore based on an independent source of data.

Typical reference sources include:

-   Local wind stations monitored by the national meteorological office
-   On-site wind potential studies
-   Private wind stations
-   Aggregated measurements provided by international meteorological organizations

For example, the US National Climatic Data Center[10] provides wind speed measurements for every grid-point across the globe, at a 2.5 degree resolution. This data has already been used for wind derivatives and is appropriate for remote sites like offshore wind farms.

3.1.3 Criteria to select the wind index

The risk taker selects the optimal reference source on a case-by case basis.

The reference data source is selected as the best compromise to the two constraints: to be as close as possible to the wind farm site in order to minimize basis risk and to provide as much as possible confidence to the risk taker.

Factors improving chances to find a better compromise are:
-    the homogeneity of the climate in the area;
-    the reliability and density of national meteorological stations.

Basis risk

The basis risk refers to the potential difference between the project's exposure (lack of wind on the wind farm site) and the hedging product definition (based on measurements at a given station). The Basis Risk is low when the production calculated from the meteorological station wind measurements is highly correlated to the actual production on-site.

The weather station should be as close as possible to the wind farm in order to minimize the basis risk. Correlation analysis between the Wind Index and the real on-site wind production are carried out to ensure that the Wind Index matches the wind farm exposition.

Reliability and independence of the weather station

In order to take the risk, Paris Re needs to be confident that the reference source of data is reliable (the station will not stop delivering measurements during the cover period) and independent (measurements are objective and cannot be influenced by the insured).

The chosen weather station should be operating and should have reliable data for the last few years. Having reliable historical data increases the risk taker's confidence in the weather station and is necessary for pricing.

Usually, wind farms have their own measurement mast installed on the wind farm site. However, this station cannot be used as the reference station unless it is monitored by an independent third-party. Financing the installation of a reliable weather station run by a trusted professional company is a relevant investment that lowers the price of the weather hedged risk management instrument.

Wind farms are very often located at a substantial distance from usual weather stations sites such as cities and airports, thus a weather station installed and run by a third party is the best option: it minimizes the basis risk and therefore suits the investor's needs without being under its control.

This approach was used in the cover Paris Re has done with the WFP for Ethiopia. Risk Management Solutions and MDA EarthSat were mandated to install and/or operate over 20 weather stations across the country.

3.2 Feasibility for La Venta III

As there is no data available yet for wind speeds measurements on the La Venta III site, the real on-site production has been estimated from La Venta II wind data. The two sites are close (5km) and separated by flat terrain, which justifies this approximation in the framework of this feasibility study.

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[10] The data is freely available from the NOAA-CDC FTP server located at:
ftp://ftp.ncdc.noaa.gov/Datasets/ncep.reanalysis.dailyavgs/surface

Selection of the data source

Four types of data sources have been analyzed in terms of
- historical data availability: a long history is necessary for the risk taker to estimate the risk and price the cover,
- regularity of the data: to be used as a reference source, the station must provide measurements every day
- correlation with La Venta III exposition

Figure 15 - Overview of La Venta region
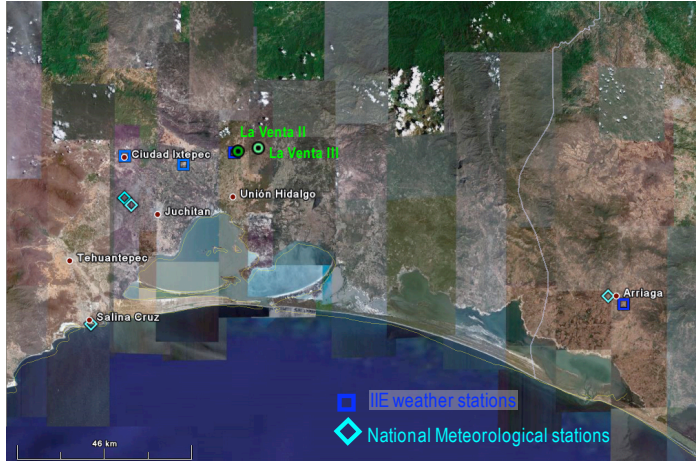
Mexican meteorological office stations

The Mexican meteorological office has 4 stations in La Venta region.

Figure 16 – National meteorological office stations around La Venta

- Ixtepec 767502: very incomplete data before May 2004
- Ixtepec 768300: no recent data
- Salina Cruz 768330: data for recent years is incomplete
- Arriaga 768400 : incomplete data

La Ventosa region is large and the meteorological network is not very dense. Only one station from the national meteorological office (Ixtepec 767502) provides regular enough data, and on a short time period (since May 2004 only). This station is considered reliable by Paris Re but the history is a bit short for the risk analysis. The correlation with on-site data is 77% which is not sufficient.

Grid data

Two Grids have been downloaded: West 95°, North 15° and North 17.5°. By comparing the wind speed at the wind farm site with that at the 4 different points limiting the grid containing the farm site, we can determine the combination that correlates the best with the power generation. However, it is not possible to find a sufficient correlation between grids data and La Venta III.

Data from wind stations monitored by the Instituto de Investigaciones Electricas

The Instituto de Investigaciones Electricas is a Mexican public institution dedicated to research and studies for the energy sector in Mexico. Within a project funded by the GEF and UNDP, the IIE has installed 22 weather stations in Mexico in order to evaluate the wind resource[11].

In particular, this institute maintains four weather stations around La Venta III site: Ixtepec, La Ventosa, La Venta and El Progreso. These stations provide reliable and regular data, with a few years of historical data. The data from La Venta I/II station most closely reflects wind conditions in La Venta III.

Figure 17 – IIE stations around La Venta

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[11] http://planeolico.iie.org.mx/iiepnud.htm?url=Infanemo.htm&mcontador=18035&url=inf%5Fanemo%2Ehtm

Jesus Tejeda (Wind Action Plan Project Coordinator) and Jorge Huacuz (Non-Conventional Energy Unit, Alternative Energy Division, IIE) have been very helpful for the data collection, and have given us relevant directions and comments on the electricity sector in Mexico and the applicability of our products in this specific environment.

3.3 Conclusion and recommendations

The study of the public stations available in the La Ventosa region shows that public data sources are not satisfying to implement the wind derivative in La Venta.

The recommended solution is therefore to use a dedicated wind mast as a data source, either an existing private station such as La Venta I/II station or a wind mast on La Venta III future wind farm. In order to be considered as an independent source, this dedicated station should be monitored by an independent third party, such as the IIE. The maintenance costs (USD 5,000 to USD10,000 per year) can be included in the insurance cost. Once again for the data to remain independent, the financial transaction with the IIE must be managed by another independent party. Marsh can there act as a broker and calculating agent.
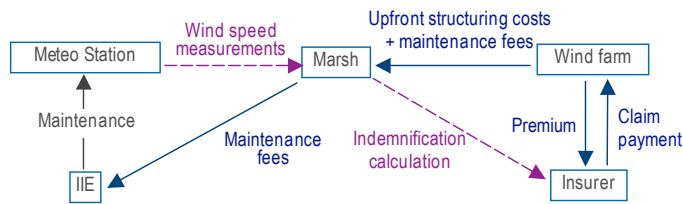
The Wind Index suggested for La Venta III is described in the following graph:

- Daily Wind Index = 24h x Power output depending on daily average wind speed
- Monthly Wind Index = Sum of daily Wind Index values

The Wind Index differs from the monthly gross production due to the Basis Risk. Moreover, the wind derivative only covers wind risk and therefore, reduced production due to any other risk than low wind speeds would not be covered.

Figure 18 - Wind Index Construction
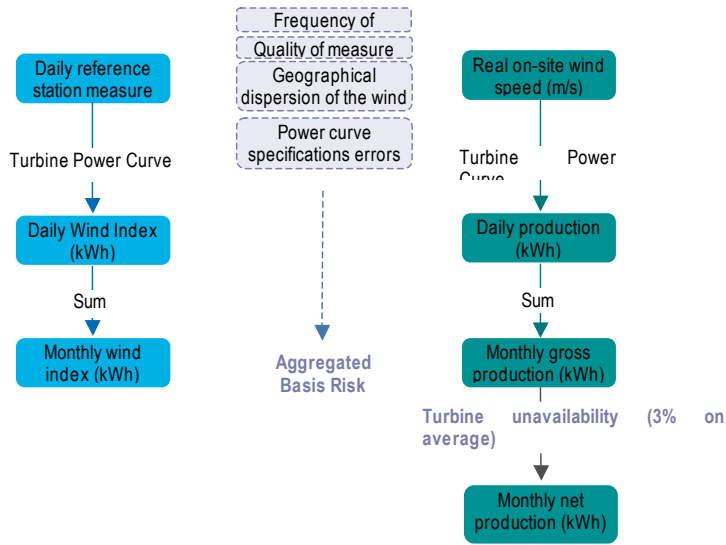
4. Financial feasibility study

4.1 Objective: Structure the most efficient hedging product for the wind project

The structuring of the product involves the following steps:
- Define the payment triggering mechanisms of the hedging instrument;
- Calibrate the level of attachment;
- Set the necessary amount of Capacity;
- Ensure a sustainable level of premium.

In theory, the parameters can be set at any level. However, they need to be calibrated in accordance with a sustainable level of Premium. Therefore, the parameters are set in function of a trade-off between the Premium level and the efficiency of the cover in terms of securing the cash flows and improving the equity return.

4.1.1 Efficiency of the product

An efficient hedging product is one that provides security to the project stakeholders at a reasonable cost. The project developers aim at smoothing and securing the operating cashflows ; the lender aims at securing debt payment ; the equity shareholders aim at improving return on equity i.e. by reducing their initial investment or by increasing the return on investment.

Hedging volumetric risk allows wind project sponsors to have better access to financing because it reduces the uncertainty associated with future cash flows. This enables a wind farm developer to:
- Reduce Debt Service Coverage Ratio;
- Increase Debt to Equity Ratio without increasing the risk exposure;
- Increase the equity return rate of the equity sponsors.

The efficiency of the product is determined by the balance between the cost and the benefit provided by the hedging product.

The cost of the cover is the premium to be paid to the risk taker. The Premium is estimated from the Expected Loss, which is the average loss that can be expected for the risk taker according to his perception of the risk, and includes additional costs. The additional costs depend on:
- the volatility of the risk;
- the Capacity (maximum amount paid in the most pessimistic scenario) provided by the risk taker;

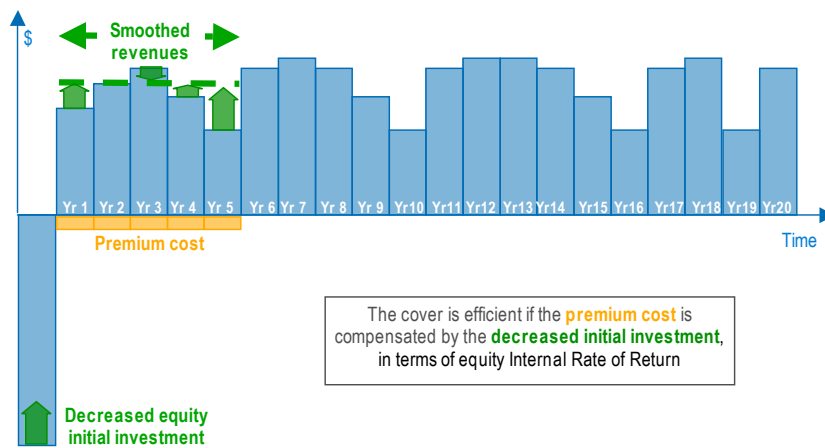*Figure 19 - Mechanism for the calculation of Expected Loss*
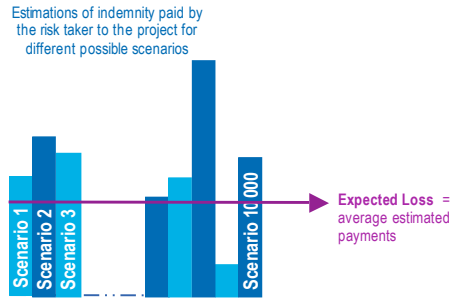
The Premium is a predetermined amount that the project is certain to pay. The Premium can be paid either by the project, by the equity or by the bank.

The direct benefit from the cover is the indemnification paid by the hedging instrument. However, on average, the direct benefit equals the Expected Loss for the risk taker. Therefore, on average, the premium (Expected Loss + additional costs) is higher than the expected direct benefits. The improved bankability of the project and increased loan amount are potential indirect benefits from the cover which have to be taken into account in the efficiency of the cover.

The increased debt to equity leverage needs to be compared to the effective level of premium in order to ensure the efficiency of the cover.
- Direct cost : Premium
- Direct benefit : Indemnity when low production
- Indirect benefit : decreased equity investment (improved project bankability)
- Indirect cost : increased debt reserve and increased debt cost

An efficient cover compensates the premium cost by decreasing equity investment.

The cover is efficient if the **premium cost** is compensated by the **decreased initial investment**, in terms of equity Internal Rate of Return

4.1.2 Comparison of the structures

The structures can be compared on two levels:

- the efficiency of the cover in terms of reducing cash flows volatility can be quantified by the financial model developed by Marsh Finances;
- the efficiency of the cover in terms of improving the equity return has to take into account the bankers' perception of the risk reduction provided by the cover : this impact has been estimated from discussion with wind projects stakeholders.

Financial model

The financial model developed by Marsh Finances simulates risk scenarios and calculates the operating cash flows without and with a weather cover. It can quantify the benefit of the cover on the operating cash flows, and support the argumentation with bankers to improve their confidence in the project when a wind derivative is in place.

Figure 20 - Wind farm stochastic business plan model
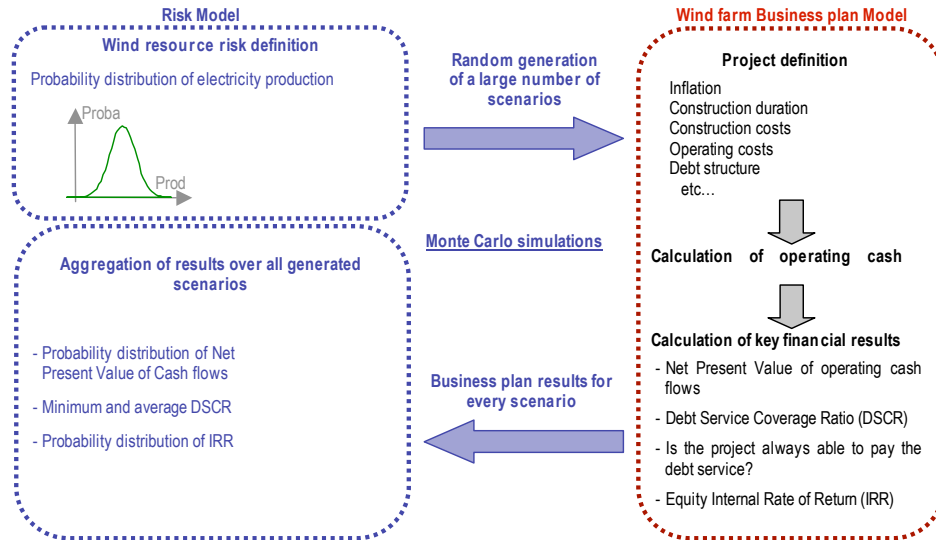
The model can provide a synthetic view of the production, the operating cash-flows and the equity return expected over the project's lifetime.

Figure 21 - Illustration of the volatility of cashflows
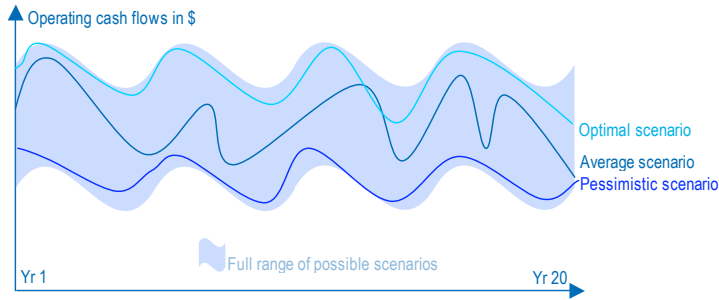
4.2 Financial study for La Venta III

Besides the standard wind derivative, two hedging instruments integrated into the financing structure have been tested: a wind reserve and a wind interest swap. For the standard wind derivative and the wind reserve, three levels of production coverage have been tested (P50, P70, P90). For the wind swap, two calibrations have been tested (a symmetric wind swap and a no premium wind swap).

The principle of the products described below could be applicable to any wind project. The wind risk hedging products have been calibrated and priced by Marsh with the confirmation of Paris Re on the prototype project La Venta III. The conditions of applicability of the range of premium provided here would have to be confirmed by Marsh and Paris Re for the implementation of the product.

The three structures presented below are applicable for a large scale wind farm. These structures have been tested and their efficiency compared.

- Standard wind derivative
- Wind reserve
- Wind swap

Today these structures are generally considered as stand-alone wind risk coverage. They are used by sponsors who are very risk adverse and are ready to pay a high premium to reduce their risk.
However, in order to be economically efficient, the wind coverage has to be integrated in to the financing structure and thus become a credit enhancement instrument. This is the purpose of the wind reserve which has a lower cost and can

4.2.1 General characteristics of the cover

Period of cover

The recommended wind derivative structure covers the first five years of the project, which is considered to be the most risky investment period for the bank. A shorter cover period is always possible. However, a longer cover period would be more difficult to guarantee because markets are usually reluctant to engage in a long-term exposition.

Wind speeds and thus wind productions are seasonal: the seasonality of wind can be smoothed with a monthly cover. In this case, monthly production and revenues are secured.

However, if debt covenants are annual, a cover with annual indemnification can be structured. Only the annual volatility is covered then. This solution is not presented in here.

Index-based covers

These hedging instruments are index-based. This induces the following specific characteristics:

- The calculation of the indemnification depends exclusively on the value of the index and not on real loss. The objective of the technical feasibility study is to determine the index that best matches real loss.
- The indemnity calculation results from the value of the index which is an objective measure. When the cover is triggered, the indemnification is very quick.
- These instruments cover exclusively the risk of wind speeds being very low over a period. In particular, other risks such as damages, interruption of turbines for technical or environmental reasons, even when they impact the production, are not covered.

4.2.2 Standard Wind Derivative

Standard Wind Derivative principle

This option is a revenue protection structure.

If the wind index is below a predefined level (the strike), the wind counterparty pays an indemnity to the project.

The indemnity covers lack of revenue due to low electricity production when wind speeds are particularly low. It is proportional to the difference between the strike and the index.

The proportionality factor– the amount of indemnity per unit of index below the strike - is the Tick.

The project pays a premium to the weather counterparty depending on the Strike, the Tick, and the Capacity.

This structure protects revenues. Revenues are floored at a minimum level which depends on the parameters of the structure (strike and tick). This decreases the probability that the project is not able to meet debt service.

Figure 22 - Mechanism of standard wind derivative
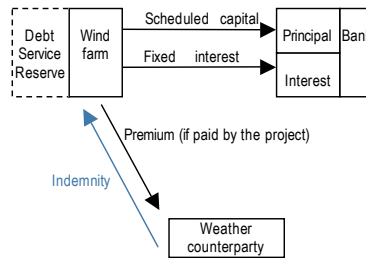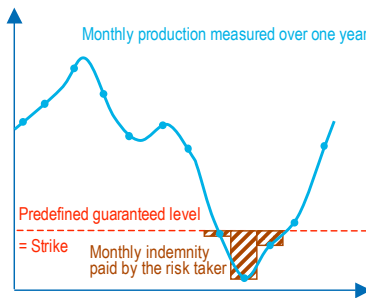
Optionally, the project can agree to abandon part of the benefits when wind speeds are particularly high. In such a good wind period, the project would drop part of its revenues to the benefit of the wind counterparty. As compensation, the Premium is decreased.

Cost and benefit of Standard Wind Derivative

Indicative level of Premium

The standard wind derivative is in place for a five years period.

Three different Strikes have been tested for the standard derivative.

- Strike at P90 (corresponding to a net production 30 GWh with 15% losses and 3% turbines unavailability)
- Strike at P70 (net production 33 GWh)
- Strike at P50 (net production 35 GWh)

The Limit is set in order to provide an optimal coverage: Limit at P99,9. This means that any production level would be fully covered, except when it is below P99,9. In other words, the probability that the Capacity is not enough is 0,1% (it is the probability that a P99,9 production level is reached).

The Tick is set equal to the revenues earned by the project per MWh of electricity sent to the grid: 58 $/MWh (includes the PPA price + the World Bank subsidy).

The table below indicated the indicative level of premium for the three Strikes that have been tested for La Venta III.

Gross production level guaranteed		Equivalent net production		Capacity	Standard wind derivative Premium		
(per turbine)		(per turbine)	(for the wind farm)	(for the wind farm)	(for the wind farm)		
(Pxx)	(in MWh)	(in MWh)	(in GWh)	(in $ for total covered period)	(in $ per month)	(in % of monthly revenues)	(in $ for total covered period)
P50	355 MWh	290 MWh	35 GWh	23 m$	[300-350] k$	16%	20 m$
P70	335 MWh	275 MWh	33 GWh	19 m$	[240-290] k$	13%	16 m$
P90	302 MWh	250 MWh	30 GWh	14 m$	[160-180] k$	9%	10 m$

These indicative premium levels have been estimated by Marsh and confirmed by Paris Re. These premium levels would have to be reconfirmed with real project data.

Impact of the cover on the operating cash flows

The cover has two impacts on the operating cash flows:

- best scenarios are lower due to the Premium payment
- all scenarios with a production below the Strike are improved

Figure 23 - Impact of P90 standard wind derivative on project cashflows
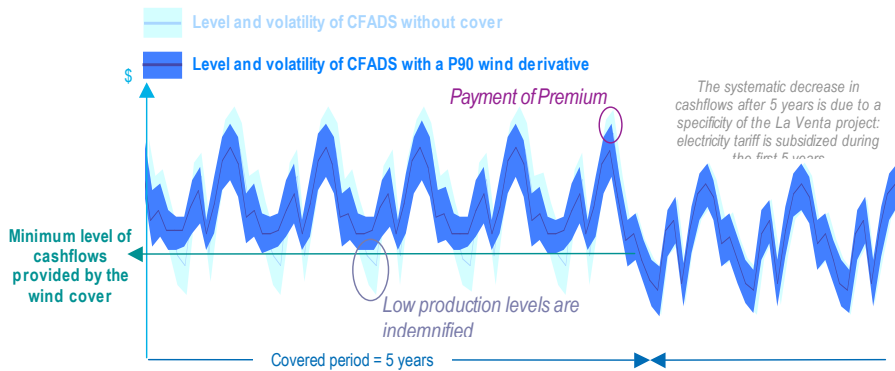
The periods with lowest production levels are the period where the risk that the project is not able to pay the debt service is highest. With the cover, these periods benefit from indemnities paid by the weather market. Therefore, the risk that the project does not have enough revenues to pay debt service is reduced.
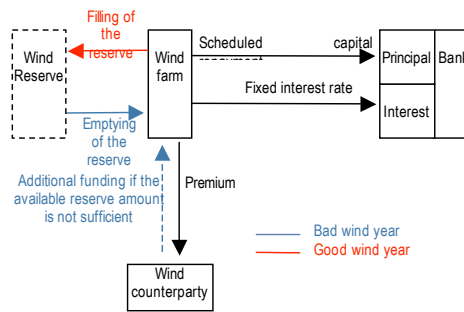
4.2.3 Wind Reserve

Wind Reserve principle

This structure is based on an experience account filled and emptied according to the value of the wind index. This reserve account is guaranteed by the weather market.

- When the Wind Index is above the Strike, cash is filled into the wind reserve account
- When the Wind Index is below the Strike, cash is provided from the wind reserve to the project
- When the Wind Index is below the Strike and the reserve is empty, the weather market provides additional cash to the project

The wind reserve smoothes the production seasonality and most of the volatility. The weather market guarantees the availability of free cash so that the project can meet debt service when the wind electricity production is low.

Figure 24 - Wind reserve mechanism

Cost and benefit of the Wind Reserve

Indicative level of Premium

Three different Strikes have been tested for the wind reserve (as for the standard derivative).

- Strike at P90 (corresponding to a net production 30 GWh with 15% losses and 3% turbines unavailability)
- Strike at P70 (net production 33 GWh)
- Strike at P50 (net production 35 GWh)

The Tick is set equal to the revenues earned by the project per MWh of electricity sent to the grid: 58 $/MWh (includes the PPA price + the World Bank subsidy).

The wind reserve Capacity is set according to the seasonality profile in La Venta III, in order to ensure that in an average scenario, the wind reserve will be enough to cover the periods with lowest production (June and September), and finish the seasonality cycle in October with a null (or low) balance. The wind reserve maximum Capacity is therefore equivalent to 34,6 GWh i.e. 1,7 m$.

The weather market Limit is set in order to provide an optimal coverage: Limit at P99,9. This means that any production level would be fully covered, except when it is below P99,9. In other words, the probability that the Capacity is not enough is 0,1% (it is the probability that a P99,9 production level is reached).

Gross production level guaranteed (per turbine)	Equivalent net production		Weather Market Capacity (for the wind farm)	Wind Reserve Premium (for the wind farm)		
	(per turbine)	(for the wind farm)				
(Pxx) (in MWh)	(in MWh)	(in GWh)	(in $ for total covered	(in $ per	(in % of	(in $ for total

				period)	month)	monthly revenues)	covered period)
P50	355 MWh	290 MWh	35 GWh	8,2 m$	[90-110] k$	5%	6 m$
P70	335 MWh	275 MWh	33 GWh	3,3 m$	[30-40] k$	2%	2 m$
P90	302 MWh	250 MWh	30 GWh	1,2 m$	[5-10] k$	0,5%	500 k$

These indicative premium levels have been estimated by Marsh and confirmed by Paris Re. These premium levels would have to be reconfirmed with real project data.

Impact of the cover on the operating cash flows
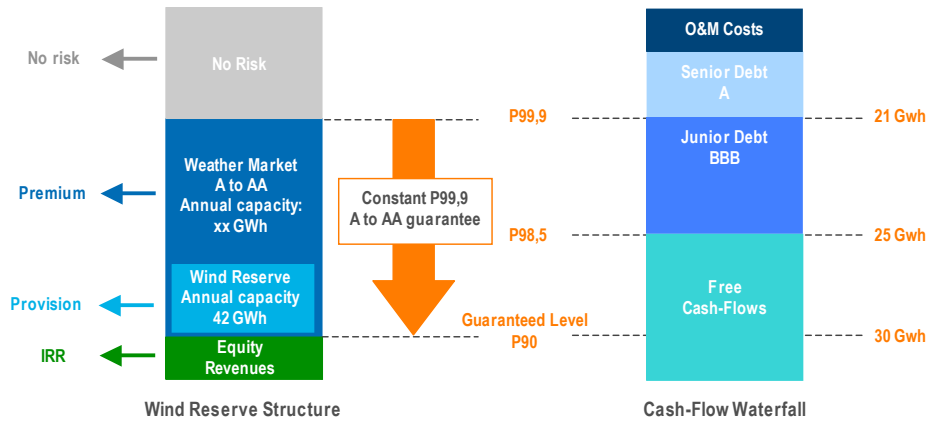
4.2.4 Wind Interest Swap

Wind interest swap principle

This structure integrates the wind derivative into the financing structure.

The wind project pays debt interest at a floating rate calculated from the wind index. The bank receives a fixed interest rate from the wind counterparty. When the wind index is high, the project pays a high interest rate. The wind counterparty earns the difference between the high floating rate and the fixed rate. When the wind index is low, the project pays a low interest rate. The wind counterparty pays the complement between the low floating rate and the fixed rate.

The example below describes the payment of interest by the project with the following assumptions:

- the fixed interest rate requested by the bank is 8%
- the swap production is P50 and the swap rate is 8%
- the maximum interest paid by the project is 16% when the production is above P10
- the minimum interest paid by the project is 0% when the production is below P90
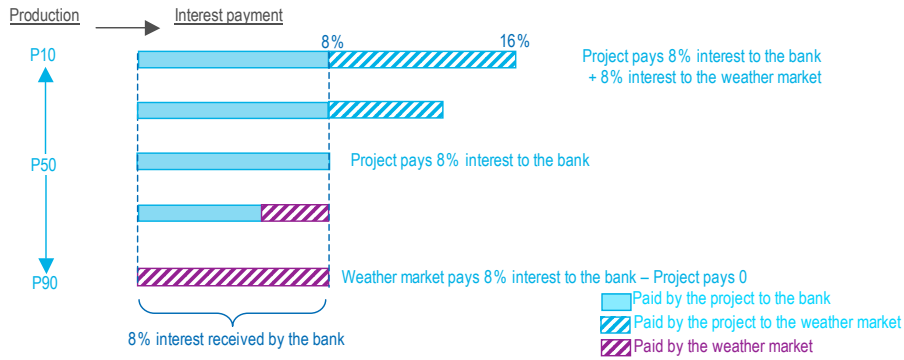
The wind counterparty therefore guarantees the payment of debt interest when the wind electricity production is low. The project pays a floating rate adjusted to the level of production during the period.
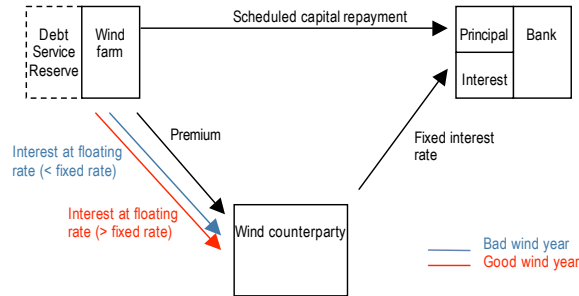
A major specificity of this structure is that besides the premium, part of the upside (benefit in favorable scenarios) has to be retroceded to the weather market. Thanks to this mechanism, the level of premium for this type of structure is low. However, the project owner has to accept that benefits will be shared with the weather market in favorable situations.

Cost and benefit of the Wind interest swap

The first structure tested corresponds to the example presented in the above paragraph, and assuming that both loans are covered.
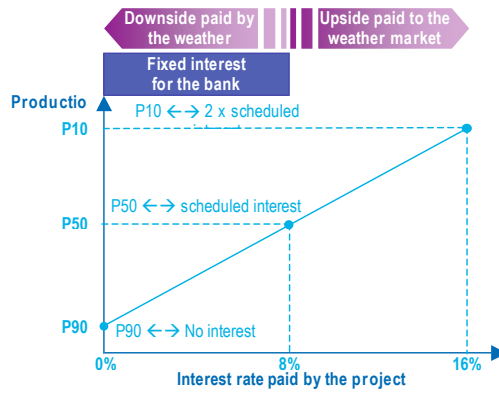
The total Capacity required from the weather market for this cover is 10m$ for the wind farm and the total covered period. The level of premium calculated for La Venta III is USD780,000 for the five years covered, i.e. USD13,000 per month.

The second wind swap structure has been calibrated so that no Premium is paid.
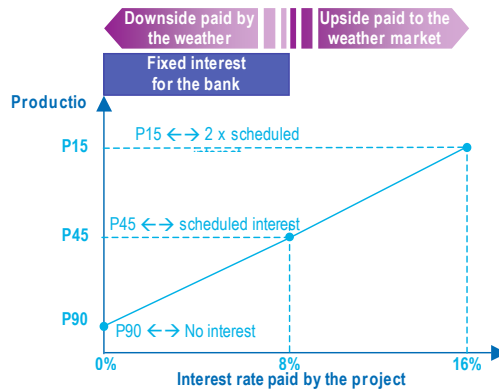
These indicative premium levels have been estimated by Marsh and confirmed by Paris Re. These premium levels would have to be reconfirmed with real project data.

4.3 Conclusion and recommendations

Standard wind derivatives are available today for wind projects to protect their wind risk exposition. However, it remains a very expensive cover (16% of revenues for a P50 guarantee).

The wind reserve and wind swap are innovative solutions developed by Marsh Finances for this study, based on a wind derivative, and calibrated specifically as credit enhancing instruments (wind risk is replaced by the weather counterparty credit risk). We have developed them according to our experience of weather derivatives markets and wind projects issues.

The wind swap is a product with a low premium. However, when the wind conditions are favorable, the project has to give back part of this upside to the weather market (under a similar mechanism as standard interest swaps on the financial markets). Even though the premium is attractive, this solution might be less adapted because the investor has to give away part of its upside revenues (production above the strike goes to the weather market).

Among the three structures that have been presented in the consultation, the wind reserve received the most attention, with the following key points mentioned by the parties consulted:

- The wind reserve has a low premium (5% of revenues) compared to the standard wind derivative (16% of revenues)
- The wind reserve does not impose giving away part of the upside to the weather market in good years (in opposition to the wind interest swap)
- With the wind reserve, cash is blocked in the reserve account at most for 12 months and therefore does not reduce equity return

Moreover, banks that have been consulted for this study are favorable to increase the debt leverage when a wind derivative is in place. In particular, the loan amount could be expected to increase between 2% and 6% of total investment if a wind reserve guaranteeing P50 production level is in place. According to our financial model, the wind reserve premium becomes efficient with a 2% increase in debt leverage.

Therefore, we assume that the wind reserve has the potential to secure the project revenues, reduce debt default risk and increase equity return.

Typical projects which could benefit from this product are:

- large scale projects (50-100MW) or a portfolio of smaller wind farms,
- with a low debt to equity ratio (less than 80% debt financed)
- with significant exposure to monthly and annual variation in production due to wind speeds volatility.

5. Appendix

5.1 Index of figures

5.2 Definitions

Capacity

The Capacity is a parameter of a wind derivative referring to the maximum amount paid by the risk taker as indemnity. Typically the Capacity refers to the maximum amount paid over the whole covered period.

It is also possible to limit the maximum amount per period with a specific Capacity per period of settlement.

The Capacity can be expressed in MWh if divided by the tick. For example, if the maximum amount paid by the risk taker is 1m$ (Capacity in $) and the indemnity paid by MWh (the Tick) is 50$/MWh, then the maximum amount of energy that can be indemnified is 20 000 MWh (Capacity in MWh).

[The installed capacity of a wind farm has a different meaning: it refers to the maximum generation power, in W.]

Debt Service (DS)

The Debt Service refers to the total interest and principal repayment due.


Debt Service Coverage Ratio (DSCR)

The DSCR is a financial ratio commonly used in project finance as a covenant to evaluate the ability of a project to pay monthly debt service.

It is calculated for every period before the debt term as the ratio between the amount of Cash Flow Available for Debt Service (CFADS) and the Debt Service (principal + interest).

The Minimum DSCR (MDSCR) and Average DSCR (ADSCR) over the debt period are key financial ratios considered by banks.

Typically, banks require that the MDSCR is above 1.3 - 1. 5 to ensure the Cash Flow Available For Debt Service are sufficient to cover loan payments over the whole debt period.
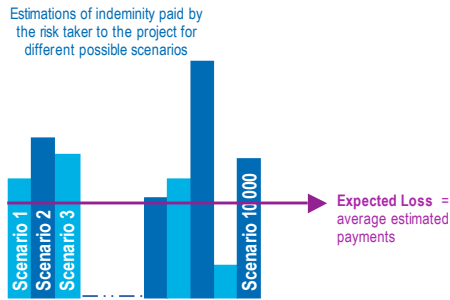

CFADS = 1,5x Debt Service
→ DSCR = 1,5

CFADS = Debt Service
→ DSCR = 1
Minimum DSCR = 1
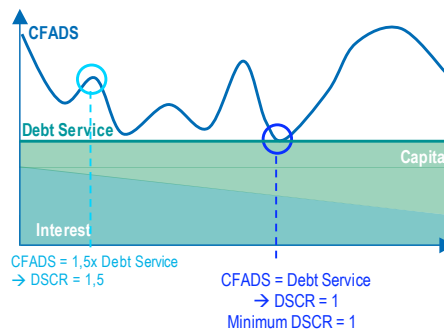
Debt Service Reserve Account (DSRA)

The Debt Service Reserve Account is a bank account, funded up-front, and which can provide additional cash to the project when CFADS are not sufficient to cover Debt Service. Then, provided the CFADS are high enough, cash will be filled back into the DSRA in the following periods, until the account balance reaches the initial amount.

The DSRA is funded up-front with 3 to 12 months debt service according to the bank requirements.
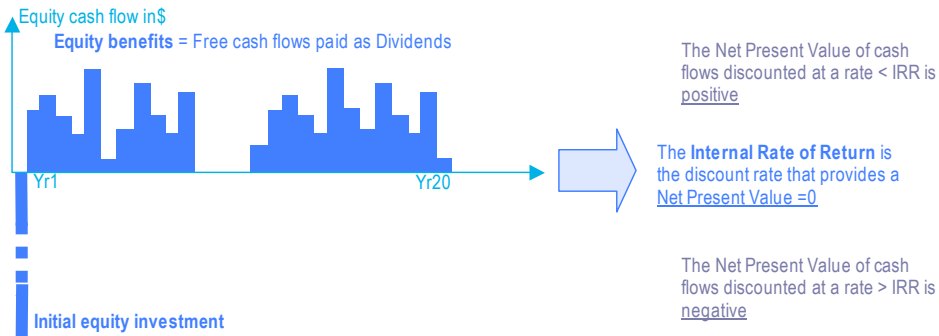

Expected Loss

The Expected Loss is measured by the risk taker to evaluate the average payments to be done according to the hedging instrument mechanism.

Estimations of indemnity paid by the risk taker to the project for different possible scenarios

Expected Loss = average estimated payments

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Internal Rate of Return (IRR)

The Internal Rate of Return is a measure for the equity investor indicating the efficiency of its initial investment, in regard to the expected benefits to be received during the project lifetime.

The IRR is calculated as the discount rate which results in a Net Present Value of the equity cash flow (initial investment and future benefit) equal to zero.


Equity cash flow in$

Equity benefits = Free cash flows paid as Dividends

Yr1   Yr20

Initial equity investment

The Net Present Value of cash flows discounted at a rate < IRR is positive

The **Internal Rate of Return** is the discount rate that provides a Net Present Value =0

The Net Present Value of cash flows discounted at a rate > IRR is negative

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Limit

The Limit of the wind derivative is the value of the Wind Index where the indemnification is maximum. There is a relationship between the Strike, the Limit and the Capacity: The Capacity in MWh is the difference between the Strike and the Limit.

MWh

Strike
Capacity
Limit
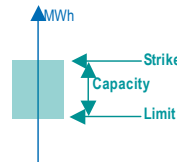
Power Curve

The Power Curve of a wind turbine is a graph indicating the power output of the turbine for different wind speeds at the turbine rotor height. This information is provided by the turbine manufacturer.
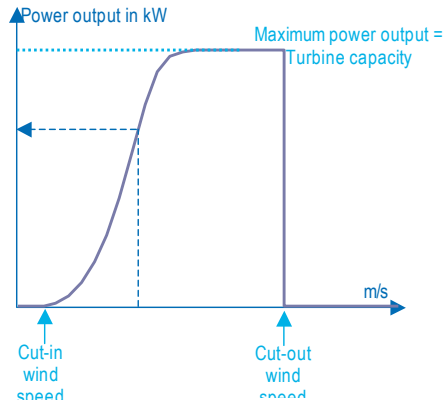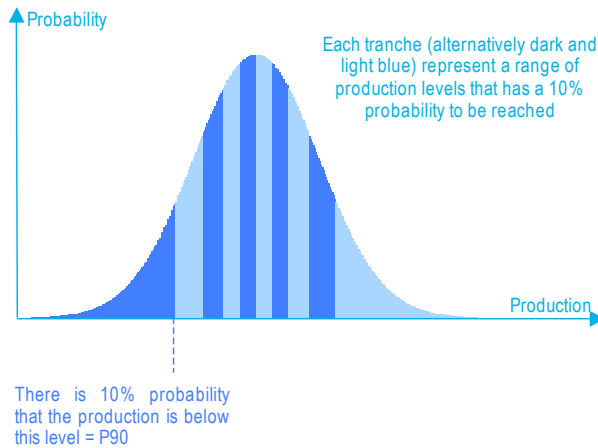

Premium

The Premium is the price of the cover to be paid to the risk taker by the project. The amount of the Premium depends on the volatility of the risk that is undertaken by the Risk Taker.

PXX i.e. Exceedance Probabilities

Probability of exceedance PXX refer to the amount of electricity produced with a XX% confidence level. This means that there is XX% probability that the electricity produced exceeds PXX. For example, P90 is a conservative measure of the expected electricity production. Statistically there would be only one chance out of ten that the project generates less than its P90. The probabilities of exceedance are calculated from the probability distribution.

Risk Taker

The Risk Taker refers to the wind derivative counterparty which agrees to undertake the wind risk against payment of a premium. Typically, Paris Re could be the Risk Taker in the wind coverage scheme that we would implement.

Strike

Parameter of a wind derivative corresponding to the level below which the cover is triggered.

Tick

The tick is a parameter of a wind derivative corresponding to the amount of indemnity per unit of Wind Index below the strike. It is expressed in $ per MWh and is usually set according to the electricity price.

Weather Market

The Weather Market refers to the weather derivative counterparty which will undertake the wind risk.

5.3 Who we are

MARSH *Finances*

MARSH MERCER KROLL
GUY CARPENTER OLIVER WYMAN

Marsh Finances develops, structures and leverages products at the cross-roads of the insurance industry and financial markets. The team has a close and long standing relationship with the renewable energy practice created by Marsh. Marsh Finances has risk management expertise in project finance and renewable energy, with a strong experience of weather derivative markets as an insurance and financial broker.

PARIS RE

PARIS RE is a mid-sized, multi-line re-insurer. Paris Re, previously known as AXA Re, is a worldwide leader/pioneer in the weather covers and has a proven experience in providing protection for renewable energy projects. Paris Re led and underwrote the first weather derivative for the Untied Nations World Food Program to cover the consequences of an extreme drought in Ethiopia. Paris Re weather exposure is spread over several countries including Mexico.

UNEP

As an innovating agency of the United Nations system working with the finance sector since the late 1990s, UNEP works with the private sector to identify new investment approaches, to reduce transaction costs and to manage related financial risks with renewable energy projects in emerging and developing countries. This work also involves the coordination with BASE of the Sustainable Energy Finance Initiative (SEFI).

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PARIS RE