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Global Warming's Impact on Wind Speeds: Long-Term Risks for Wind Farms May Impact Guarantees and Wind Derivatives Tied to Wind Energy Production

by

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ABSTRACT

While there is debate among the scientific community as to whether global warming is, in fact, occurring, this paper presumes that, based on certain recent research findings, global warming exists. This paper analyzes increases in global temperature over the last several decades and how continuing global warming trends in future decades may alter the jet stream, impact wind speeds and wind directions, intensify storms and other extreme weather conditions, and change the wind patterns that historically have characterized particular areas. It also discusses how these changes in wind speeds and weather conditions may impact the usefulness of meteorological and other feasibility studies conducted prior to the construction of a wind farm at a particular location, and how such altered wind patterns may adversely influence the performance and productivity of utility-scale wind turbines in terms of their electricity generating output, particularly toward the end of their 20 – 30 year life span. This paper also examines how global warming-induced shifts in wind speeds may alter the landscape of certain risk-based contracts, such as guarantees that turbine manufacturers currently offer and financing products such as wind derivatives that are used to hedge risks associated with certain wind speeds, including how these products are structured. As a result, this paper concludes that rising global temperature and its impacts on wind speeds and wind turbine energy production may ultimately alter products in the finance markets, and that wind farm project developers should plan ahead now in anticipation of such impacts.

I. Introduction

When one thinks about global warming and its impact on climate change, one generally does not contemplate how shifts in temperature globally and locally may impact wind speeds and wind farms in the long-term. This needs to change. New research findings indicate that global warming may alter the jet stream, either increase or decrease the average wind speeds in particular locations, and cause certain areas to experience more brutal or violent weather conditions with corresponding increased turbulence and wind speeds ("Global Warming Research").

Before a utility-scale wind farm is erected, the potential developer conducts extensive feasibility studies to gauge wind speeds, wind direction, the consistency or intermittency of wind flow over a given parcel, and to use findings from these studies to ultimately determine whether to construct a wind turbine array on such parcel. If the projections from Global Warming Research are accurate, then the results of these feasibility studies and other historical data that such developer may use for wind forecasting purposes may be rendered inaccurate for purposes of predicting wind speeds, wind direction, and weather severity with respect to the later years of a utility-scale wind turbine's 20 – 30 year average life expectancy, and with respect to other turbines in the wind farm to which it belongs. Impacted turbines may experience higher wind intermittency periods than originally predicted, increased stress and loads on their blades from higher wind speeds, more severe and erratic wind gusts, and increased turbulence from wind blowing from inconsistent directions. As a result, these turbines may need to be shut down when such conditions occur, or may experience blade damage, at a higher rate than the feasibility studies predicted originally. This increase in turbine down-time translates into a corresponding decrease in such turbines' overall efficiency, performance, and energy production.

Wind farm project developers need to consider the long-term impacts such shifts in wind speeds and wind patterns pose in terms of utility-scale wind turbine shut down risk and blade damage risk, as such risks may impact their future profits toward the end of a wind turbine's life cycle. This is because increased time when turbines are shut down or are otherwise non-operational translates into less energy produced during a fixed period than originally anticipated. Such decreased energy production results in decreased profits from the impacted turbines. Developers' awareness of such potential decrease in turbine productivity levels may impact the structures of risk-mitigation contracts and other financial instruments, such as wind derivatives, that the developers use to maximize their return while minimizing their risk.

This paper explores the impacts of global warming and climate change on wind patterns, examines how such changes may impact turbine productivity in the long term, and suggests how these changes may impact the current structure of financial risk hedging instruments aimed at mitigating the risk of decreased wind turbine energy production. It also suggests that wind farm project developers take into consideration such impacts, so that they may be better prepared in the future when considering how to make their wind farm remain financially profitable.

II. Background on Wind Energy Use in the United States and Wind Energy's Role in Reducing Global Warming

While the domestic wind industry is still in its infancy, it continues to flourish. According to The Select Committee on Energy Independence & Global Warming's 111th Congress Staff Report ("Staff Report"), more than 10,000 megawatts ("MW") of new wind energy generating capacity was installed in the U.S. in 2009, the second year in a row that a higher amount of wind capacity was installed than coal, natural gas, or any other resource.[1] The American Wind Energy Association ("AWEA") noted that as of 2009, over six states produced

[1] The Select Committee on Energy Independence & Global Warming, 111th Cong. Staff Report 2010 (hereafter, "Staff Report"), at 7.

more than five percent of their electricity from wind energy.[2] Although there are currently no operational offshore wind farms in the U.S., offshore wind turbines can harness more wind energy than can onshore turbines, as offshore turbines are larger and can capture the higher, more constant wind speeds that blow offshore.[3] The U.S. Department of Energy ("DOE"), in its "20% Wind Energy by 2030" report (the "20% by 2030 Report"), states that wind power could reduce the consumption of four trillion gallons of water if the U.S. generates 20 percent of its energy from wind power by the year 2030 through the installation of 300,000 MW of new installed wind capacity (the "20% Scenario").[4]

Utility-scale wind turbine installations play a significant role in helping to reduce global warming. The greatest source of industrial air pollution in the U.S. is electricity generation, with 40% of carbon dioxide ("CO_2") emissions generated by the electric power sector.[5] When wind turbines are operational, they do not produce greenhouse gas ("GHG") emissions. GHGs, including CO_2, methane ("CH_4"), nitrous oxide ("N_2O"), hydrofluorocarbons ("HFCs"), perfluorocarbons ("PFCs"), sulfur hexafluoride ("SF_6"), and nitrogen trifluoride ("NF_3"), trap heat in Earth's atmosphere that would otherwise escape into space.[6] Each of these gases has an impact on climate change, based on its heat-trapping characteristics, atmospheric concentration, and atmospheric lifetime.[7] Notably, approximately 80 percent of CO_2 emissions over the past several decades have been caused by the burning of fossil fuels.[8] For every megawatt-hour ("MWh") of wind energy produced, there are approximately 1,200 pounds of avoided CO_2 emissions.[9] AWEA estimates that based on the wind capacity installed in the U.S. through 2008 alone, there has been approximately 44 million tons of annual avoided CO_2 emissions domestically.[10] Moreover, the DOE estimates in its 20% by 2030 Report that under the 20% Scenario, 825 million tons of GHG emissions could be avoided.[11] Due to its GHG-reducing potential alone, utility-scale wind power generation is something that, as a matter of public policy, serves a beneficial purpose for the U.S. population and therefore merits public support and attention. For this reason, it is in the public interest to understand and become more educated about how climate change may impact future wind turbine operations and power output.

III. Global Warming

A. Impact on Changes in Wind Patterns

Despite the promise of reduced and avoided CO_2 emissions, the installation of utility-scale wind turbines may help slow, but will not hault, the current global warming trend. As

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[2] See *2009 U.S. Wind Industry Annual Marketing Report: Rankings*, http://www.awea.org/documents/factsheets/Industry_Rankings_Factsheet.pdf. Notably, Iowa is the first state to have over 10% of its annual energy generated from wind power.

[3] See, *Offshore Wind Energy*, http://www.awea.org/documents/factsheets/Offshore_Factsheet.pdf.

[4] See, *20% Wind Energy by 2030*, PowerPoint presentation (hereafter, "20% Wind Energy"), slide 23, 33, http://www.20percentwind.org/20percent_Summary_Presentation.pdf.

[5] See, *How Wind Helps Reduce Global Warming*, http://www.awea.org/documents/factsheets/Climate_Change.pdf.

[6] Staff Report, supra note 1, at 26.

[7] Id.

[8] Id. at 28.

[9] Id. at 26. A megawatt is the equivalent of one million watts. One watt is a unit that measures the rate of energy conversion, and is equal to one joule per second. See http://en.wikipedia.org/wiki/Megawatt#Multiples.

[10] Id.

[11] See 20% Wind Energy, supra note 4, at slide 34.

background, the 2010 meteorological year was the hottest year on record since 1880.[12] Scientists at NASA's Goddard Institute for Space Studies ("GISS") have been conducting an ongoing global temperature analysis, using the 30-year period between 1951-1980 as the baseline (due to the U.S. National Weather Service's using such period to define "normal" average temperatures) (such period, the "Baseline Period").[13] This GISS analysis shows visible temperature anomalies, wherein the mean global temperature has been shown to have increased from the Baseline Period during the period from 1990 – 2009 by a fraction of one degree Celsius.[14] This is significant, as global temperatures are expected to increase by 0.36 degrees Fahrenheit per decade, or approximately by one degree Fahrenheit over the next 30 years.[15] Generally, warming is greater onshore compared to offshore, as water is slower to absorb and release heat than is land, even though levels of warming may differ within particular land regions and ocean basins.[16]

Increased global temperatures may result in a corresponding impact on wind speeds and wind resource distribution. Researchers are currently divided as to whether climate change will increase or decrease wind speeds.[17] For instance, a 2009 study from Iowa State University found that domestic average wind speeds had decreased between .5 percent and one percent since 1973.[18] In contrast, researchers at the University of California-Santa Cruz in December 2008 found that climate change could increase winds along the U.S.'s West Coast by up to two meters per second, a significant change relative to the average winds that currently blow at a speed of five meters per second there, due to the thermal gradient caused by land temperatures increasing faster than those over the ocean.[19] The general wisdom is that as the temperature difference between the poles and the equator decreases, global air circulation will slow (particularly in the northern latitudes), but in specific areas, local wind speeds may increase due to local temperature gradients.[20]

Moreover, climate change could alter the jet stream.[21] Jet streams, which flow from west to east, are caused by the Earth's rotation and atmospheric heating.[22] Wind speed along the jet stream varies according to temperature, with wind flowing along the boundary of the "hot" air mass and the "cold" air mass.[23] A rise in global temperatures could modify the jet stream, impacting global air circulation as well as local wind flows. Scientists such as Johannes Feddema of the University of Kansas, who is also a scientist at the United Nations' Intergovernmental Panel on Climate Change ("IPCC"), and Melinda Marquis of the National Oceanic and

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[12] Staff Report, supra note 1, at 34.

[13] See, *Earth Observatory: Global Temperatures*, http://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php.

[14] Id.

[15] Staff Report, supra note 1, at 34. For purposes of comparison, one degree Celsius is 1.8 times the interval for a degree Fahrenheit, so 1degree Fahrenheit = (1.8 x degree Celsius) +32. See, *How Many Fahrenheit Degrees are in a Celsius Degree?*, http://wiki.answers.com/Q/How_many_Fahrenheit_degrees_are_in_a_celsius_degree.

[16] See, *Earth Observatory: Global Temperatures*, supra note 12.

[17] Maril Hazlett, *Climate Change Could Have Major Impacts on Wind Resources*, N. AM. WINDPOWER, Jan. 4, 2011, http://www.nawindpower.com/print.php?plugin:content.7130.

[18] Id.

[19] *Stronger Coastal Winds Due to Climate Change May Have Far-Reaching Effects*, SCI. DAILY, Dec. 22, 2008, http://www.sciencedaily.com/releases/2008/12/081219172037.htm. The scientists involved in this particular study were Mark Snyder, Travis O'Brien, and Lisa Sloan.

[20] Hazlett, supra, note 17.

[21] Id.

[22] See, *Jet Stream*, http://en.wikipedia.org/wiki/Jet_stream.

[23] Id.

Atmospheric Administration both agree that an altered jet stream could impact ocean currents and global air circulation, thereby changing local wind patterns.[24]

B. Impact on Changes in Extreme Weather Conditions

According to the Staff Report, global warming has already altered the frequency, intensity, duration, and geographic span of certain weather patterns, with potentially severe impacts on the U.S.[25] The Staff Report indicates that due to global warming, there has been an increase in heavy winter precipitation and flooding.[26] This is because global warming results in warmer air, which absorbs moisture similar to a sponge.[27] Therefore, as global temperature increases, so does the amount of moisture in the air.[28] When this moisture hits below-freezing air temperatures, it produces vast amounts of snow.[29] As evidence, in addition to the record snowstorms during Winter 2009-2010,[30] the Northeast U.S. and other parts of the country have experienced brutal winter storms during Winter 2011. In fact, the climate monitoring branch of the National Climatic Data Center ("NCDC") determined that certain cities, such as New York City and Philadelphia, experienced snowfalls in January 2011 alone that ranked among the top 10 heaviest on record.[31] The Staff Report further indicates that global warming is expected to result in stronger hurricanes, more destructive winds, more frequent cold-season storms, greater amounts of flooding, and increased wave heights.[32]

C. Impact on Wind Resource Assessment, Feasibility Studies, and Turbine Productivity

Proper siting is key to maximizing each wind turbine's energy production potential and actual energy output. For this reason, developers conduct meteorological ("met") studies and feasibility studies to determine whether certain parcels or offshore areas are suited for wind farm construction. SODAR (sonic detection and ranging), LIDAR (Doppler Light Detection and Ranging), high-tech wind flow modeling software, and supercomputers that measure atmospheric turbulence using computational fluid dynamics ("CFD") to measure airflow and fluid flows over a given space are just some of the tools used to calculate seasonal fluctuations in wind speed, wind frequency, and wind direction to assess potential turbine power output at a given location. Collecting such data for a potential site may take several years, particularly as met data is considered unreliable unless the related met study has been conducted for over one year. Moreover, the data gathered from met studies are used to gauge the capacity factor of the potential wind farm. "Capacity factor" refers to the amount of electricity a wind farm is expected to generate, based on the project's estimated installed capacity, over a fixed period of time

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24 Hazlett, supra, note 17.
25 Staff Report, supra note 1, at 41.
26 Id. at 42.
27 Jessica Dailey, *Yes, the Massive Snowstorms Plaguing the East Coast are Related to Climate Change*, Inhabitat, Feb. 2, 2011, http://inhabitat.com/yes-the-massive-snowstorms-plaguing-the-east-coast-are-related-to-climate-change/.
28 Id.
29 Id.
30 Staff Report, supra, note 1, at 42.
31 Pete Spotts, *Winter Storm Raises the Question: What's Going on with the Weather?*, THE CHRISTIAN SCI. MONITOR, Feb. 3, 2011, http://www.csmonitor.com/USA/2011/0203/Winter-storm-raises-the-question-What-s-going-on-with-the-weather.
32 Staff Report, supra note 1, at 42-43.

(typically, one year).[33] For example, a wind farm with 50 utility-scale wind turbines that are 1.5 MW each in size will have an installed capacity of 75 MW (50 x 1.5 MW = 75 MW). If such wind farm has a capacity factor of 30 percent over the course of one year, then this wind farm would be expected to produce an average of 22.5 MW of electricity during such period (75MW x 0.30 = 22.5 MW).[34]

The findings of these studies and the capacity factor as relates to a specific wind farm, however, do not necessarily account for changed wind patterns and more extreme weather conditions in the future that may adversely impact a commercial such turbine's productivity toward the end of its 20 – 30 year life cycle and increase the wind farm's overall energy production volume risk. For instance, when a thunderstorm occurs, winds do not blow from a constant direction, do not blow at a uniform speed, and could exceed over 200 mph in a downburst under an active thunderstorm cell.[35] Moreover, severe thunderstorms may cause tornadoes to form.[36] When operating, a wind turbine's control system adjusts the pitch of the blades to ensure that the rotor speed does not exceed certain limits during changes in wind speeds.[37] Feathering the blades, or, rather, turning them so that they are parallel to the airflow, causes the rotor to stop when wind speeds surpass these limits.[38] It is plausible that if there are increased bouts of intense wind conditions and turbulence caused by thunderstorms, hurricanes, tornadoes, or other extreme weather conditions, then there may be increased periods when the blades feather, stop spinning, and stop producing electricity. As illustration, utility-scale wind turbines are generally designed so that their blades automatically stop when wind speeds exceed a certain capped, threshold level (the "turbine cut-out wind speed").[39] If such threshold level is reached with a higher degree of regularity than the met studies or feasibility studies indicate, then more turbines than anticipated at an impacted wind farm will be producing 0 MW of electricity for longer or more frequent-than-predicted periods, and, as result, the average annual turbine energy production at such wind farm will likely be less than its original capacity factor predicted. The wind farm, consequently, may run the risk of having an energy output shortfall, given that it may produce less energy annually than anticipated.

Moreover, wind gusts from a passing storm may simultaneously hit a turbine's blades from different directions and at different speeds.[40] As a result, even with advances in blade and turbine design, aerodynamic loads and twisting moments on blades can be greater than the limits that such blades can withstand.[41] Consequently, these blades may stall, may be damaged even when they are shut down, or may break. At a minimum, stronger winds and more frequent storms and related turbulence may increase loads on blades and may increase wear-and-tear on the turbine gears to which the blades are connected. This turbulence issue is exacerbated in the situation where a downwind turbine experiences wake effect from an upwind turbine; after wind flows through the upwind turbine, the air downwind of such turbine has a lower wind speed and higher turbulence than wind in the freestream. Also, due to the wear-and-tear on turbines

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[33] Edward D. Einowski, *The Law of Wind: Project Finance for Wind Power Projects*, Chapter 8 at 4, in The Law of Wind: A Guide to Business and Legal Issues, Stoel Rives LLP, Fifth Edition, 2009.
[34] Id.
[35] Dick Kleeman, *Failures of Wind Turbines*, National Wind Watcher, Nov. 22, 2007, http://www.wind-watch.org/documents/failures-of-wind-turbines/.
[36] See, *Wind Shear*, http://en.wikipedia.org/wiki/Wind_shear.
[37] See, *Blade Pitch*, http://en.wikipedia.org/wiki/Blade_pitch.
[38] Id.
[39] MARSH Finances and Pairs Re, *Weather Derivative Solutions for Wind Farms Financing in Mexico*, Feasibility Study, May 2008, at 17 (hereafter, "Weather Derivatives Study").
[40] Kleeman, supra note 33.
[41] Id.

resulting from potentially considerable shifts in wind speeds and weather intensity, the power lines connecting a turbine to the electric grid may be adversely impacted unless vibration dampers on these power lines are installed.[42]

IV. How Changes in Wind Speeds and Weather Dynamics May Alter Performance Guarantees and the Terms of Wind Derivatives in the Future

A. Mechanical Availability and Output Guarantees from Turbine Manufacturers

Alterations in wind speed severity and increases in violent weather patterns may cause the terms of certain risk mitigation products to undergo re-evaluation and modification in the future. For instance, performance guarantees from turbine manufacturers, including mechanical-availability guarantees and output guarantees, are generally sought for large wind projects.[43] In the case of mechanical-availability guarantees, such products guarantee that turbines from that manufacturer that have been used to populate a particular wind farm will be reliable insofar as they will be ready to produce energy 95 percent of the time annually.[44] If the turbines are mechanically unable to meet this 95 percent threshold, or, rather, the guaranteed mechanical availability percentage at the end of a the contract year, then the turbine manufacturer must pay liquidated damages in the amount of cost of the replacement power used to cover the turbines' energy generation shortfall.[45] Going forward, despite continued advances in turbine designs, wind turbine manufacturers who are cognizant of future cumulative impacts of wind speeds and weather changes 20 – 30 years from now on their products that were built today may re-evaluate and re-set the turbine mechanical availability percentage. Consequently, future mechanical-availability guarantees may contain a lower mechanical availability percentage, such as 90 percent, 85 percent, or lower.

Also, turbine manufacturers that offer turbine output guarantees and are aware of impacts of increased wind speeds and more extreme weather systems on their products may reassess certain terms of these guarantees as well. An output guarantee aims to ensure that a manufacturer's turbines in a given wind farm will produce a certain level of total energy output over a fixed period, usually a year.[46] This output level, called the "mean annual output," is expressed in terms of the number of MW hours ("MWh") produced in one contract year.[47] An output guarantee generally guarantees that 75 percent of the mean annual output is achieved. Therefore, if the actual MWh produced during the fixed period is less than this percentage, then the manufacturer covers the shortfall.[48] In the future, though, manufacturers may not provide as favorable terms for their output guarantees, and may decrease the guaranteed 75 mean annual output percent to 70 percent, or lower. Under this hypothetical, the turbine owner would have higher exposure to turbine energy output risk.

B. Wind Derivatives

Decreased long-term productivity for wind turbines due to global warming impacts may also alter how wind derivatives are constructed, given the correlation between lost wind farm

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[42] Thomas Ham and Jurgen Kroning, *In the Wake of a Wind Turbine*, FLUENT NEWS, Spring 2002, at 7.
[43] Einowski, supra, note 33, at 6.
[44] Id.
[45] Id.
[46] Id.
[47] Id.
[48] Id.

revenues and wind speed statistics. Wind derivatives are financial hedging instruments that use an index (usually based on findings from a wind measurement/weather station located as close as possible to the wind farm) on which both the developer/project owner/protection buyer and the counterparty/protection seller agree upon, rather than actual losses sustained at the wind farm itself, to determine losses suffered.[49] They are also structured on a case-by-case basis, and are tailor-made, based on the wind availability findings from data from nearby official weather stations (independent from the wind farm developer) conducted in advance of the project.[50] A standard wind derivative contract has a term of between three and five years.[51]

Wind derivatives operate as follows. The pre-determined "trigger level" under which the wind index may fall to trigger coverage payments is called the "strike."[52] If the wind speeds on the wind index used for the particular wind farm fall below the strike, then the protection seller makes an indemnity payment to the protection buyer.[53] This indemnity payment is intended to cover the revenue shortfall from the wind farm that occurs due to low electricity production resulting from wind speeds being too low, or due to turbines automatically shutting down when they reached the turbine cut-out wind speed.[54] Also, there is a fixed floor limit (the "limit") of wind index wind speeds below which the counterparty will not make indemnity payments.[55] This limit represents the highest indemnification payment value the protection seller will pay the protection buyer if wind speeds on the wind index remain at such level for a certain fixed period (such as a month).[56] The range of wind speeds between the strike and the limit represents the wind index-based wind speeds for which the protection seller has agreed to pay indemnity payments to the protection buyer. The amount of the indemnity payment is based on the number of units below the strike but above the limit to which the energy production has fallen. Payments are made by the protection seller at set intervals, such as monthly, in exchange for regular, fixed premium payments from the protection buyer (the amount of premium paid is determined by the protection seller, based on the level of risk it is undertaking).[57] Such indemnity payments may be placed by the protection buyer in a debt service reserve, with the intent that the protection buyer will have sufficient funds to make scheduled monthly loan payments of principal and interest to the wind farm project lender, even during months when wind energy production is low.[58] A wind derivative, therefore, is a means of providing a certain level of comfort to the lender that the project developer will not default on its loan repayments to such lender.

There is debate about which items would be altered what way in a wind derivative's structure if wind patterns or weather conditions changed. Wind derivatives are relatively expensive hedging instruments.[59] While they used to be traded on the Nordix Financial Wind Indexes on the now defunct U.S. Futures Exchanges ("USFE"),[60] they are presently a non-liquid

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[49] See Weather Derivatives Study, supra, note 39, at 2.
[50] Id. at 4.
[51] Id. at 4, 28.
[52] Id. at 28.
[53] Id.
[54] Id.
[55] Id. at 3, 28.
[56] Id. at 37.
[57] Id. at 38.
[58] Id. at 28.
[59] Id. at ii.
[60] See David Watkins, *U.S. Futures Exchange to List Wind Derivatives*, Risk.net, News section, July 3, 2007, http://www.risk.net/energy-risk/news/1510953/us-futures-exchange-list-wind-derivatives; see also, *U.S. Futures Exchange*, http://en.wikipedia.org/wiki/U.S._Futures_Exchange; Doug Cameron, *End of Line*

product, as they are not currently traded in the U.S. on any exchange. As wind derivatives' terms, including the strike level, limit, annual premium, and duration are negotiated between the protection seller and the protection buyer, any of these items individually or in conjunction with one another may be negotiated in the future so that such terms remain attractive to the protection seller, and still afford the protection buyer a reasonable amount of coverage. For example, the protection seller may (i) raise its baseline premium, (ii) shrink the range between the strike level and the limit, (iii) shift the range between the strike level and the limit, (iv) assign a lower indemnity payout value per incident for every incident that falls within the range, (v) increase or decrease the length of the of the contract term, or (vi) use a combination of two or more of these modifications. Again, because wind derivatives are tailor-made, much will depend on amount of risk the protection seller is willing to take, whether the protection seller employs an aggressive or conservative strategy relative to the rate of return and profit margin it receives, and whether the protection buyer is willing to accept the costs and risks associated with the new terms for the product offered.

The above modifications to wind derivatives' terms, though, do not take into account that sudden bursts of extreme winds due to more frequent, intense storms and other weather patterns could result in increased occurrences of turbine cut-out wind speeds. This means that although the wind index used for a particular wind farm registers a high average wind speed during the time which the wind event is occurring, the turbines could actually be shut down during such occurrences. This differential between high wind speeds and production levels of "zero" during such occurrences is a disparity for which current wind derivatives may not compensate adequately. This phenomena, given its potential increased frequency in future years, may need to be factored into future wind derivatives, either in terms of factoring into categories (i) - (vi) of the potential modifications to wind derivatives noted in the immediately prior paragraph, or in terms of creating an entirely new category of coverage for a narrow band of high wind speeds tied to the wind index, with its own separate strike level and limit, and with its own separate per incident indemnity payout value, for which an additional premium may be paid. The current landscape of wind derivatives, therefore, could potentially be impacted by global warming trends in certain predictable ways, and in other ways that may completely alter the designs of these products from how they appear today.

V. Conclusion

While there is debate over the existence of global warming, recent scientific data nevertheless indicates that the Earth's temperature has been rising over the past several decades, and likely will continue to rise in the future. The continued introduction of GHGs into the atmosphere may help to facilitate this temperature increase and keep moisture in the air. Use of utility-scale wind turbines, either onshore or offshore, may assist in reducing the amount of CO_2 emitted into the atmosphere. Nevertheless, even with this reduction, global temperatures may continue to rise, potentially resulting in altered wind patterns and more violent, frequent storms and other severe weather patterns.

Data from met studies and feasibility studies conducted at potential wind farm sights measure wind speeds, wind direction, and other factors to determine whether to move forward with construction of the wind farm at that location. However, these studies do not account for future weather patterns that may accompany rising global temperatures, such as shifts in wind

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for Futures Exchange, WALL ST. J., Dec. 24, 2008, http://online.wsj.com/article/SB123007926246731807.html.

patterns, altered wind speeds, or increased numbers of storms with more intense, turbulent wind. As a result, particularly toward the end of its 20 – 30 year life cycle, a utility-scale wind turbine may experience increased incidents of turbine cut-out wind speed that were not predicted in the original met studies or feasibility studies, causing a related increase in the time such turbine is not operational and is not producing electricity.

In response to the increased down-time and instances of decreased energy production that utility-scale wind turbines may face due to altered wind patterns, certain turbine manufacturer guarantees and products in the finance markets, such as wind derivatives, may be structured differently in the future than they are today. Potentially, products such as wind derivatives could be modified in the future to include new categories of protection that do not exist today in order to better address the risks of tomorrow that wind farms may experience as a consequence of altered wind speeds and changed weather patterns. Wind farm project developers should be aware of these potential impacts so that they have reasonable expectations as to what manufacturer guarantees and wind derivatives may look like in the future, what they will need to do to maintain lender confidence and insure regular income streams during incidents of decreased wind turbine energy production, and what they will need to do to otherwise plan ahead so that each turbine in its wind farm continues to remain financially profitable in the long term.