CHAPTER – I: INTRODUCTION

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CHAPTER – I: INTRODUCTION

1.1 Nature of Problems

In the field of finance literature, risk has been a subject of study in many different ways. In general, risk is popularly understood as the uncertainty of the outcome of future events, and is normally estimated by the standard deviation of expectations. Risk has been traditionally separated into two categories - pure risk and speculative risk. Pure risk is a chance of loss or no loss, whereas speculative risk is defined as a chance of loss or gain. An example of pure risk is catastrophic risk, such as an earthquake, flood or hurricane. Speculative risk, on the other hand, may yield a gain or loss in the end, for example, investment in equity market. Speculative risk is further categorized as systematic (non-diversifiable) and unsystematic (diversifiable) risk. Managing unsystematic risk is comparatively easy and is normally done through diversifying investment portfolio. Systematic risk, on the other hand, is comparatively more difficult to handle and is normally managed through hedging. In traditional concept, pure risk is managed through insurance, whereas financial risk management concentrates into speculative risk and is primarily mitigated through capital market. For a long time period, insurances have been separated from finance based on this stated classification but, with time, new sources of risks are being continuously discovered, and innovative strategies and tools are created to manage them thereby converging both the types of instruments. With the growing emergence of new and unconventional sources of risk, its management process is also becoming an increasingly important area of decision making for almost all corporations. A proper understanding of different sources of risks and its resultant losses can help business firms gain a competitive cost advantage through well developed, cost-effective and efficient risk management strategies. Ideally, a business firm should manage or mitigate all non operational risks faced by it. The advantages of a well-managed risk management program include not only a less fluctuating financial performance and an improved profitability, but also an increased predictability of future profit and hence higher firm value. Less risky corporate operations and payoffs generate more value for the risk-averse investors and therefore are preferred by stakeholders.

One of such systematic and non operational sources of risk, which has gained enough importance and has been frequently discussed in recent past, is regular weather fluctuation and its impact on
business activities. Weather continues to be a major determinant of several economic activities even in this technology driven era. Almost all the businesses are exposed to the weather risk factors in varying degree. Some industries get affected by the cyclical movement of weather like agriculture or energy; others get affected by irregularity of weather conditions like construction. In a 1998 testimony to Congress, former Commerce Secretary of United States of America, William Daley, stated, “Weather is not an environmental issue; it is a major economic factor. At least $ 1 trillion of the $ 7 trillion U.S. economy is weather-sensitive”. The similar statistics for India is not expected to show any different trend; rather the dependency of Indian economy on weather is expected to be far more intensive in nature. A low monsoon not only affects the agricultural production of India adversely, but also leaves a gloomy impact on the economy as a whole. Sectors like power, energy, entertainment, tourism, construction are largely weather sensitive in their performance. The variation in their operating and financial performance due to unpredictable, uncertain weather is one of the largest risk to which these industries are exposed. This is called ‘Weather risk’. Of all, the sectors that are likely to be maximum sensitive in their performance to the varying weather are agriculture and power.

Weather risk can formally be defined as the financial exposure of a company’s earnings and cash flows attributable to weather deviations from ‘normal’. It refers to the impacts of warmer or cooler temperatures than ‘normal’ on companies’ financial performance and equity values. It also includes the effects of weather beyond just the impact of temperature deviations from ‘normal’, such as rainfall, snowfall, and wind levels. One basic character of weather related risk is that, unlike other sources, it is geographically localized and volumetrically driven i.e. firms located in the same geographical area are exposed to similar kind of risk and it is not generated out of fluctuating price but due to fluctuation in demand and supply volume. Thus it affects the quantity of sales rather than the price component. For example, in a comparatively cool summer, the price of soft drink does not change but its volume of sales declines resulting in less revenue for the company. In this sense, weather risk is unique relative to the other risks. Another unique characteristic of this risk is that it is based on the normal fluctuation of weather, and not on catastrophic weather event. This is a high frequency-low density risk factor which does not comply with the risk pooling concept of insurance.
In order to understand the weather risk, i.e. the risk of fluctuating weather conditions, it is necessary to point out the differences between the terms ‘climate’ and ‘weather’. ‘Climate’ is traditionally being defined as averaged meteorological conditions over an area during some longer period of time, most commonly 25 to 30 years. On the other hand, weather refers to the present condition of the same meteorological elements. Hence, it follows that relationship between climate and economy is significantly different than the one between weather and industry. The impact of long term climate change on economy will be determined by the climate type currently present in a given area. For example, it can be expected that countries with cooler climate will benefit from global warming, which cannot be said for countries with tropical climate. On the other hand, changes in weather have a greater impact on individual businesses rather than the economy as a whole.

Again, the impact of weather on business can be classified under two broad categories. The regular fluctuation of weather condition causes fluctuation in the revenue and profit of a company, like an entertainment park has less than normal number of visitors on a rainy weekend or a power company faces lower power demand on a comparatively cooler summer day. This needs to be differentiated from the catastrophic weather events (known as CAT risk) like tornado or tsunami that causes extreme damages to property and life. The earthquake and tsunami that occurred in Japan in March 2011 caused physical damage that may range from $250 billion to as large as $309 billion (Source: CRS Report to US Congress, March 2011), a figure that matches the GDP of Greece approximately and twice that of New Zealand. The first type of risk, however, specifically concentrates on the fluctuation of firm’s profit due to normal weather fluctuation and is termed as ‘weather risk’. Such fluctuations are frequent, but do not have devastating impacts. Such type of risk also needs to be differentiated from ‘climate risk’, i.e. the uncertainty that the companies are likely to face because of climate change and concern for global warming which may induce them to change their technology, or take up financial contracts, commonly known as ‘climate trading’ or ‘carbon trading’, to manage the emission of green house gases. The melting polar ice due to global warming and the resultant increase in the ocean level is one of the biggest climatic risks the world is facing today. However, global warming may lead to both of more volatility in weather condition, as well as increased number of extreme weather events thereby enhancing both weather and CAT risks.
CAT risk has been long accepted and traditionally mitigated through insurance products, although few innovative financial products are also available now. However, companies are still categorising weather as an unmanageable source of risk, especially in a developing country like India. According to Rallis India - “FY12 was a challenging year for the domestic pesticide industry on account of adverse weather conditions. At the same time, it was one of the strongest growth years for the global pesticide industry. Domestic industry is estimated to have declined in FY12 and in line with the same, Rallis’ domestic pesticide sales have shown de-growth (~2% YoY) in FY12” (Source: Annual Report: Rallis India, 2012-13). BBC News (24th September, 2004) captions - ‘Cold weather cools Cadbury sales’ - a news on how wet summer has put the dampers on drinks’ sale volume at the world's biggest confectionery group, Cadbury Schweppes. However, in the presence of a widely divergent weather risk management practices across industries in western front, and more frequent volatile weather events emerging from changing climate, ‘adverse weather’ will not continue to appear as an acceptable excuse for bad performance of the companies. Assessment and quantification of the risk along with its diverse mitigation strategies are to be explored simply because of the reason for survival.

Although corporate are now keen on focusing in risk management, and majority of them accept that their business is exposed to weather conditions, very few are actually addressing the risk. Leggio (2007) suggested that there are five reasons why firms have to hedge weather risk: smooth revenues, cover excess costs, reimburse lost opportunity costs, stimulate sales and diversify investment portfolios. In a study commissioned by Chicago Mercantile Exchange (CME) Group and Storm Exchange (Myers, 2008) done among the senior finance and risk managers of US and Canada market, 21% confirm that their business are ‘highly exposed’ to risk coming from weather volatility which could have severe impact on their financial performance. Another 38% said that their companies are ‘very exposed’ and need protection from the same. 80% of them have even admitted that the global climate change and accompanying volatile weather pattern will require changes in their business model in the coming time. Although majority of them understand the risk, only 10% of the risk managers admitted that their companies are taking advantages of the readily available financial tools to address the risk; another 12% said that they have the plan to do so in years ahead. Only 10% of the respondents said that they have used weather risk management tools, but a significantly high 35% of
respondents, who belong to energy industries, said that they have done so. Of the companies who have used weather hedging tools, 86% said that they are useful.

Energy is one of the most important contributors in developing economic infrastructure. Uninterrupted and adequate supply of power is a critical component for growth of both agriculture and industry. Power is a unique product which cannot be stored, and hence power distribution at a given point of time cannot exceed the demand. There are three major functions in power sector - generation, transmission and distribution or meeting the demand. All these three major functions are affected by weather condition. Again, based on the source from which power is generated three major sources: - fossil fuel like coal, gas or oil, hydro and other sources like bio-gas or wind power can be identified. Based on the source, the generation is again dependent on weather factor. A detailed analysis of each of such dependences is discussed in section 2.3 of chapter 2. Again, since different regions of India are endowed with different average climatic conditions, which can be defined as the base weather, deviations from this base weather are generally responsible for the variation in power demand. In such a scenario, a reasonably accurate demand forecasting, which would help in better and efficient operation of the power system, is largely based on expected weather fluctuations.

Indian power sector is currently suffering from capacity shortage, poor reliability and quality of electricity. Although economic reforms during nineties introduced private participation, India’s electricity sector still remains dominated by the public sector, which contributes to more than 50% of electricity generation and intra / inter-state transmission, and includes central sector power generator such as National Thermal Power Corporation (NTPC), Power Grid Corporation of India Limited (PGCIL), and various others. Under the ambit of the Ministry of Power, the Central Electricity Regulatory Commission (CERC) and Central Electricity Authority (CEA), work closely with State Electricity Regulatory Commissions (SERCs) in fixing energy prices of long and medium term power contract, execution of the national tariff policy, and in implementing Government of India’s policy decisions on the sector. The impact of weather on such utility companies’ earnings and cash flows are due to variations in consumer demand for energy. In the case of merchant power generators, weather risk is associated with the fluctuating demand level of bulk purchasers of energy, who in turn supply power to retail customers. As most of the power from Inter State Generating Stations (ISGS) is traded at prefixed regulated
rates, risk due to direct price fluctuation is not prominent under current industry scenario; however, weather often affects the recovery of cost for a power generator in an indirect way even in current system. A power generator under current system recovers its cost under two components – capacity cost and unit cost. Capacity cost receivable by generators depends on the Declared Capacity (DC) made by them, and besides other factors, this declaration depends on expected weather conditions. Bulk customers, on the other hand, get their schedule dispatch based on their entitlements out of the DC of the generators and on demand forecasts made by them, which again is based on expected weather conditions. Generators can recover its full fixed cost provided target capacity utilization as per regulated norms is achieved; on the other hand, fixed capacity cost is payable by the bulk customers on the basis of their entitlement rather than the actual demand placed for power. Adversity of weather is a hindrance to both of these achievements.

Electricity Act, 2003 opened the prospect of power trading in India, and since then, a huge quantum of generation is being traded through Inter State Transmission System (ISTS) both by public sector and private sector traders, which makes price of electricity to fluctuate. As a result, price fluctuation risk arising out of the gap between expected and actual generation, or expected and actual demand, or a combination of all these has become apparent in power sector. Weather is a major factor in creating the above variations and continues to be a major source of price risk too for the power sector. So power market’s players namely generators, transmitters, distributors and agents, all try to respond proactively towards the fluctuating effect of weather on their operating performance because quality of such responses would, in turn, affect their financial performance.

Many financial products, instruments and mechanisms are readily available and used in energy sector as a part of its risk management process including weather risk, at least in international front. Some regulated utilities have selected to address this risk in the regulatory process through normalization clauses in their tariffs, which allow them to transfer the risk to the ultimate power user in the form of hiked power price. The other risk management instruments that can be considered are long-term energy contracts, energy derivatives, energy insurance, carbon trading (for fossil fuel dependant thermal power sector) and weather derivatives. Each of these instruments has its own advantages and difficulties in implementation. Long-term energy
contracts are basically purchase contracts between bulk purchaser and generator at a fixed rate and of fixed volume. Energy derivatives are derivatives with underlying as flexible market driven energy price. Energy insurances provide insurance services on the whole range of activities and equipments including grid line that the energy firms and oil and gas companies use. Long term energy contract, energy derivative and energy insurance are designed to hedge the price risk alone; the volume risk still remains un-hedged through above instruments. Moreover, the introduction of energy derivatives in India is subject to the development of an active spot market for power and open access system of distribution and transmission. Although the Electricity Act 2003 has indicated the movement of Indian power sector towards fulfilling of the above-mentioned conditions through a well functioning power exchange, it requires huge investment in such areas. Thus implementing the above mentioned instruments in India is expected to be costly and time consuming in nature. Insurance against bad weather or weather insurance products are mainly available against the risk of damages caused by natural calamities, which is rarely expected but capable of creating disaster. On the contrary, risks related to fluctuating weather are expected to be far more frequent, but less devastative. With this background, the need has arisen to examine the prospect of using ‘weather derivatives’ as a tool to hedge the ‘volume risk’ associated with fluctuating weather conditions, specifically in Indian power sector.

A derivative (or derivative security), as is commonly understood, is a financial instrument whose value depends on, and is derived from the value of other basic underlying variables. It is a contract that does not constitute ownership, but a promise to convey ownership on a pre specified day called the ‘expiry’ (Hull, 2005). Before expiry, other factors like time to expiry, volatility of the underlying and expected development contributes to determining the value of a derivative. On expiry, the derivative ceases to exist and the derivative’s value becomes entirely determined by the underlying. The value of a derivative at expiry is determined by the price of an underlying, which can be categorized into five groups - stocks, commodities, interest rates, currencies and indexes. Historically, weather could not fit into any of these groups of underlying assets. By creating indexes on the weather, this problem has been circumvented, and some valuation techniques can now be applied to weather derivatives. While the different categories of underlying assets vary in nature, a derivative on a stock is very similar to a derivative on a commodity. In recent years, derivatives have become increasingly important in the field of
finance. Futures and options, especially on commodities, securities, and foreign currencies, are now traded actively on many exchanges. Over The Counter (OTC) markets are available for forward contracts, swaps and for many other different types of options. Derivatives are meant essentially to facilitate hedging of price risk of inventory holding, or a financial / commercial transaction, over a certain period which usually lasts for a few months. These instruments enable transfer of risk to those who are able and willing to bear it. The new concept of ‘weather derivatives’ has emerged primarily to hedge the weather dependent volume risk, i.e. financial gain or loss arising due to variability in daily weather condition. It operates like any other standard index derivatives, with the underlying being an index developed on weather condition. These underlying include temperature (average, maximum, minimum), precipitation (rainfall, snowfall), humidity etc. That is, weather derivatives are contingent contracts that promise payment to the holder based on the difference between an underlying weather index - accumulated snowfall, rainfall, or ‘degree days’ over a specified period, and an agreed strike value. Weather derivative instruments comprise weather futures / forwards, swaps, vanilla options, option collars and caps, and exotic options.

Recently, weather derivatives are being used in almost all developed countries to hedge the weather related risk. According to the Chicago Mercantile Exchange (CME), the weather derivative market is the fastest growing derivative market today (Source: Website of CME group - www.cmegroup.com). However, it was only in 1997 that the first OTC weather derivative trade took place between Koch Energy and Enron on a temperature index on Milwaukee, Wisconsin for the winter of 1997-98. In September 1999, CME has begun listing futures and options on temperature indices of 10 U.S cities. The European weather derivatives market appeared in July of 2001 with the establishment of the London International Financial Futures and Options Exchange (LIFFE) that launched a series of contracts based on indices related to the daily average temperatures in London, Paris, and Berlin. Since then, the international weather derivative market has been growing and spreading across countries. In 2007-08, the market has experienced 35% growth in number of trading contracts, from 730,000 in 2006-07 to 985,000 in 2007-08, and a 76% growth in notional value from $19 billion in 2006-07 to $ 32 billion in 2007-08 (Source: website of Weather Risk Management Association (WRMA) - www.wrma.org). However, as with other forms of financial products, the weather market also crashed during 2008-09 and 2009-10, but the important fact as noted by WRMA is that the market grew outside
US even in this period and expanded beyond energy companies and temperature. The two most popular contract variables in temperature are heating degree days (HDD) and cooling degree days (CDD). A degree day measures how much a day’s average temperature deviates from 65°F (or 18.33°C). It is assumed that for each degree below 65°F, more energy is needed to heat the room and for each degree above 65°F, more energy is needed to power the air conditioners. Therefore, HDD and CDD respectively measure the degrees which consume power for heating and cooling off. Mainly, derivative contracts are written on cumulative HDD or CDD over a period of time. Nearly 85% of total weather derivative contracts are written on temperature. At present, CME offers listing and trading of temperature based index futures and options on futures on average, seasonal and monthly weather based on CDD, HDD and CAT (cumulative average temperature) in 47 cities worldwide. In spite of several advantages, and the increasing interest in weather risk management, the volume of trade in weather derivatives has been growing relatively slowly. Several factors can be identified that contribute to this lack of liquidity, including (a) the absence of a forward market in a relevant weather index, (b) potential basis risk, (c) problems defining meaningful weather data, and (d) the lack of agreement over a common pricing model, and hence create an opportunity for research on the subject.

Although weather derivative is yet to be introduced in India, weather based financial instruments exist in agriculture in the form of monsoon insurance. The index based rainfall or monsoon insurance was first introduced in Mehubnagar district of Andhra Pradesh in 2003 by ICICI Lombard and Basix with the support from World Bank. Later on, the pilot scheme of ‘Versa Beema Yojna’, as announced in the Union Budget of 2007-2008, has been implemented by Agricultural Insurance Company of India Ltd. The pilot scheme has been introduced in Karnataka during Kharif 2007 for eight rain fed crops covering 50,000 hectare of land for an insured sum of Rs. 50 crore (Source: Economic Survey Report, 2007-2008). However, no effort for managing the weather risk has ever been made in India for any other sectors, including power, the most active and pioneering sector in international weather market. One prime reason of such reluctance is perhaps the strong presence of government in the sector and the resultant administered pricing mechanism. Another contributing factor is the demand driven nature of the Indian power sector which makes the problem of fluctuating supply condition and hence idle capacity less probable. But, Indian power sector is expected to undergo a rapid change in coming years. The market is expected to be more competitive and efficient, and will call for huge private
investment, given the growing demand for power by an ever increasing population. The implementation of ‘Electricity Act 2003’, ‘National Electricity Policy 2005’ and ‘National Tariff Policy January, 2006’ reflects the possibility of fluctuating power price in Indian market and hence an increased amount of exposure to weather related risk. As a major portion of the forthcoming investment in power will be from private investors, the sector will be interested in adopting risk mitigation strategies like weather derivatives in the years to come. In this changing environment, introduction of weather instruments in India is only a matter of time.

1.2 Literature Survey

Weather risk and its management through weather derivatives have gained enough attention in recent time both from industry and academics. Vast research works have been carried out in establishing the correlation of weather and different businesses including power, agriculture, tourism, construction etc., on use and efficiency of weather instruments in general and weather derivatives in specific, and most importantly, on the structure and pricing of weather derivatives. Some of the studies are discussed below.

Numerous studies have indicated correlations between weather and economic variables. Smith and Tirpak (1989) have done an early comprehensive assessment of the potential effects of climate change on the USA, across a range of sectors including electricity. A study (Eto, 1988) on electricity demand in US office building shows that energy consumption is influenced by numerous weather conditions including air temperature, relative humidity, and wind speed. Franco and Sanstad (2008) have expressed daily demand of electricity of California as a function of simple average of daily temperatures and got a \( R^2 \) (coefficient of determination) of as high as 0.92. They found a high correlation in a cubic polynomial form between the simple average daily temperature from the four cities selected and daily electricity demand of the area. Although all the studies reflect the existence of a very strong relation between power demand and temperature, its relation with the other weather variable is rather indecisive. In a study conducted by Lam (1998) on the electricity demand in Hong Kong, he selected cooling degree-days (CDD) (i.e. deviation of outdoor air temperature from a pre-set threshold level measuring electricity demand for cooling), latent enthalpy days (i.e. humidity reduction requirement), and cooling radiation days (i.e. measure of cooling load due to solar radiation) as the three critical
weather parameters. Although CDD has proved to be statistically highly significant, the other two have failed to be significant as explanatory variables in the multiple linear regression model he used. Subsequently, Yan (1998) has followed a similar study over the time period of 1980 through 1994 and investigated the impacts of vapour pressure, cloud cover, humidity, and mean air temperature on residential electricity consumption. He has found that vapour pressure and cloud cover are not statistically significant in explaining energy consumption in the residential sector, while mean temperature exhibits a strong relationship. Sailor (2001) has conducted an analysis that measured air temperature, wind speed, and humidity effects in a regional study covering eight states located in the United States. He used heating degree days (HDD), cooling degree days (CDD), humidity and wind speed as independent variables. HDD and CDD have proved again to be statistically significant in all eight states, where as wind speed is statistically significant in four states and humidity is statistically significant in only one state. Whereas, Douglas et al (1981) has used a population weighted degree day approach to fit a linear parametric model to estimate the electricity demand along with day, month, and holiday and yearly growth factor, and found all of them to be significant.

Although several studies have emphasized on the relationship between temperature and electricity demand, comparatively very few have concentrated on the same between rainfall fluctuation and hydroelectricity generation. Few studies (Mimikou and Baltas (1997), Lehner et al (2005)) have emphasized on the impact of climate change on availability of water resources and hydroelectricity production. Aribisala (2007) has presented a time series model to decide on an optimal hydro production cum water release policy. However, the impact of regular monsoon fluctuation in India on its hydro electricity production is hardly addressed in any national or international literature. Moreover, majority of the studies have used regression analysis as methodology for relationship building (Douglas et al (1981), Sailor (2001)). Toeglhofer et al (2012) has first applied the concept of ‘Value at Risk’ in measuring the impact of weather with reference to accommodation industry, which captures both the exposure and the sensitivity of business and economic indicators to weather variable.

Many have suggested the use of weather derivative as a tool for weather risk management. Ellithrope and Putnam (2000) have discussed on how to measure the weather exposure of power and natural gas market and the implications of using weather derivatives. The structure and use
of weather derivatives in power sector’s risk management has also been strongly suggested by many including Cao, Wei and Li (2004), Muller and Grandi (2000) etc. Cao and Wei (2004) have stated that about 20% of US power market gets affected by weather. They further argued for the use of weather derivatives from an investment perspective stating “Still unrecognized by the investment community is the broader role of weather derivatives in portfolio management. From the perspective of Markowitz mean-variance efficiency, as long as the market is not complete, a new asset class will always improve the risk-return trade-off. The relatively lower correlation between weather derivatives and conventional financial assets suggests that weather derivatives can be an excellent diversification vehicle”. Muller and Grandi (2000) have advocated the use of weather derivative as it provides a complementary effect to instruments that are suited for hedging price risk. Leggio and Lien (2002) have shown that hedging of gas bills through use of an optimum mix of weather derivatives and derivatives drawn on the gas price is more effective than use of derivatives on price alone. They have successfully modelled a natural gas company’s ability to adjust for consumer sensitivity and customers’ exposure to gas bills through the optimum mix of gas price derivative and weather derivative.

Lennep et al (2004) have shown the use of precipitation derivative as an efficient risk management technique for agricultural, chemical and wine industry of Australia. Leggio (2007) has applied the concept of precipitation derivative to mitigate the risk exposure of a golf course. Cao, Wei and Li (2004) have strongly argued for the use of precipitation derivatives for risk mitigation of a hydro electricity firm. They pointed on the dual impacts that lower than normal rainfall may have on the profit of a hydro firm – firstly, in the form of low production due to low reservoir level, and secondly, in terms of higher prices that the firm may have to pay to other generators for purchasing power in order to make up for the supply shortage. In their work, they mentioned three precipitation based deals out of which two involves hydro electricity power generators. Hyman and Gary (2001), in an exploratory study, have suggested the use of ‘head derivative’ with the underlying of river/lake level for mitigating the hydroelectricity production volume risk. They have also suggested the use of few more exotic weather contracts including ‘wind index contract’ and ‘solar flux derivative’.

Although there is little controversy regarding the economic impact of weather and the use of weather derivatives, several studies have discussed the key factors affecting the development of
the product. As for example, *Brockett, Wang and Yang (2005)* have identified the following three major gaps in the emerging weather market - the hedging effectiveness of standardized weather derivatives, optimal weather hedging in consideration of the trade-off between basis risk and credit risk, and, most importantly, the pricing of weather derivative in the incomplete market. They also concluded that it is important to explore nation-wise analysis of basis risk and hedging effectiveness of weather derivatives, and a further possible extension could be company-specific analysis of basis risk and hedging effectiveness to design more effective standardized weather derivatives. *Yang, Brockett and Wen (2009)* have analyzed the efficiency of a standardized weather instrument in the presence of basis risk, whereas *Golden, Wang and Yang (2007)* have analyzed the trade-off between basis and credit risk in the context of weather derivative and assessed the effectiveness of a basis derivative, a derivative developed based on the basis risk of a weather contract.

However, the major thrust area related to weather derivatives is lack of a commonly acceptable pricing approach. Conceptually, a weather derivative product is similar to any commodity derivatives, yet the use of ‘no arbitrage pricing’ technique for weather derivatives is somehow limited as delta hedging is not possible in weather market due to the absence of spot weather market. Till now, there exists no universally agreed upon pricing model that determines the fair price of weather derivatives. Furthermore, pricing approaches have mainly focused on temperature derivatives, since they are the most actively traded of all weather derivatives. Researchers have discussed, tried, tested, and objected to a number of different market pricing approaches. As classified by *Kariya (2011)*, there are two basic types of models - time-continuous diffusion model and discrete time series model, and three types of pricing approaches - no-arbitrage, actuarial (statistical) and consumption-based methods. *Cao and Wei (1999), Campbell and Diebold (2002), Caballero, Jewson and Brix (2002), and Caballero and Jewson (2003)* have preferred to work in discrete time. Common to these works is the use of models that all lay within the larger class of Autoregressive Moving-Average (ARMA) models. *Dischel (1998a, 1998b)* have pioneered the use of continuous-time processes, followed by *Dornier and Queruel (2000), Alaton et al (2002)* and many more. The common point to all of their works is that they considered the temperature fluctuation to follow a Gaussian distribution. Both the groups, whether they use discrete or continuous time series model, take into account the empirical temperature characteristics of mean-reversion, seasonality, and a possible positive time
trend while constructing their models. Jewson and Brix (2005) have discussed a series of modelling and valuation techniques of weather derivative based on statistical time series analysis. One of the earliest attempts that they have discussed, as a practice of insurance industry, for finding a suitable weather derivative pricing model is a simple actuarial pricing approach called ‘historical burn analysis’. Under statistical modelling, most studies have focused on modelling the daily average temperature directly, while only a handful of authors like Davis (2001), Jewson and Brix (2005) etc. have modelled the entire index distribution. Although actuarial pricing approach based on the evaluation of conditional expectation of the future outcome and related pay off are quite useful in weather insurance market, they are not appropriate in pricing weather derivatives according to Sloan, Palmer and Burrow (2002). Some approaches are developed by Brix, Jewson and Ziehmann (2002), Jewson and Brix (2005) based on the principle of no arbitrage, where they have used other basic weather derivative products like costless weather swap, written on the same index, as a substitute of ‘weather’ as an underlying asset while finding the optimum premium of a weather option. Cao and Wei (1999) have suggested a consumption based valuation technique by including temperature as a fundamental variable in the economy in a generalized Lucas model framework. The representative agent maximizes the expected utility subject to a budget constraint by choosing the optimum value of consumption, risky and risk free asset.

Where majority of pricing models have concentrated on temperature derivative, literature related to modelling rainfall is really limited. Martin, Barnett and Coble (2001) have modelled precipitation index through gamma distribution for modelling a derivative. Cao and Wei (2004) have presented a valuation model combining a binary variable and gamma distribution for daily precipitation. Thus, a suitable pricing mechanism is one of the biggest preconditions for development of a weather derivative market anywhere in the world.

1.3 Research Gap and Significance of the Study

Though, internationally, the strategies involving weather derivatives, its pricing and use have been a major research area in recent past, its feasibility and applicability in Indian context are yet to be explored. There is no precedence of any published research in India in modelling weather derivative for the purpose of hedging, especially in power sector. The scope and effectiveness of
the only related product available in India in the form of monsoon or rainfall insurance in agricultural sector is also in nascent stage. However, Parchure (2002), Sinha (2007) are few well known researchers who have advocated for weather insurance over the traditional crop insurance scheme in India. Pawale et al (2007) have explained the problem faced by the weather insurance market in India. As far as the application of weather derivative in power sector is concerned, in the only exploratory study, that could be identified so far in Indian context, Sharma and Vashishtha (2007) have concluded that application of traditional risk-hedging tools and techniques in Indian agricultural and power sectors have proved to be costly, inadequate, and more importantly, a drag on the country’s fiscal system. They also suggested that an appropriate weather based derivative contract may prove to be a more flexible, economical and sustainable way of managing the volume-related weather risk in an economy, like India, having predominant agricultural and power sectors. Hence, in view of this research gap the present study is undertaken to fill up the vacuum in Indian literature on weather derivatives, to the extent possible.

Accordingly, a systematic study of Indian power sector’s exposure to weather risk entailing a detailed identification of the nature of its exposure and its measurement, and the resultant development of a weather derivative instrument may contribute positively in the field of effective hedging techniques for a potential market oriented and more de-regularized power sector attracting much needed private investment, as that of India.

1.4 Objectives of the Study

Very little is known on the impact of weather related risk and the applicability of weather derivatives in Indian power sector. However, there is tremendous potential for weather derivatives market in Indian power sector, especially in view of the enactment of Electricity Act, 2003 through which Government protection against losses due to mismanagement is expected to be minimized. So, the general objective of the study is to explore the intensity of weather risk and opportunities for mitigating the same, and understand the applicability and effectiveness of weather derivatives in mitigating weather risk in the context of Indian power sector. More specifically, the study attempts to:
• explore the nature and sources of weather related risk, its presence in power sector, both in international and in Indian context (Chapter II);
• examine the development of weather derivative in international front, its effectiveness in mitigating the weather risk and associated issues and problems, if any, as a financial instrument (Chapter III and II);
• understand the general structure and framework of Indian power sector and explore the possible changes in the sector with references to existing and proposed policy decisions (Chapter IV);
• explore the sensitivity of Indian power sector towards weather variable from the viewpoint of generators, distributors and bulk customers (Chapter IV);
• analyze the feasibility of introducing weather derivatives in India (Chapter IV);
• formulate empirically ‘weather derivative’ product for a specific energy market player in India (Chapter IV);
• apply the existing pricing model of derivatives to find out the probable pricing of weather derivatives in Indian context (Chapter IV);
• determine the resultant profit/loss for Indian Power sector with and without the use of designed weather derivative product for risk mitigation and hence establish the effectiveness of weather derivatives in Indian context (Chapter IV), and
• make recommendations for possible use of weather derivatives in India, and suggest areas for further research (Chapter V).

1.5 Research Methodology

The study is explorative, and is based on a case study as well. The explorative part of the study is based on (i) interviews with the individuals who have expertise on the power sector and necessary ideas on the subject; (ii) existing sources of secondary information on Indian power sector collected from various reports of Central Electricity Regulatory Commission (CERC), Central Electricity Authority (CEA), Damodar Valley Corporation (DVC) etc.; (iii) existing information about weather market worldwide in various reports and websites of Chicago Mercantile Exchange (CME), Weather Risk Management Association (WRMA) etc., and (iv)
studies conducted in this field by various other entities, especially in international front, as obtained from books and journals published in this regard.

For case analysis, secondary data are collected on power generation of a specific generator like Damodar Valley Corporation (DVC), power consumption by bulk customers like West Bengal State Electricity Distribution Company Limited (WBSEDCL), and weather data of specific areas of Eastern India (both temperature and rainfall). This helps in designing the scenario in most optimal way as Eastern Region of India has all the fluctuations of Indian weather. A comprehensive case study is carried out on Damodar Valley Corporation (DVC) to have a description of the real event or situation where the major functions of power sector i.e. generation, transmission and distribution, interrelate with the weather variables, namely temperature and rainfall in the region. The rationale for choosing DVC as a sample organisation is that, on one hand, it generates power from each of the two major sources, hydro and thermal, and on the other, it is involved in all the three major functions of power industry, namely generation, transmission and distribution. So, this case study is well equipped to explore all possible presence of weather risk in power sector and the required mitigation strategies. The case study empirically evaluates two different types of derivatives, one on temperature index and the other on rainfall index. Statistical modelling, time series analysis and simulation are used to understand the interrelationship of the above mentioned variables and feasibility of weather derivative products in India. Published financial reports and production record of DVC are used to understand the impact of weather on its profitability. Considering its appropriateness for the development of the proposed weather derivative product, the methodology for the case study is discussed in greater detail under ‘Chapter IV’.

1.6 Design of the Study

In order to achieve the objectives outlined in section 1.4, the study is divided into the following five chapters -

Chapter I: Introduction (problem identification, objectives, methodology and plan of work)

Chapter II: Conceptual Overview of Weather Risk and its Management through Weather Derivatives
Chapter III: Present International and Indian Scenario regarding Weather Risk Management

Chapter IV: Prospects of Use of Weather Derivatives in Indian Power Sector – A Case Study with Special Reference to DVC

Chapter V: Conclusion and Recommendations