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Department of Business and Management

Master thesis in Advanced Corporate Finance

SUMMARY

ENERGY DERIVATIVES AND RISK MANAGEMENT

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Summary

This thesis aims to provide an overview about the relevance of risk management practises and energy derivatives for the energy companies.

The energy sector, characterized by a high degree of uncertainty, is particularly interesting to study this topic, because its business is highly dependent on commodity price risk exposure. The research conducted in this work will be oriented to find out how companies operating in this sector may deal with risk, and the instruments available to hedge against it.

Energy derivatives will be regarded as the main hedging instruments, but if on the one hand companies may take advantage from their use, they can also become source of volatility, if they actually contribute to increase the exposure. Thereby, this thesis is also committed to describe risk management systems and quantitative tools that companies necessarily need to use in tandem with derivatives, in order to control their exposure.

The goal will be that of showing the benefits that risk management may provide to energy companies and, under which conditions, energy derivatives may be effective hedging instruments.

Energy markets are a collection of commodities, such as oil, gas and electricity, differing in composition but all having in common a high degree of volatility. A high level of uncertainty, strengthen by deregulation in most of energy markets, comes from the commodity price risk exposure, related to the consequences that commodity price fluctuations could cause to the companies operating in the energy sector, both from the offer and demand sides. It is sufficient to imagine the consequences that an *oil shock* would cause to the energy companies' profits if they did not care about risk. Indeed, despite their differences, "today's energy markets follow the same impulses:

energy producers and users alike wish to hedge their exposure to future uncertainty [...]"[1]

Given the magnitude of energy risk, the energy sector becomes an interesting focus for the aim of this thesis, that is studying the use of risk management practises, and in particular of derivatives, to hedge against risk. This focus leads to discuss about a particular kind of financial instruments used as hedging tools in the energy markets, that are the energy derivatives. Energy forwards, futures, swaps and options, their combinations and the strategies built with them, are the most intuitive tools applied by the energy companies to hedge against energy risk. Nonetheless they are only a part of the risk management systems that many energy companies built to deal with risk, made by organizational practises, risk culture, risk department and CRO figures in some cases, as well as quantitative tools, risk metrics, to keep control of risk and to use in tandem with energy derivatives. In fact, if on the one hand energy derivatives are applied for a hedging purpose; on the other hand, they can lead to increase the exposure if incorrectly used: metrics, like VaR, need to be used as well, to provide a measure of the risk involved in an energy derivatives portfolio.

Although they will be shown as useful financial instruments to take an opposite position to that of the risk in the market, so to mitigate it, the role of derivatives in the current crisis is widely documented[2]. As a result, they need to be used in an integrated risk management system within the enterprise.

In order to discuss the above mentioned topics, and to answer to a research question, requiring to illustrate the benefits of energy derivatives and risk management for the companies operating in the energy sector, this thesis follows a logical process spread out five chapters.

After this short introduction, the beginning of the work, in the first chapter, is made of a general definition of risk. Risk definitions from literature, applied to the enterprise, are provided to the reader, because to deal with something, it is essential to have a

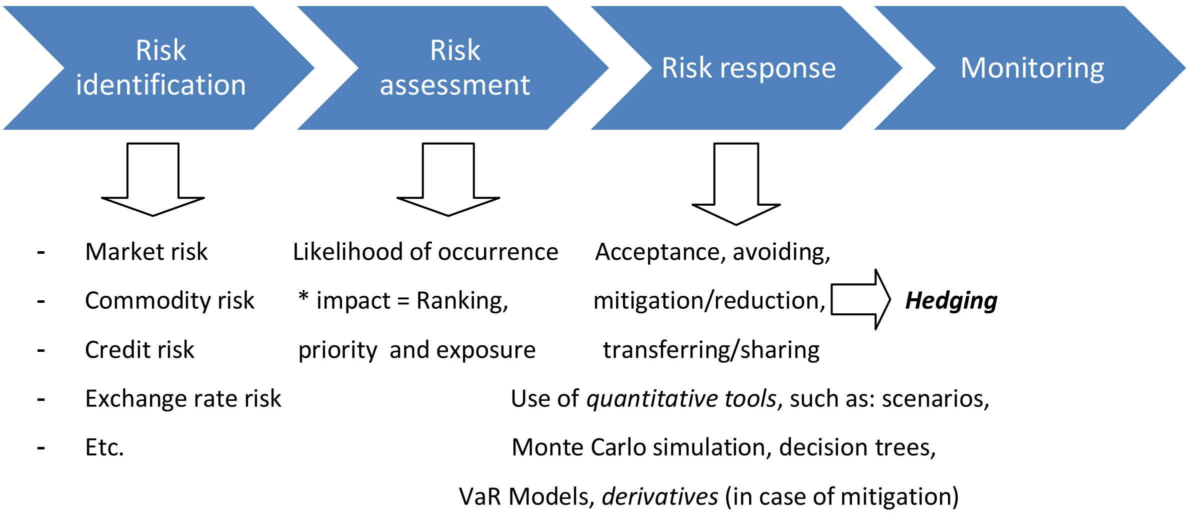
[1] PILIPOVIC, D. (1998). *Energy risk: valuing and managing energy derivatives*. McGraw-Hill.

[2] OLDANI, C. (2012). *Derivati ed energia: la gestione dei nuovi rischi globali*. FrancoAngeli, 1° edizione.

knowledge about it. Together with risk definitions, the most known risk measures are illustrated, starting from the elementary variance and standard deviations, to arrive to the models linking risk to return, such as CAPM, APT and Fama and French models. Then, the role of risk in corporate finance and capital investment is treated, as well. The analysis of risk from different points of views is necessary to introduce the reasons why firms hedge. Moreover, a paragraph is devoted to the shift from hedging to risk management, made essential by the volatility of some businesses (like the energy one), where risk may be perceived not only as a threat but also as an opportunity[3]. This last step is *ad hoc* to forecast the topic of the second chapter.

The second chapter is about risk management within the firm, the so-called Enterprise risk management (ERM). Several definitions of this system have been found, but all agree about the fact that ERM is an integrated system of actions that companies take to deal with risk. It is generally put in practise within a framework (like COSO's one), usually made by the phases summarized in the following graph (Fig. 1):

Fig. 1 **The risk management process**

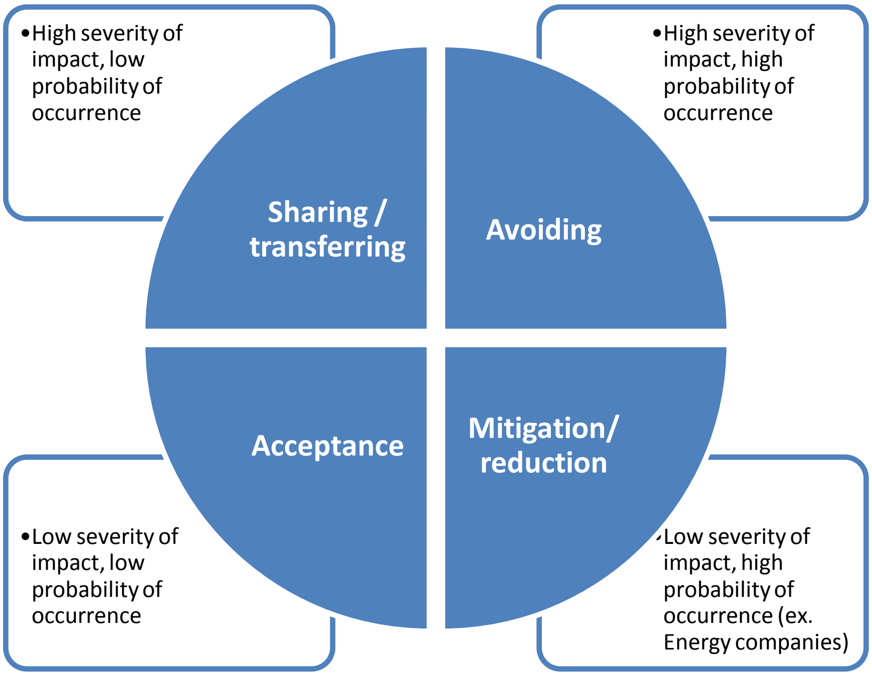


Hedging and energy derivatives belong to the risk response phase, in the case a company decides to pursue the mitigation strategy, but this is not the only one

[3] DAMODARAN, A. (2007). *Strategic risk taking – A framework for risk management*. Wharton School Publishing.

strategy to pursue, specifically determined by the likelihood of occurrence and the severity of impact of a risk (Fig. 2).

Fig. 2 **Risk-response matrix**[4]



A more practical part of the chapter is devoted to concrete examples of how energy companies apply ERM, found in literature or taken from some energy companies' websites (Eni, Enel, ExxonMobil and ShellGlobal). The usefulness of the given examples relies in the willingness of this thesis to show the practical benefits of risk management practices for the energy companies, that are becoming important supports for strategic decisions, as well (some companies even introduced the figure of the Chief Risk Officer in their organizational structure).

The ERM is not only made by organizational practices, but it also needs to be supported by quantitative tools, to quantify and measure the risk. Indeed, the third chapter provides an overview about the quantitative methodologies used with this

[4] DAFIKPAKU, E. (2011). *The strategic implications of enterprise risk management: a framework*. Mba, b.eng (hons), prince2, miet, mcmi . 2011 enterprise risk management symposium.

purpose. VaR and similar measures are proposed as the main risk metrics to use in tandem with energy derivatives, because they also evaluate the risk involved in a portfolio of derivatives. Three are the techniques to compute VaR: historical simulation, variance-covariance matrix and Monte Carlo simulation. A particular mention is for the Monte Carlo method, because it seems to be the most suitable technique to simulate the price fluctuations in a highly changing environment, like the energy one. Despite its popularity, VaR has some drawbacks. First of all, it can be insufficient when there are big changes, that is it does not tell us what happens in 5% of cases, when the potential loss exceeds the threshold. VaR is not able to provide information about the magnitude of the loss, when the 95% confidence interval is violated, a likely scenario in the energy markets. Another pitfall is the lack of "sub-additivity": "VaR of a two asset-portfolio can be greater than the sum of individual VaRs of these assets"[5]. It means that it may be not coherent with the diversification principle, according to which diversification should reduce the risk of the portfolio. In order to correct these pitfalls, the conditional Value-at-risk (CVaR) has been introduced. CVaR corrects VaR because it can estimate the loss exceeding VaR and it is sub-additive, since it considers the risk reduction effect of diversification. Two alternatives to Value-at-Risk are: sensitivity analysis and cash flow at risk. While the former is less sophisticated than VaR and suitable for simple portfolios, the latter is even more sophisticated than VaR[6]. Cash flow at risk can be estimated through Monte Carlo method, too. Anyways, its application is different, because the simulation is done for a longer time horizon, and the focus in on cash flows, since the goal is assessing the impact of risk and derivatives on operating cash flows. Each factor impacting on cash flows is considered, rather than only market factors, as in VaR. They must be aware of more drivers of risks, operating as well, and include them in the statistical distribution. In addition to price and volatility factors, growth, technology, demographic and

[5] EYDELAND A. AND K. WOLYNIEC (2003). *Energy and Power Risk Management: New Development in Modeling, Pricing and Hedging*. New York, NY: John Wiley.

[6] LINSMEIER, T.J. AND PEARSON, N. D. (1996). *Risk Measurement: An Introduction to Value at Risk*. Working Paper.

macroeconomic factors need to be included. Much more computation than VaR has to be conducted. As a consequence, a great knowledge is required to those implementing a risk measurement system based on cash flow at risk, not only about the factors, but also about their interactions. On the other hand, if well applied, an ambitious risk measurement system like this has a great efficacy, especially in the long term.

Another risk measure, not as competitor but complementary to VaR, is *Credit VaR*. It has the specific aim of measuring the credit risk, that is the risk that the counterparty will not meet its contractual obligations. We cannot say *ex-ante* which technique is the best one for energy risk management, but this is left to energy companies discretion, that has to weight attributes as ease of implementation, efficiency, efficacy and so on, according to their contingencies.

In the fourth chapter, the focus is on a specific tool of risk management, which is that of the energy derivatives. Historically, energy commodities are divided into three groups: fuels (oil, gas, coal, and their derivatives); electricity; weather and emissions. Each kind of commodity and each sub-category has a market.

Futures and options for both crude oil and natural gas are traded on the New York Mercantile Exchange (NYMEX), while forward and swap contracts are traded in over-the counter market[7]. In Italy, energy derivatives are traded on IDEX (Italian Derivatives Energy Exchange), a segment of Italian market of derivatives (IDEM), managed by Borsa Italiana[8].

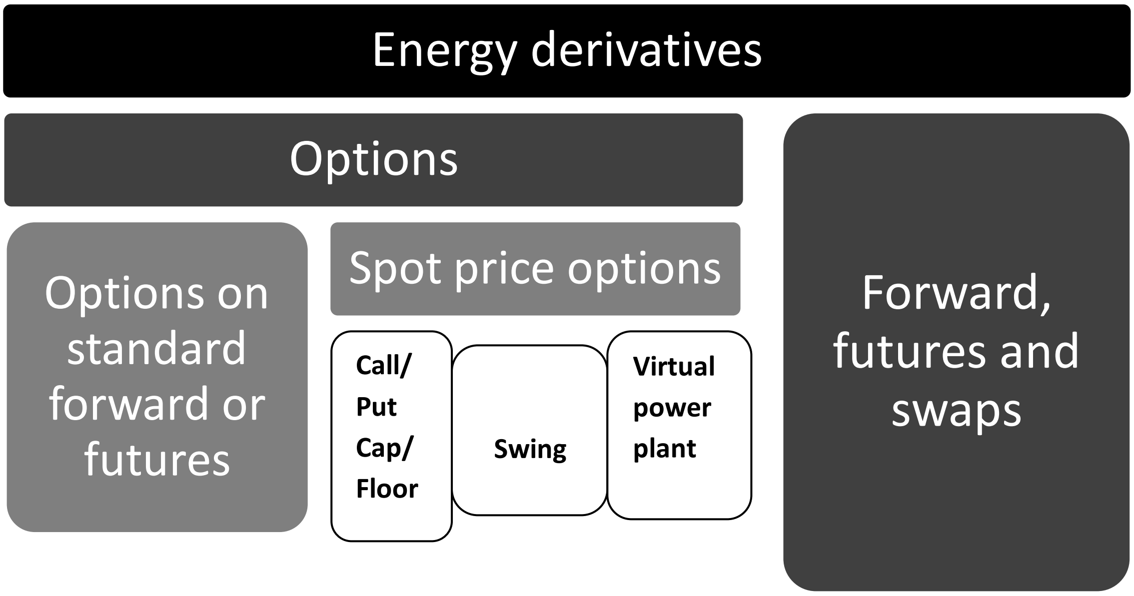
An introduction of derivatives in general forecasts the description of energy forwards, futures, swaps and options, whose classification is summarized in the following graph (Fig. 3): they may be divided into options and contracts without "optionality", such as forwards, swaps and futures, that are the most liquid ones[9].

[7] HAUSHALTER, G.D. (2000). *Financing policy, basis risk and corporate hedging: evidence from oil and gas producers.* Journal of Finance, Vol. 55, issue 1, pp. 107-152.

[8] www.borsaitaliana.com

[9] BURGER, M., GRAEBER, B., SCHINDLMAYR, G. (2007). *Managing Energy Risk: An Integrated View on Power and Other Energy Markets.* Wiley Finance.

Fig. 1 **Energy derivatives classification**[10]



Since they are private agreements between two parties, forward contracts are traded in the OTC market. In the case of commodity, they consist in bilateral agreements to purchase or sell a certain amount of a commodity (oil, gas, electricity) on a fixed delivery date at a predetermined contract price. They are usually paid at maturity.

Energy futures are quite similar to forwards, that is why their prices are used to estimate forward contracts value. Their advantages respect to forwards are related to the elimination of the credit risk, that is guaranteed by stock exchanges, and the reduction of transaction costs, because of the contract standardization. Furthermore, the daily trading allows an easy market-to-market evaluation, respect to forwards and swaps.

Swaps in energy markets are very similar to swaps in financial markets, and very close to forwards, that can be seen as "one period swaps". They are traded OTC, very flexible and customizable, and suitable for hedging. They usually imply the payment

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[10] BURGER, M., GRAEBER, B., SCHINDLMAYR, G. (2007). *Managing Energy Risk: An Integrated View on Power and Other Energy Markets*. Wiley Finance.

from a party to a counterparty of a fixed amount, in exchange of payments related to a variable index (commodity spot price, for example). Swaps have the advantage, respect to forwards and futures, to be flexible, versatile and never rigid, so that they are an indispensable tool for energy risk management. In fact, there is a diversity of swap structures in the energy OTC market.

After futures, forwards and swaps, calls and puts are the most common risk management instruments. In energy markets, a *call option* is the right, but not the obligation, to buy energy at a predetermined strike price, and a *put option* is the right, but not the obligation, to sell energy at a predetermined strike price[11].

Then, numerical techniques for the valuation of derivatives, such as Monte Carlo simulation and trinomial trees, and numerical techniques to hedge the exposure, are described, as well.

The methodology of this thesis has followed a logical process, integrating theoretical and practical aspects of the main topic. Energy derivatives and risk management have been studied on their essential parts and they have been integrated by practical examples, when necessary. Qualitative information prevailed on quantitative one, available in a minimal part. It has been collected mainly from academic publications, but also from companies' websites and publicly available sources. The academic research of publications, that has been at the basis of this work, has been preferred to the case study methodology essentially for two reasons. Firstly, risk management practices are applied by different companies in different manners, such that studying them on a single or few subjects, would not have allowed to extend the conclusions to other subjects, as well. Secondly, not all the relevant information about risk management, and especially about energy derivatives, are published by the companies, and they are not likely to disclose more than what has been collected to write the paragraph called "Empirical observations", contained in the second chapter.

However, these chapters satisfy the need to provide an answer to the research question that has driven this thesis. To be clear, the goal of this research has been that

[11] EYDELAND A. AND K. WOLYNIEC (2003). *Energy and Power Risk Management: New Development in Modeling, Pricing and Hedging*. New York, NY: John Wiley.

of showing the benefits of risk management and of energy derivatives for the energy companies. The reason of the focus on the energy sector relies on the multiplicity of risks that characterize this industry, and that make necessary the use of instruments to manage them and to protect the firms operating in.

Regarding to the structure, the chapters 1, 3 and 4 have been written to provide a theoretical knowledge, respectively, of risk management practices, quantitative tools and energy derivatives. On the other hand, the chapters 2 and 5 have a more practical approach: while the former contains the practical applications of risk management practices that actually have been observed in firms; the latter includes practical applications of energy derivatives for hedging purpose, with some numerical supports, when required.

The preceding chapters have been focused on the description of the main risk management tools and methodologies, with a particular mention to energy derivatives. It has been explained why risk management is important for firms, and more specifically for energy companies, and which are its main instruments. Some well-known risk management users have been mentioned, and the tools they can use to fight with risk, as well. Nonetheless, one final step has to be done, if the aim of this work is that of showing the relevance of risk management, and more specifically of energy derivatives, for the companies operating in the energy sector. A very useful research of the final chapter is that of finding and showing some applications of energy derivatives, in order to prove the benefits that its users can achieve thanks to their use. Since the focus has been from the beginning on the hedging purpose, arbitrage and speculation aims will be left out from this analysis.

In order to provide a complete overview of the topic “hedging against energy risk”, the mechanism is illustrated for each of the main commodities (oil, gas, electricity), and mentioning some case studies is a complement to the analysis through some practical examples.

The first example is about oil hedging on NYMEX, the fundamental market where oil transactions take place. After a brief description of how the New York Mercantile Exchange system works, the paragraph offers a simple numerical example about hedging. It is practically shown how an oil producer may hedge through futures the risk of declining oil price. Despite its simplicity, the example is very useful, since it demonstrates through numbers how concretely oil producers may enjoy a cash flow stability thanks to futures. The application of oil futures "in numbers", regarding the positive effects achieved by hedging, is followed by a historical case study widely debated in literature, that is that of MetallGesellSchaft. In this case, energy derivatives were seen, on the contrary, to produce the negative effect of huge losses. Nonetheless, a historical simulation demonstrates that a correct application of derivatives would have provided the beneficial effects seen in the preceding paragraph. After a historical case, a current one is provided, that is that of airline companies, hedging oil day by day to run their business. The case is important to show how this practice may be essential for the survival of a business indirectly related to oil, but funding its success on the benefit of hedging oil, as well. In fact, without fixing the jet fuel price, for an airline company, it would not be easy even to sell tickets.

Further to the cases about oil, the discussion about *hedging against energy risk* moves to another commodity, that is electricity. As for oil, a numerical example of short hedge is provided. Two scenarios of falling and rising electricity prices are prospected, and the net sales revenues in both cases are computed. They seem to be equal in both cases: it means that the objective of the cash flow stability is achieved, even though it is not possible to exploit the upside price fluctuations, but this is the hedge cost. Till now, hedging oil and electricity seem to be very similar, but a big difference exists and it is observed in the cases of the Nordic Power Exchange and of Texas electricity market. Since electricity cannot be stored and moved worldwide as oil, its demand and price are widely influenced by the local needs. Both cases confirm the expectation that models for pricing and hedging with power derivatives need to be adapted to local factors, if they want to be successful.

Despite the usefulness of oil and electricity examples to understand how energy derivatives are concretely used for hedging purpose, the discussion would not be complete without mentioning gas as commodity and options as energy derivatives. Futures are very diffused and immediate instruments, but options have a role in hedging against energy risk as well, especially in highly volatile markets. The example proposed in the paragraph, called *Gas hedging with options,* shows empirically how these instruments may offer a downside protection in a highly volatile market, like the gas one, affected by transportation issues.

Finally, the chapter comes to an end with a discussion about pros and cons of energy derivatives. This further step is done in order to have an evidence of the benefits, but also the pitfalls, derived from the concrete application of these instruments. This final part of the thesis includes some criticism, that makes the core discussion of the research to emerge. If on the one hand, energy derivatives are source of benefits for energy companies, because they allow to hedge against energy risk; some cases, like the Enron one, show that a misleading use of them may cause the opposite effect. Thereby, the debate of the work, as follows, shows which are the conditions, the methodologies and the practises, that may forecast a correct use of energy derivatives, so that they can produce the beneficial effects companies may take advantage from.

As this work had the aim of showing the relevance of risk management and energy derivatives for the energy companies, the goal has been achieved.

The energy risk, caused by the commodity price fluctuations, is the source of risk this thesis has focused on, to whom energy companies are exposed. In order to protect themselves from it, they often recur to hedging strategies, but they are only a part of risk management.

Risk management has been defined as a process made by more phases, such as risk identification, evaluation and control, where hedging is only an eventual tool, because having a risk does not necessarily imply that it should be hedged. As sustained by Damodaran[12], the main difference between risk hedging and risk management is that: while the former considers the risk as a threat; for the latter, it may be a threat, but also an opportunity. This is the reason why in some situations, it may be convenient to exploit a risk or to accept it, and to do hedging only if necessary. The only way to

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[12] DAMODARAN, A. (2007). *Strategic risk taking – A framework for risk management*. Wharton School Publishing.

evaluate these contingencies and the opportunity to hedge for a company, is to have a risk management system, that is called Enterprise risk management (ERM).

The ERM becomes necessary when a company has several risks, deriving from several sources, that is what happens to the energy companies. A system of ERM allows them to develop a framework (like COSO[13]), where risk is identified, evaluated and monitored. After it has been classified according to its probability of occurrence and severity of impact, it may be accepted, shared or transferred, avoided or mitigated, according to the risk response matrix resolutions[14]. Hedging applies only if the mitigation strategy is pursued, and energy derivatives are the hedging tools for energy companies. It is important to remark that ERM succeeds when it is applied in an integrated way overall the organization, that is when the risk management practices are shared across departments. As the purpose of this work was to show the relevance of risk management for the energy companies, successful cases of ERM implementation have been part of the research, so that case studies and empirical observations came out as evidence of its application. The former support, coming from case studies, made clear how energy companies actually find useful to develop frameworks to deal with risk, and disclosed the necessity of the energy sector "to shift from an avoid risk culture to a think risk culture"[15], given the high volatility of the business. The latter support, provided by the empirical observations of energy companies adopting risk management, confirms the expectations that, dealing with many risks, they take a great advantage from the implementation of ERM. These systems are more or less developed from firm to firm: some of them even hired a Chief Risk Officer (ex. Enel); others are planning to do that; all of them are aware about the fundamental role played by risk management within the organization.

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[13] COSO (2004). *Enterprise risk management – Integrated Framework*.

[14] DAFIKPAKU, E. (2011). *The Strategic Implications of Enterprise Risk Management: A Framework*. MBA, B.Eng (Hons), PRINCE2, MIET, MCMI . 2011 Enterprise Risk Management Symposium.

[15] CLARKE, C.J. , VARMA, S. (1999). *Strategic risk management: the new competitive edge*. Long Range Planning. Vol. 32, Issue 4., pp. 414–424.

Dealing with energy risk, companies necessarily need to put in practice financial instruments to hedge against it, when required. Energy derivatives are the hedging instruments for energy companies and they have been studied to provide several benefits to the users: possibility to take an opposite position to that of the risk in the market, so to reduce the exposure; possibility to lock prices in advance, with the result of avoiding losses and ensuring a cash flow stability; contribution to the performance improvement and to the value creation. These benefits, already guessed in the fourth chapter from energy derivatives technical description, have been practically shown with concrete hedging examples. The cases proposed confirmed the expectation that hedging, whatever are the commodities, the derivatives, or the markets, may provide the mentioned advantages, assuming to apply them in the correct manner.

In fact, some criticism argues that, in many cases, derivatives have contributed to increase the exposure and to take too much risk, instead of reducing risk. Enron and MetallGesellSchaft cases[16] provide the evidence that a misleading use of these instruments may cause losses instead of benefits. Nonetheless, these cases should not deviate the attention from the positive effects achieved from hedging through energy derivatives, when they are correctly applied. On the contrary, they should encourage to adopt these instruments with more care, in order to take advantage from their use.

From the analysis conducted in this work, it comes out that one way to adopt energy derivatives while controlling the exposure, is that of using them in tandem with metrics able to predict the risk involved in a portfolio of derivatives, such as VaR and Monte Carlo simulation, and in an integrated ERM framework, where risk is constantly monitored. Furthermore, simpler strategies of derivatives are less risky than more complex ones. Finally, as Enron case demonstrates, using derivatives to carry on speculative actions is counter producing for energy companies, whose core business is not a financial activity. If energy companies use energy derivatives for hedging purpose and integrated in a risk management framework, they are more likely to gain from them the above mentioned advantages.

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[16] OLDANI, C. (2012). *Derivati ed energia: la gestione dei nuovi rischi globali*. FrancoAngeli, 1° edizione.