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VOLTAGE and VALUE:

**An Analysis of Power Market Hedging dynamics
with
Empirical Insights from ENI**

*Analisi delle Metodologie di Copertura nel Mercato Power
supportata
da un caso studio su ENI*

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Abstract

Quando accendiamo la luce, stiamo indirettamente acquistando dollari - un'asserzione dal sapore apparentemente surreale che disvela la complessa realtà celata dietro un gesto apparentemente ordinario. Questa azione comune esemplifica mirabilmente la delicata e articolata posizione dell'Unione Europea nel mercato energetico globale.

La presente dissertazione esplora l'intricata complessità ed interconnessione tra i mercati energetici e valutari nell'Unione, con precipua attenzione alle strategie di risk management nel settore elettrico.

La disamina disvela le molteplici sfide poste dall'attuale scenario geopolitico ed economico, dove l'UE si configura come un sistema di straordinaria vulnerabilità energetica: dipendendo per il 63% da importazioni esterne, con l'85% delle transazioni ab origine regolato in dollari statunitensi; circostanza che ingenera negli operatori del settore ragguardevoli rischi di cambio.

Muovendo dai principi cardinali della gestione del rischio, il lavoro scandaglia le peculiarità ontologiche del mercato elettrico - contraddistinto dall'impossibilità di stoccaggio efficiente e dalla imprescindibile necessità di equilibrio istantaneo tra domanda e offerta - e le sfide che ne promanano in termini di volatilità dei prezzi e rischi operativi. La ricerca abbraccia una prospettiva multifattoriale, contemplando le implicazioni derivanti dai mutamenti geopolitici, dalla transizione verso energie sostenibili e dall'impetuosa metamorfosi digitale.

Attraverso una disamina accurata degli strumenti derivati vieppiù utilizzati per la copertura dei rischi e un case study incentrato sul gruppo ENI, l'elaborato fornisce una prospettazione empirica dell'efficacia delle strategie di risk management nel contesto energetico italiano ed europeo.

Lo studio si prefigge di colmare una lacuna nella letteratura esistente, apportando un contributo originale alla comprensione delle dinamiche di gestione del rischio in un settore caratterizzato da sempre più marcata complessità e da cogenti imperativi di transizione verso fonti energetiche sostenibili.

Gli esiti della ricerca palesano l'importanza cruciale di implementare strategie sofisticate di risk management, che assurgono non più a mero orpello ma a necessità impellente in risposta di sfide poliedriche.

INDEX

INTRODUCTION	7
ANALYTICAL PERSPECTIVES ON RISK MANAGEMENT AND CORPORATE HEDGING	10
1.1 MANAGING UNCERTAINTY IN AN ERA OF INCREASING RISKS.....	10
1.2 CORPORATE EXPOSURE – LEVERAGING RISK MANAGEMENT CAPABILITIES FOR BUSINESS SUCCESS.....	13
1.3 THE DOUBLE NATURE OF RISK: THE SYSTEMATIC & UNSYSTEMATIC COMPONENT	17
1.4 RISK AND FINANCIAL HEDGING DECISIONS	21
HIGH VOLTAGE RISK: DECODING THE ELECTRIC ENERGY MARKET	24
2.1 ELECTRICITY MARKET: DYNAMICS, INEFFICIENCIES, AND UNIQUE CHARACTERISTICS	25
2.2 RISKS IN ENERGY MARKETS: CHALLENGES AND UNCERTAINTIES.....	29
2.3 OPERATIONAL AND BUSINESS RISKS IN THE ELECTRICITY SECTOR	33
HEDGING.....	36
3.1 FINANCIAL DERIVATIVES IN THE ELECTRICITY MARKET	37
3.2 HEDGING WITH FUTURES	41
3.2.1 <i>Delivery risk</i>	46
3.2.2 <i>Basis Risk</i>	47
3.2.3 <i>Liquidity</i>	48
3.2.4 <i>Mis-matching Strategies</i>	49
3.3 HEDGING WITH OPTIONS.....	50
3.4 HEDGING WITH SWAP.....	51
INSIDE	55
4.1 ITALY'S ELECTRICITY ENERGY MARKET	55
4.2 EUROPE'S ENERGY SECTOR	59
4.3 ENI	63
4.3.1 <i>ENI's Market position and Financial performance</i>	64
4.3.2 <i>Emerging Challenges</i>	68
4.3.3 <i>Exchange Risk Exposure in ENI's Business Model</i>	70
CONCLUSION	74
BIBLIOGRAPHY.....	77

FIGURES INDEX

FIGURE 4.1 STRUCTURE OF THE ELECTRICITY MARKET (SOURCE: TERNA).....	56
FIGURE 4.2 STRUCTURE OF THE ELECTRICITY SYSTEM (SOURCE: TERNA).....	57
FIGURE 4.3 THE 7 MARKET ZONES (SOURCE: TERNA)	58
FIGURE 4.4 ENI’S ACTIVITIES (SOURCE: ENI).....	65
FIGURE 4.5 ENI VALUE CHAIN (SOURCE: ENI)	67

Introduction

When we turn on the light, we are indirectly buying dollars—a seemingly surreal statement that unveils the complex reality beneath a simple flick of a switch. This everyday action exemplifies the complex and delicate reality of the European Union's position in the global energy market.

The world runs on energy. From powering our homes and cities to fueling our transportation and industries, a constant flow of resources like crude oil, natural gas, and electricity keeps everything moving. However, this fundamental necessity carries profound financial implications, particularly for import-dependent regions like Europe.

While the national electricity price in Italy (PUN) is denominated in euros, Italian power plants burn fossil fuels that are priced in dollars on the international spot and futures markets. This dynamic exemplifies a broader European vulnerability: Italy meets over 50% of its energy demand through imports, while the European Union relies on external sources for 63% of its energy needs (Eurostat 2023, Energy imports dependency 2023).

Geopolitical shifts—exacerbated by Russia's invasion of Ukraine—have reshaped Europe's energy dependencies, with the United States (46%), Norway (43.5%), and Algeria (21.6%) emerging as key suppliers by mid-2024 (IEA, 2024).

85% of EU energy imports are settled in US dollars, exposing European companies to significant foreign exchange risks. These dynamics pressure corporate treasuries to navigate volatile markets while ensuring financial stability.

The energy sector, particularly the electricity market, operates in a unique paradigm. Unlike other commodities, electricity cannot be stored efficiently, requiring a real-time balance of supply and demand. This introduces extraordinary challenges, from price volatility to operational risks such as accidents and supply disruptions. Geopolitical tensions, climate-driven shifts, and evolving regulations further

compound the complexities. Digital transformation brings both opportunities for optimization and heightened vulnerability to cybersecurity threats.

At the core of these dynamics lies the imperative of transitioning to sustainable energy. Spurred by resource scarcity and environmental mandates, this transformation demands unprecedented investments in new technologies and infrastructure. The shift from traditional oil operations to diversified energy portfolios—integrating renewables, hydrogen, and gas—illustrates the magnitude of change.

Recent events, such as the COVID-19 pandemic and geopolitical conflicts, have acted as catalysts, accelerating the sector's vulnerabilities and highlighting the urgency for adaptation.

Implementing sophisticated risk management strategies becomes not merely a luxury but a compelling necessity in response to these multifaceted challenges. Continuous access to and price stability of energy commodities represent a vital concern for every economic unit, from individual firms to entire states.

While the literature on energy risk understanding and exposure measurement remains relatively limited, particularly in optimal hedging strategies, this thesis addresses that gap by investigating the intricate interplay between energy market volatility and risk management mechanisms within the European energy context.

Lessons from financial markets reveal that derivatives, including futures, options, and swaps, are powerful tools for mitigating risks when properly designed and utilized. These instruments facilitate price stability, enable sound investment decisions, and enhance market resilience.

This thesis embarks on an electrifying journey. Beginning with core principles of risk management and corporate hedging, the research explores how organizations adapt to mounting uncertainties. The analysis then illuminates the unique characteristics of electricity markets and the distinctive challenges energy companies face.

Our investigation progresses through a comprehensive examination of hedging instruments and strategies in this market, analyzing the effectiveness and limitations of various financial derivatives, from futures

to options and swaps. The study then broadens its scope to address the critical issue of foreign exchange risk in Europe's energy sector, providing valuable insights into the interconnected nature of currency and energy markets. An in-depth case study of ENI offers a practical lens to view the implementation and effectiveness of risk management strategies in one of Italy's premier energy companies.

When we turn on a light in our homes, we are not only illuminating a room but also engaging with the intricate web of economic and geopolitical factors that influence our energy security.

CHAPTER 1

ANALYTICAL PERSPECTIVES

ON RISK MANAGEMENT AND CORPORATE HEDGING

1.1 Managing Uncertainty in an Era of Increasing Risks

From the earliest days of humanity, making decisions under uncertainty has been a fundamental aspect of our existence, an innate drive for self-preservation in the face of risks.

In the contemporary era, powerful forces are reshaping our world with remarkable rapidity and intensity. These transformative processes alter the fabric of our societal structures and individual experiences. Within this rapidly evolving global context, people feel a growing need to find ways to shield themselves from the unexpected challenges that life presents, pursuing various forms of protection.

This growing need for adaptation to uncertainty reflects our species' historical resilience and capacity to evolve in response to new and emerging threats: the wonderful human of survival.

In earlier times, human societies operated with simpler tools, systems, and organizations, and failures or crises had a generally less severe impact. However, our modern world has undergone a significant transformation. Contemporary society is characterized by increasingly complex technologies and vast economic interconnections, and breakdowns or disruptions in these systems can have far-reaching consequences (Clifford W., *et al.*, 2007).

In this decade of unpredictability and constant change, it becomes essential to clearly distinguish between two key concepts: *risk* and *uncertainty*. Recognizing the differences can provide valuable insights into how we approach decision-making, policy formulation, and strategic planning in our complex, rapidly evolving world.

The distinctiveness among the concepts originally has been outlined by Frank Knight and John Maynard Keynes.

The early 20th century saw two towering figures in the economics of risk and uncertainty: a silver spoon versus a wooden spoon.

While Keynes provided valuable insights into probability, Knight offered a solid framework for comprehending the idea of uncertainty. Knight argues that there are fundamental differences between risk and uncertainty. To emphasize this point, he used blunt terms like "radically distinct" and "categorically different" (LeRoy, Stephen F., *et al.*, 1987).

So, the crucial query is: What are the differences between these two ideas?

Knight remarked:

"A measurable uncertainty, or "risk" proper, as we shall use the term, is so far different from an unmeasurable one that it is not in effect an uncertainty at all. We shall accordingly restrict the term "uncertainty" to cases of non-quantitative type. It is this "true" uncertainty, and not risk..."

The idea admits a basic level of ignorance, the boundaries of human understanding, and the unpredictable nature of future events.

Uncertainty is a broader concept, referring to the inability of individuals to assess the probability of future events, primarily due to a complete lack of knowledge about the potential consequences of unpredictable occurrences on human decisions. The idea of uncertainty refers to the challenge of determining the range of likely outcomes involved in the casuistry, alongside the difficulties for economic agents to define an accurate probability distribution (Nesticò, A., He, S., De Mare, *et al.*, 2018).

Several definitions of risk are provided, nicely highlighted in a Crowe and Horn article (1948).

Knight defined risk as "measurable uncertainty." Dannenberg, echoed by Mehr and B.A., described it as the "uncertainty of loss." Hedges (1963) defined it as "the uncertainty concerning the occurrence of loss."

These definitions share the understanding that risk comprises two key components: uncertainty about the future and the undesirable or unfavorable entity known as "LOSS."

As Mehr (1963) states, "loss is an inadvertent decrease in, or disappearance of, value." Consequently, risk boosts the possibility that businesses may suffer a possible loss of value and be placed in a delicate position, having to balance ensuring safety with battling possible loss and damage.

Risk theory explores how events might unfold differently than we expect.

Risk management involves identifying our expectations and analyzing how likely and significant deviations from these might be.

Interestingly, while risk can lead to negative consequences, it's also the reason businesses can earn higher returns. In the financial world, risk takes on a specific meaning: It's the chance that an investment's actual return will differ from what was expected. This difference could be positive (upward risk) or negative (downside risk) (Damodaran A., 2005).

For companies, the risk is a double-edged sword. It can threaten financial stability but also presents opportunities to outperform competitors. This dual nature is beautifully captured in the Chinese characters for risk (风险), which combine symbols for both danger and opportunity.

Successful individuals and organizations are those who can effectively navigate this landscape, managing risks while seizing opportunities.

Risk shouldn't be viewed solely as a threat to be avoided. Instead, it's a complex aspect of decision-making that, when managed skillfully, can lead to significant benefits. The key lies in understanding the nature of risk, anticipating potential outcomes, and developing strategies to handle both the challenges and opportunities it presents.

1.2 Corporate Exposure – Leveraging Risk Management capabilities for business success.

A mix of volatile and unpredictable forces marks the future. Companies must adopt interdisciplinary approaches that can help them respond more quickly to significant problems and strengthen their capacity for resilience-building.

In such a scenario, risk management has emerged as a crucial discipline, enabling businesses to be compliant with their long-term goals while proactively managing the risk they are exposed to. Companies employ risk management as a well-established procedure to have a genuine and open understanding of the dangers they face.

The discipline of risk management comprises three fundamental components, often referred to as the "*three Ms*" of risk analysis:

1. *Modeling Risk*: This initial step involves identifying economically significant uncertainties and their associated risk factors, data collection, and probability estimation to quantify and control potential risks.

2. *Measuring Risk*: This component focuses on the quantitative assessment of the organization's risk exposure, providing a clear picture of the magnitude and nature of potential threats.

3. *Managing Risk*: All actions required to mitigate risks or alleviate the consequences of adverse events. This includes selecting appropriate risk management techniques and making optimal decisions.

By integrating these three components, businesses can develop a comprehensive approach to risk management that not only protects them from potential threats but also positions them to capitalize on opportunities. This holistic strategy enables companies to thrive in an ever-changing business environment, turning challenges into drivers of growth and innovation.

Companies must navigate a diverse array of challenges, and to effectively address them, it's essential to understand the various categories of risk that businesses encounter.

One fundamental distinction in risk classification is between market risk and corporate risk.

Market risk, often referred to as systematic risk, is an exogenous factor affecting all participants in the financial markets. This risk stems from broad economic conditions and cannot be eliminated through diversification. In contrast, corporate or unsystematic risk is endogenous, arising from company-specific factors. Unlike market risk, *corporate risk* can be mitigated through diversification strategies as it relates to the unique characteristics and operations of individual businesses.

Throughout their lifecycle, companies must remain vigilant in identifying and addressing the primary sources of risk that impact their performance and value. This necessitates a comprehensive classification of potential threats (Becherer D., 2003).

The main categories of risk that businesses typically face in their daily operations include:

1. *Strategic risk*
2. *Operational risk*
3. *Financial risk*
4. *Legal risk*
5. *Compliance risk*

Each risk category requires a tailored management approach, as they cannot be effectively addressed within a single, uniform framework. By developing targeted strategies for each type of risk, businesses can better protect themselves against potential threats and maintain their competitive edge in the market. Fundamentally, a company's operations lie in its strategies and business decisions. A well-executed strategy can strengthen a company's market position, while poor strategic decisions or misalignment with the overall business plan can weaken competitiveness and potentially lead to both current and future losses.

Day-to-day operations also present their own set of challenges. Operational risks arise when internal processes, human resources, or systems fail to function as expected. The Basel II Capital Accord of 2004

defines operational risk as "the risk of substantial losses due to the inadequacy or failure of internal procedures, human resources, and systems, or external events.". These risks can significantly impact the efficiency and effectiveness of a company's routine activities.

Financial risks play a crucial role in a company's performance and are closely tied to its economic structure and dynamics. The balance between equity and debt, net debt levels, and the ability to manage cash flow fluctuations all contribute to a company's financial risk profile. Effective management of these risks often involves the use of hedging instruments to mitigate potential negative impacts.

Compliance with laws and regulations is another critical area of risk management. Legal and compliance risks can result in severe consequences, including fines, sanctions, and penalties. In extreme cases, non-compliance may even lead to the temporary suspension of business operations, underscoring the importance of adhering to regulatory requirements (EY Insights, 2024).

Proactive risk management strategies anticipate, control, and mitigate potential risks, implementing robust hedging programs that help businesses navigate unforeseen challenges, maintain their resilience, and improve their chances of long-term success.

People often focus on risks they're familiar with because they've already established ways to measure and assess these known threats. This habit of relying on established methods and familiar metrics can lead to a limited perspective, consequently, they fail to weigh unfamiliar and relevant sources of disruption.

Disruptive events can severely impact even the most successful companies, nevertheless, they also present growth opportunities. Forward-thinking managers can anticipate and effectively manage these disruptions and may find ways to improve their business performance.

A recent and striking example of a disruptive force was the COVID-19 pandemic. The pandemic led to widespread productivity issues, increased stress and anxiety among workers, and a collectively

traumatized workforce. All these factors increased the extent of risk companies had to address and cope with (Reeves, M., Koehn, N. *et al.*, 2021).

Effective risk management isn't just about minimizing exposure to specific threats. Instead, it involves carefully balancing potential risks against expected profits. However, many organizations still view risk management as a cost rather than a strategic concern.

Relay on the nature of the risk source, businesses handle risk and uncertainty by employing financial or operational hedging programs.

Financial hedging, which includes insurance policies and derivative contracts, offers companies a way to mitigate short-term exposure and transfer systematic risk to third parties. It's important to note that these methods don't eliminate risk entirely but shift it to counterparties.

On the other hand, *operational hedging* techniques address risks specific to a company's business model and operations. The core principle behind this approach is the implementation of diversification strategies and other operational activities aimed at reducing cash flow variability. Although operational hedging typically requires significant capital investments, it has the potential to create long-term competitive advantages and beneficial effects for companies (Valdés, León, and René Caldentey, 2024).

Effective risk management goes beyond merely reacting to disruptive situations. It involves achieving organizational resilience by implementing comprehensive programs to manage risk proactively and reasonably.

However, it's crucial to understand that taking on risk doesn't always lead to value creation or competitive advantage. Companies that are ill-prepared to handle uncertainty may find themselves overwhelmed by the consequences of their decisions. Therefore, managers must be selective in choosing which risks to take to pursue a competitive edge. The ability to make strategic decisions in exploiting risk is a fundamental quality in developing any risk management program. Risk acceptance should align with reward potential.

1.3 The Double Nature of Risk: The Systematic & Unsystematic Component

A company's risk profile can be characterized by a broad variety of risks that can occur during daily operations. It could be split into two major classifications, as mentioned above: systematic and unsystematic risk.

Market risk, often known as *systematic risk*, is the outcome of market movements that have the power to affect businesses' activities negatively or positively.

This risk category has an exogenous nature, and it arises from macroeconomic factors that shape the performance of all companies. Systemic risk in finance refers to the threat of the financial system failing at its essential functions, showing up through fluctuations in foreign exchange rates, interest rates, inflation, and commodity prices. While systemic risks accumulate gradually beneath the surface, their emergence is typically sudden and severe. Ergo, they cause extreme endogenous or setback risk with sporadic incidences.

Due to the uncommon occurrence of systemic crises, systemic risks are easily neglected in investment managers' day-to-day dispositions. Long-term performance is still made or broken by a manager's way of anticipating and managing systemic risk (Novales. A., *et al.*, 2019).

When a systemic crisis worsens, institutions' priorities shift from seeking returns to short-term capital preservation. Consequently, efficient positioning or flow principles are often suspended and reversed. What were once the best positions can quickly become the worst.

Systematic risk has been evaluated by companies using the most used *Capital Asset Pricing Model* (CAPM) (Pham, C. D., & Phuoc, L. T., 2020).

The model's cornerstone is the beta coefficient, which quantifies an investment's systematic risk by measuring its volatility in overall market movements. Beta captures how sensitive an investment is to market fluctuations. The CAPM framework demonstrates that an investment's expected return embraces two fundamental components: the risk-free rate and the risk premium.

The risk-free rate represents the return from virtually risk-free investments (typically government securities), while the risk premium compensates investors for assuming additional market risk. Since investors are generally risk-averse, they require sufficient incentive to deviate from safe investments. This means they will only opt for riskier investments if the potential returns adequately compensate for the additional risk exposure. Consequently, any risky investment must offer returns that match or exceed those of comparable risk-free alternatives plus an additional risk premium. This premium serves as direct compensation to investors for accepting more significant market uncertainty and potential volatility in their investment choices.

The magnitude of this risk premium directly correlates with the level of systematic risk: higher risk exposure necessitates a larger premium to compensate investors appropriately for their increased risk.

The Capital Asset Pricing Model operates on a fundamental principle: investors seek to minimize risk through diversification while holding a portion of the market portfolio.

Risk management, viewed through the lens of CAPM, takes on a precise meaning: it's the process of aligning the actual portfolio risk with the investor's desired risk level. To achieve this alignment, investors can employ two strategies with the market portfolio: either combine it with risk-free assets to reduce risk or leverage it by borrowing at the risk-free rate to increase potential returns (Joshi N., 2013).

This framework demonstrates that effective risk management isn't about eliminating all risk but achieving the optimal risk level for each investor's objectives. Investors can adjust their exposure to market risk by carefully balancing their allocation between the market portfolio and risk-free assets, ensuring their portfolio maintains precisely the level of risk they're willing to accept.

Despite its wide use, the CAPM has notable limitations, largely due to its assumptions, which often don't align with real-world conditions. Rational, risk-averse investors in frictionless markets, reliance on beta's instability, inability to fully capture market exposures, and practical constraints (liquidity needs,

transaction costs, taxes, regulations, and personal values) challenge CAPM applicability (Mcquarrie, E. F, 2024).

Given these challenges, CAPM has faced skepticism, leading to developing models that relax its assumptions and incorporate additional risk factors. Examples include the Fama-French three-factor model or alternative methods for estimating expected returns, such as the arbitrage pricing theory, multifactor models, and the dividend discount model, which provide further options for investors.

In idealized, frictionless capital markets, only systematic risk is seen as significant when evaluating various alternative investment assets. However, relying solely on systematic risk leaves out the whole spectrum of potential challenges that could affect a business's productivity and overall worth. Companies face systematic and unique, company-specific risks- known as idiosyncratic -that they must actively manage.

This *idiosyncratic risk* arises from microeconomic factors within the business, including management decisions, operational challenges, and market positioning, which all significantly influence the company's life cycle. Idiosyncratic risk has an endogenous nature driven by the set of strategic solutions for running the business and governing the company taken by the management team (Florackis C., *et al.*, 2020).

Most theoretical papers overlook the distinction between idiosyncratic and systematic risk, assuming idiosyncratic risk can be fully diversified away and is irrelevant to equilibrium outcomes.

However, as emphasized by Townsend (1978) and Holmstrom (1979), complete diversification is often costly. Subsequent theoretical work has explored how various financial frictions—such as credit constraints or limited access to risk-sharing mechanisms—impede full diversification.

More recently, studies by Angeletos (2007) and Castro, Clementi, and MacDonald (2004) have demonstrated “that undiversified risk can have positive effects by encouraging savings through

precautionary motives or increasing entrepreneurial earnings, which can stimulate economic growth” (Michelacci, C., *et al.*, 2008).

Considering its “internal” essence, key ways to mitigate the unsystematic risk component include diversifying product lines or markets to avoid over-reliance on one revenue stream, implementing robust operational processes to handle supply chain disruptions, and adopting financial hedging to protect against currency or interest rate fluctuations. Strong governance, quality control, and ongoing customer and market analysis further help anticipate and address potential issues before they impact the business. Nonetheless, businesses generally struggle to implement successful diversification strategies into practice, as they are frequently bound to a small number of substantial contracts with key suppliers and partners. This dependence increases vulnerability to disruptions in supply chains, changes in supplier costs, or shifts in partner reliability, leaving the company exposed to risk if any of these relationships falter.

Furthermore, expanding into new markets or product lines carries risks and requires a significant financial commitment, especially if a business lacks the tools or know-how to do so successfully (Clifford W., *et al.*, 2009).

Additionally, managing unsystematic risk through quality control and operational efficiency can strain internal resources, specifically for smaller businesses with limited budgets. Finally, hedging can shield companies from financial fluctuations, but it requires ongoing monitoring and expertise, making it a challenging risk management tool to apply effectively.

These barriers highlight the necessity of a balanced and holistic approach to idiosyncratic risk, where companies prioritize flexibility and build contingency plans that enable them to handle disruptions without overstressing their resources (Hill, C. W. L., and Jones, G. R., 2008).

1.4 Risk and Financial Hedging Decisions

To effectively tackle the specific risks companies face, it's essential to outline and implement straightforward financial and operational hedging programs. While investors can reduce corporate risk by diversifying their portfolios, companies find this strategy much more challenging to implement. Suppliers and customers might diversify their risks by working with several partners, but companies often end up tied to just a few major contracts. This leads them to purchase specific derivative instruments and create targeted hedging programs to gain better control over market risk.

Insurance policies and derivative contracts allow businesses to lessen their short-term exposure by shifting systematic risk to third parties. Establishing a corporate hedging program involves carefully balancing the amount of risk a company chooses to transfer and the risk it decides to retain.

Corporate financial hedging involves two different ways: first, purchasing insurance contracts to mitigate risks related to property and liabilities, and second, holding financial derivatives as a means of transferring market risk to third parties who can better absorb it (Fusaro, *et al*, 2001).

Businesses have recognized the necessity of transferring risks that they are unwilling to cope on their own. In this scenario, insurance contracts provide a valuable opportunity to shift such risks to a third party—specifically, the insurance company—which possesses a competitive advantage in managing and absorbing these uncertainties.

Insurance policies are primarily designed to safeguard against a wide variety of risks, including property damage, liability claims, and natural disasters like hurricanes, floods, and earthquakes. These insurable risks can expose companies to unpredictable results and increase the possibility of a value loss. Such volatility typically trends downward, and only in the event of a covered loss might some premiums be refunded to the policyholder.

An insurance policy can be characterized as a combination of two pivotal components: the insured individual's payment of a risk premium and the potential occurrence of an event that triggers the insurer's

obligation to provide benefits. When a person decides to secure insurance against a specific risk, they effectively transfer a portion of that risk to a third party, expecting compensation in the event of a loss.

An insurance contract always transfers pure risk. The insurer operates under the principle that they will either incur a loss or avoid one. If no claim arises from the insured event, the insurer forfeits the risk premium; however, if the insured event does occur, the individual is shielded by the insurance policy and has the right to seek compensation (OECD, 2021).

Nonetheless, insurance contracts are just one of several hedging mechanisms businesses use to minimize risk. Among the diverse range of instruments available, *derivative contracts* have become essential tools for managing systematic risk in capital markets.

As suggested by their name, derivatives are financial instruments whose value is derived from the performance of an underlying asset. By utilizing derivatives, companies with risky assets can transfer the associated market risk to another party. This transfer helps them avoid adverse effects on optimal pricing and production functions. This process allows businesses to unbundle risk from the asset's value and exchange it in the capital market for a predetermined price in return for protective measures. A derivative contract is founded on an agreement between two parties to buy or sell a specific asset at a future date, following clearly defined terms and conditions. The parties involved consist of a hedger and a counterparty, each maintaining opposing positions. While the hedger seeks to mitigate risk, the counterparty is typically someone who may face the possibility of experiencing a loss or potential gain from the arrangement. Financial derivatives allow the hedger to transfer risks they are unwilling to tolerate, shifting those risks to a counterparty better suited to manage them.

It's important to note that this process does not eliminate risk; rather, it simply reallocates it to another party (Butnariu A., *et al.*, 2018).

While both derivative contracts and insurance policies provide similar tools for risk management, they differ significantly. An insurance contract typically transfers risk to third parties and requires compliance

with specific terms outlined in the policy. Moreover, the risk involved is considered pure, and the insurer anticipates either a loss or no loss. Conversely, when engaging in a derivative contract, the parties involved can limit their downside risk while still retaining the potential for significant upside should favorable conditions arise. The nature of risk in derivative agreements is speculative, unlike the pure risk seen in insurance policies. The third party in a derivative contract willingly assumes the risk, expecting to either incur a loss, avoid a loss, or realize a gain. The financial outcome—whether a loss or gain—will vary based on changes in the value of the underlying assets during the contract period. Both derivative contracts and insurance are essential as hedging mechanisms to manage financial risk. Yet, they differ considerably in terms of the risk and the incentives driving the buyer's decisions (Bohmann, M. J., *et al.*, 2019).

The allure of financial derivatives lies in their versatility in addressing various forms of risk, including interest rate risk, foreign exchange risk, and commodity price risk. With a broader range of derivative instruments available, companies can customize their hedging strategies to meet diverse business needs and tackle different market risks.

CHAPTER 2

HIGH VOLTAGE RISK:

DECODING THE ELECTRIC ENERGY MARKET

The world runs on energy. From powering our homes and cities to fueling our transportation and industries, a constant flow of resources like crude oil, natural gas, and electricity keeps everything moving. But where does this energy come from, and how does it get to where it's needed? Enter the lively world of energy trading, a complicated yet fascinating market where resources' power is bought, sold, and carefully managed. This ever-evolving market offers a unique blend of risk and reward, attracting diverse players.

The constant fluctuation in energy prices creates opportunities for producers and consumers, while skilled traders can leverage their expertise to profit.

Understanding derivatives contracts and their role in energy markets highlights these instruments' potential benefits when used effectively. Rather than being demonized as they often are, derivatives can play a valuable role in bolstering the stability of financial markets.

Instruments such as futures, options, and swaps are widely adopted in the energy sector due to their effectiveness in managing the risks associated with market volatility.

In today's context, with a global shift toward sustainability underway and the value of renewable energy sources continuing to rise, it becomes increasingly important to examine how these derivatives can be utilized efficiently and effectively to support this transition.

Unlike many other markets, energy product markets exhibit a high degree of volatility, characterized by rapid and unpredictable price fluctuations. The reasons for this volatility stem from factors beyond the simple law of supply and demand, rooted in much deeper issues such as geopolitical events, government

policies, and other external factors. In this high-uncertainty environment, derivatives assume a crucial role, enabling market participants to manage and mitigate risks.

The utility of derivatives transcends mere risk management; when utilized appropriately, derivatives possess significant potential benefits and functionalities able to foster sustainable energy initiatives and contribute to the long-term value creation for companies within the intricate landscape of the energy sector.

2.1 Electricity Market: Dynamics, Inefficiencies, and Unique Characteristics

The global electrical industry has experienced profound transformations in recent decades, with an increased emphasis on environmental sustainability, market liberalization, and deregulation. Electricity is a critical component of both social and economic systems, functioning as the primary energy source for industrial and commercial sectors. Given its pivotal role in the economy, it is imperative to comprehend the risks associated with energy price volatility and develop strategies for effective management. In this context, derivatives emerge as a fundamental tool within the market.

First, it is essential to define what electricity is. It is a secondary energy source, meaning it can only be produced through the utilization of primary energy sources with the assistance of specific generators. Various sources contribute to electricity generation, including chemical energy derived from fossil fuels, nuclear energy harnessed from atomic reactions, hydraulic energy extracted from water resources, wind energy generated by the kinetic forces of air, solar energy derived from solar radiation, and geothermal energy obtained from thermal energy within the Earth's crust. This form of energy is widely used due to its efficient conversion into other types of energy, such as mechanical, light, or thermal energy (Terna S.p.A., 2024).

Electricity generation occurs in power plants, and transmission is carried out through transmission and distribution networks. The supply chain includes generation, wholesale trading, transmission,

distribution, and retail sales. Generation is undertaken by production companies that convert primary energy sources into electricity. These entities are responsible for the procurement of raw materials, the transformation processes, and the integration of generated energy into the grid, along with the construction and maintenance of related facilities.

The energy is then transported through high-voltage networks. In Italy, only one company holds a monopoly to ensure efficiency and safety in transportation: Terna SpA. Distribution companies convert high-voltage energy to low-voltage energy before physically delivering it to consumers. Retail companies procure energy through contractual agreements or market exchanges and sell it to end users. The principal actors in these markets include energy producers, distributors, suppliers, consumers, and regulatory authorities (Italian Ministry of Economic Development, 2018).

The energy market can be categorized into two main segments:

- *Wholesale Markets:* In this segment, energy producers sell their goods to major distributors and suppliers. Contracts in wholesale markets are often intricate and detailed, ensuring transparency and stability for all parties involved. A multitude of factors, such as supply dynamics, geopolitical events, and regulatory influences, significantly impact pricing in this arena.
- *Retail Markets:* In these markets, suppliers interact directly with end consumers, who may include businesses, industries, and private individuals. Consumers actively seek the best prices and contract terms in the retail market, fostering supplier competition.

Various factors, including supply and demand levels, fuel costs, reserve availability, consumer demand inelasticity, carbon taxes, and climatic conditions influence the wholesale electricity price. Price risk is ever-present in this market, and as a result, several derivative financial instruments are widely employed. The spot price of electricity reflects a range of unique characteristics of this commodity. One of the primary factors is its *non-storability*: unlike other energy sources, electricity cannot be easily stored due

to technical inefficiencies and expensive storage costs. Because reserves are almost non-existent, supply must always match demand, making prices highly sensitive to external events. As a result, spot prices must account for the non-storability feature (Werner D., 2014).

Regarding probability distribution, electricity prices also differ from those of other commodities. Extreme price fluctuations are more likely, especially during specific times of the year. Electricity prices' *volatility* also surpasses other commodities, with spot prices frequently experiencing brief spikes, especially during peak demand hours (Han, C., Hilger, H., *et al.*, 2021).

Despite this volatility, electricity prices can sometimes be forecasted by analyzing seasonal demand patterns and climatic factors specific to certain regions. In this context, one of the most well-regarded models for predicting electricity spot prices was developed by D. Pilipovic:

$$S_t = S_t^{\text{Und}} + f(t)$$

Where the spot price S_t is derived from the underlying spot price S_t^{Und} , adjusted for seasonal effects through an additional component $f(t)$ that accounts for seasonality.

Electricity trading typically occurs through spot and forward contracts, with forwards and futures being the most common. These contracts incorporate not only future spot price expectations but also a risk premium. Additionally, they include the cost of carry (transportation costs) and the convenience yield—the advantage derived from possessing the physical commodity rather than its derivative. The relationship between spot and forward prices is typically expressed as follows:

$$F_{t,T} = S_t e^{r(T-t)}$$

Where $F_{t,T}$ represents the forward price at time t for delivery at time T , S_t is the spot price, and r is the risk-free rate.

Due to the unique qualities of electricity, particularly its non-storability, this formula does not always apply perfectly. The inability to store electricity complicates the estimation of convenience yield and impacts the conditions for arbitrage opportunities.

Since energy can't be stored, it's tough to think arbitrageurs could use strategies to take advantage of price differences: they can't buy spot contracts to sell later or short-sell either. Second, the idea of convenience yield becomes unclear because it's hard to measure the value traders place on having energy reserves versus a forward contract, mainly because it's technically impossible. As a result, traditional pricing methods often fall short, highlighting the need for alternative approaches to clarify the relationship between spot and forward prices (Conejo A., *et al.*, 2018).

One widely accepted alternative is the *risk premium approach*, based on Keynes's *hedging pressure theory*. This theory suggests that the strike price can be seen as the sum of expected future spot prices plus a risk premium, which may be positive or negative. According to Keynes, producers are frequently willing to pay this premium to hedge against price risk, indirectly benefiting consumers. Consequently, the spot price can be higher than the forward price, leading to a downward-sloping price structure known as *backwardation*. Producers may discount consumers to ensure stable revenue, creating negative risk premiums (Casula L., 2022).

Under the hedging pressure theory, electricity market participants, including buyers, may be interested in hedging against price risk, incurring additional costs. Since both sides are likely to pay to mitigate risk, the risk premia could be positive or negative.

Risk premia can be further classified as follows:

- Risk premium ex ante: $RP(t, T) = F(t, T) - E_t[S(T)]$

This is the difference between the forward price $F(t, T)$ and the expected future spot price $E_t[S(T)]$.

- Risk premium ex post: $RP(T) = F(t, T) - S(T)$

Here, the observed future spot price $S(T)$ replaces the expected future spot price, as we are now at time T , and $S(T)$ is directly observable. Combining these, the actual risk premium can be expressed as:

$$RP(T) = RP(t, T) - \varepsilon(t, T)$$

where $RP(t, T)$ is the anticipated risk premium (ex-ante), and $\varepsilon(t, T)$ represents a forecast error. Therefore, the expected premium plus a forecasting error determines the actual risk premium. In an efficient market, where forecasts are rational, the average error should equal zero. This implies that the ex-ante risk premium will converge toward the ex-post risk premium. By utilizing historical variables, it is also possible to delve deeper and construct one or more historical factor models (Harrison M., *et al*, 2018).

2.2 Risks in Energy Markets: Challenges and Uncertainties

Energy markets encounter a myriad of challenges daily, shaped by factors such as technological advancements, evolving energy and environmental policies, climate variability, and geopolitical dynamics. These elements can impact producers, consumers, companies in general, and even governments.

Here are some typical and peculiar risks and uncertainties observed in energy markets:

- *Commodity Price Scenario*, an overview of risks deriving from unfavorable commodity price fluctuation (Brent, natural gas, and other commodities) compared to planning assumptions. To mitigate these risks, businesses should focus on portfolio resilience and flexibility by monitoring

cash flows from traditional operations, supporting growth in new ventures, and optimizing capital budgeting. Additionally, diversifying the supply portfolio, implementing an active market-aligned hedging strategy, optimizing plant setups, and maximizing synergies between renewable capacity and the power customer portfolio through integrated energy management is essential (Bevilacqua, M., Grünewald, T., *et al.*, 2024).

- *Competition and Consolidation* refer to growing market competition and imbalances between demand and supply. These events drive significant challenges, including reduced sales and volumes, difficulty retaining customers, downward pressure on product prices, and declines in overall demand. Moreover, mergers and acquisitions reshape the competition landscape, influencing price stability and driving innovation.
- *Operational risks* are related to blow-outs and other accidents affecting assets in the upstream segment, refineries, and chemical plants, or that could happen during transportation by sea and land of hydrocarbons and derivatives (i.e., fires, explosions, etc.), damaging people and assets and affecting the company's profitability and reputation. To mitigate these risks, companies are implementing comprehensive measures, including insurance coverage, preventive actions through advanced technologies, real-time sound monitoring, and proactive incident tracking (IEA, 2020).
- *Geopolitical Risks* are linked to specific crises (wars, terrorist attacks, pandemic events, conflicts between nations), which can cause political instability and alter the normal course of international relations. These risks can lead to supply disruptions due to cuts in energy production or transport, instability, slower development of new infrastructure and technologies, and changes in the energy mix of different countries. Often, after such tensions, a government may diversify its energy sources, leading to new scenarios.

- *Climate-related events and disasters* uniquely impact the energy market, affecting supply and demand. On the supply side, they can disrupt production, increase costs, and cause long-term effects—like droughts reducing hydroelectric output—or severely damage infrastructure in catastrophic events, such as earthquakes. On the demand side, extreme weather, such as intense heat, raises electricity use for cooling. These disasters can also drive up insurance costs for energy companies, leading to high overall risk due to direct and indirect effects.
- *Regulation and Environmental Policies*, constantly changing laws and regulations can alter the established energy framework, modifying many underlying elements and becoming a significant source of risk. Regulations, including emission standards or taxes, can drive up costs and necessitate new infrastructure, adding significant financial burdens on energy operators.
- *Investigations and HSE proceedings* arise from regulatory scrutiny or incidents involving potential violations of HSE standards, posing risks to the company's legal standing, reputation, and operational stability. To mitigate these risks, companies implement a range of measures, including establishing a robust legal defense strategy, creating dedicated teams to provide legal assistance and manage national and international regulatory relations, reinforcing compliance, strengthening protocols, and developing better communication to enhance transparency and traceability (Ash, J. S., 2008).
- *Permitting* relating to possible delays or failure to issue authorizations, renewals, or permits by the Public Administration.
- *Technological changes and innovations* are rapidly evolving, affecting both the production and consumption landscape. Companies' increased reliance on digital technologies makes them prime targets for cyberattacks, which pose risks to data and system reliability.
- *Tariffs and Trade Tensions*. These factors impact on a global scale. High tariffs tend to discourage exports and imports from a trade restriction perspective. Even minor tariffs can disrupt supply

chains, prompting countries to relocate supply and demand, which creates instability. Investments will likely decrease if trade tensions or highly restrictive policies are in place.

Recent events have sharply highlighted these risks in action.

The COVID-19 pandemic emerged as a "black swan" event, creating a perfect storm for the energy sector and exerting pressure on companies globally. Oil demand and prices fell more rapidly and deeply than ever before.

While many companies focused on immediate pandemic-related challenges—rigs laid up, cashflow shortages, and heightened operational risk—others began conceptualizing a future shaped by an accelerated energy transition.

This transition has quickly climbed to the top of the agenda among executives in the oil and gas sector, with COVID-19 acting as a catalyst. Consequently, 2020 and 2021 witnessed a surge in announcements from oil and gas companies outlining their decarbonization strategies and net-zero commitments. (Akyildirim, E., *et al.*, 2022).

Energy companies are increasingly exploring alternatives—mainly hydrogen—to meet the ambitious targets set by the Paris Accord. Currently, fossil fuels provide around 80% of global fuel demand, a figure that will need to fall to about 50% by 2050 to reduce carbon emissions and limit global temperature increases to below 2°C. To make this transition possible, energy companies are shifting from integrated oil to integrated energy companies, incorporating renewables, gas, and hydrogen into their operations to become carbon neutral (International Energy Agency, IEA, 2024).

Europe has been at the forefront of this shift with the European Green Deal, which aims for climate neutrality by 2050 and a 55% reduction in emissions by 2030. Achieving these goals will require new technologies, innovations, and solutions, but it also presents new complexities and risks for the sector. (European Commission, updated 2023).

An additional trend within this evolution is the rise in mergers and acquisitions (M&A) in the energy sector, viewed as a valuable opportunity to bolster balance sheets, create value synergies, and better reposition themselves for the energy transition.

In this context, M&A activity operates as the twin arms of a pincer strategy; one arm focuses on the divestment of carbon-intensive segments of their portfolios, while the other emphasizes the acquisition of and investment in renewable energy assets.

Another critical game-changing event in the last few years is Russia's war against Ukraine, which has been rapidly and profoundly changing the European energy system and having larger global impacts, with both immediate and lasting consequences.

The Ukraine war has forced Europe to redefine its energy security policies toward more diversification and less reliance on Russian energy. This may be seen as an opportunity to open closer long-term strategies for energy cooperation with the Middle East, strengthen energy trade partnerships (particularly with Qatar), and integrate North African energy markets and infrastructure to ensure a steady energy supply (IEA, 2024). The recent Russia-Ukraine conflict illustrates the vulnerabilities of energy dependency and the urgent drive for independence. As a result, there has been increasing interest in energy decentralization. However, diversifying supply sources requires significant investments, which may pose challenges for numerous market participants.

In conclusion, the energy market is a key sector of the global economy and one of its most complex areas. Ensuring its stability is essential, which is why implementing effective risk management practices is vital for mitigating these critical risks.

2.3 Operational and Business Risks in the Electricity Sector

A company operating in the energy sector is primarily exposed to macroeconomic and market risks. All the general risks described above must be considered while acknowledging the unique characteristics

specific to the energy sector: extreme price volatility, non-storability, seasonality, and demand inelasticity.

However, additional risks exist that are uniquely specific and intrinsic to the electric energy sector. Below is an in-depth analysis of these operational risks.

- *Value Risk* is tied to energy prices and involves the risk of holding long or short positions in the market. The existence of these positions stems from having assets (production capacity and end customers) that, in the first case, result in excessive production capacity compared to the customers to be served (long position). In contrast, in the second case, a short position, customer demand exceeds production capacity. Such positions are thus exposed to price volatility, as market prices fluctuate significantly (Broker, T., Durr, D., *et al.*, 2019).
- *Basis Risk* is associated with the variation between a hedged asset's value and the financial instruments used to hedge it. For example, an energy producer intending to engage in a hedging operation through the sale of energy contracts faces the risk that, when the contract is settled, the volume of energy produced falls short of the standardized amount specified in the contract.
- *Credit Risk* involves the potential insolvency of one or more counterparties or a change in a counterparty's creditworthiness to which there is exposure. Such changes can lead to unpredictable variations in the credit position volume.
- *Exchange Rate Risk* arises from the company's operations in currencies other than the euro (primarily the US dollar) and can affect the company. First, it influences the economic outcome due to the varying significance of costs and revenues in foreign currencies compared to when the pricing conditions were initially set (*economic risk*). Additionally, it impacts the conversion of commercial or financial receivables and payables denominated in those foreign currencies (*transaction risk*) (Bao, M., Ding, Y., *et al.*, 2021).

- *Replacement risk* is associated with the customer portfolio or production unit. It arises when production shortfalls or a change in the consumption patterns of end customers compared to medium-long-term forecasts occur. The objective of managing replacement risk is to reduce uncertainty concerning the actual volumes of energy sold, allowing for more frequent adjustments of positions to minimize risk as much as possible (Zhilkina, Y., & Akhmetshin, A., 2019).
- *Imbalance risk* refers to the discrepancy between consumption and/or production forecasts and the actual volumes exchanged in the short term. Such discrepancies may arise from unforeseen weather conditions, shutdowns, and sudden failures. Imbalance risk is primarily caused by variable grid input from production plants or withdrawals for end-customer consumption relative to day-ahead forecast volumes. Scheduling energy volumes on Italian platforms, along with the binding injection and withdrawal plans, exposes companies to imbalance charges imposed by the grid operator, Terna S.p.A.
- *Profile Risk* refers to the discrepancy between the historical load-injection profile used to develop forecast models and the actual traded volume. Profile risk arises from the disparity between the forecasted withdrawal profile of end customers at the contract signing and the exact profile at the time of delivery, resulting in exposure to market price differentials (Zhilkina, Y., *et al.*, 2019).
- *Production Efficiency Risk* is linked to energy production and transformation plants that use primary sources for electricity generation. Typically, efficiency indices decline over time due to wear and tear on production machinery. To mitigate this type of risk, a constant commitment to operational excellence is essential.

CHAPTER 3

HEDGING

In commodity markets, managing price swings is essential for businesses that aim to stay financially stable and grow sustainably. Hedging, mainly using commodity derivatives, plays a vital role in reducing the financial risks associated with price fluctuations. Studies show that companies using these derivatives for hedging experience much steadier stock prices. This effect is robust for firms with lower bond ratings, which tend to hedge more compared to those with higher credit ratings.

Energy prices are among the most unpredictable in the commodity sector, with recent years showing even greater price variability. This increased volatility poses significant risks for businesses reliant on energy inputs or directly affected by energy costs. In such situations, hedging becomes a vital tactic for companies looking to manage risks associated with energy prices. By adopting hedging strategies, businesses can lessen the impact of price fluctuations on their financial performance, which promotes more predictable financial outcomes (Halkos, G., & Tsirivis, A. S., 2019).

By mitigating energy risk, firms can enjoy several advantages: greater debt capacity, reduced capital costs, and improved access to funding for strategic investments. This is particularly important during periods of unexpected downturns or low cash flows, when hedging can help firms avoid the financial distress costs that can arise from market volatility. A strong hedging strategy allows businesses to better navigate the unpredictable nature of energy markets, promoting long-term financial strength and resilience.

3.1 Financial Derivatives in the Electricity Market

The company's market exposure and the high volatility of electricity prices have led to a greater focus on risk management in the electricity sector. Generation companies, power marketers, and load-serving entities (LSEs) seek certainty in costs and revenues through hedging, contracting, and active trading.

Market participants commonly use financial derivatives, such as forwards, futures, options, and swaps, to protect themselves. When understood and appropriately utilized, these derivatives help share and control undesired risks through well-structured hedging strategies.

Forwards Contracts

Electricity forward contracts represent a binding agreement to buy or sell a specified quantity of electricity at a predetermined price, the forward price, at a designated time in the future, the maturity or expiration time. Electricity forwards are tailored supply contracts between a buyer and a seller, where the buyer commits to purchasing power, and the seller agrees to supply it.

At the outset of a forward contract, the price is set at zero, meaning the forward price matches the current market price. In this initial stage, neither party experiences a profit or loss. However, as the delivery price diverges from the spot price of the electricity, gains or losses for each party will materialize. The profit or loss is finalized at maturity when one party delivers the specified electricity, and the other pays the agreed-upon price. If the spot price at maturity is higher than the delivery price, the buyer profits; conversely, if it is lower, the seller benefits.

The payoff for a forward contract that promises to deliver one unit of electricity at price F at a future time T is calculated as follows:

$$\text{Payoff of a Forward Contract} = (S_T - F)$$

Where ST represents the electricity spot price at time T .

Although this payoff function resembles other financial forwards, electricity forwards present unique characteristics. Unlike other financial and commodity forward contracts, the nature of the underlying electricity changes with time. The settlement price, ST , is typically determined based on the average electricity price over the delivery period leading up to maturity.

Consider a forward contract for on-peak electricity on day T . On-peak electricity refers to the electricity delivered during peak demand hours, traditionally defined in the industry as 06:00–22:00. To determine ST , one would calculate the average of the 16 hourly prices spanning from 06:00 to 22:00 on that day.

Electricity forwards can be classified based on the delivery period within a day into three categories: on-peak electricity, off-peak electricity, and 'around-the-clock' electricity, which covers all 24 hours of the day (Alexandridis G., *et al.*, 2020).

Natural sellers (short-side) of electricity forwards typically include generators and independent power producers (IPPs), while load-serving entities (LSEs) and utility companies generally act as buyers (long-side). The maturity of electricity forward contracts ranges from a few hours to several years; however, contracts with maturities extending beyond two years tend to be less liquid.

Some electricity forwards are purely financial, settled through monetary transactions based on a specific market price index at maturity, while others involve the physical delivery of the underlying electricity.

Short-maturity electricity forwards, those lasting one hour or one day, are frequently structured as physical contracts. In contrast, those extending several weeks or months may be either physical or financial contracts and are predominantly traded through brokers or directly among market participants in the over-the-counter (OTC) markets (Deng, S. J., and S. S. Oren., 2006).

Electricity forward contracts are the primary instrument for managing electricity price risk. Local distribution companies, or LSEs, often integrate multiple months of forward or futures contracts to align closely with their customers' long-term load profiles.

Futures Contracts

Futures contracts are one of the most widely used derivatives on the electricity market. Electricity futures contracts have a similar payoff structure to electricity forwards; however, electricity futures are distinguished by their high degree of standardization concerning contract specifications, trading venues, transaction requirements, and settlement procedures. The specified delivery quantity significantly differs between electricity futures and forwards, with electricity futures typically stipulating a smaller amount than their forward counterparts. Electricity futures are exclusively traded on organized exchanges, whereas electricity forwards are negotiated over the counter (OTC) in bilateral transactions.

Trades occur anonymously, with participants submitting bids and asks on designated platforms, where transactions are matched based on price. Each trading day, exchanges publish a settlement price as the reference forward price. On days devoid of trading activity, this price may be estimated through secondary sources, such as prices of comparable futures in other markets, or via the "chief trader" method, relying on prices considered reliable by authorized traders. This reference price aligns with the spot price at contract expiration, making the futures price reflect broader market consensus and greater transparency than forward prices.

Most electricity futures contracts are financially settled rather than resulting in physical delivery, which effectively reduces transaction costs. The credit risk and monitoring expenses associated with futures trading are lower than those linked to forwards, as exchanges impose strict margin requirements to secure the financial obligations of all participants. In contrast, OTC transactions are more vulnerable to counterparty default risk.

Futures contracts settle gains and losses daily rather than in a single payment at maturity, as is typical with forwards. This daily settlement further reduces credit risk in futures trading (Falbo, P., *et al.*, 2014).

When evaluating electricity futures versus forwards, the futures market demonstrates key strengths in creating market-wide price references, enhancing pricing visibility, facilitating active trading, and

reducing administrative burdens. Yet, these advantages must be weighed against the constraints of futures contracts, particularly their rigid specifications and quantity limitations, which introduce multiple forms of basis risk.

Options

Options are financial instruments that grant the buyer the right, but not the obligation, to purchase or sell a specified quantity of assets at a predetermined price (strike price) until the maturity date or on the maturity date itself (exercise day). The strike price is critical as it is the price at which the option holder can transact in the underlying securities or assets. In the context of the electricity market, options are based on future prices determined by existing futures contracts. The option buyer (holder) retains the right to exercise the option until its maturity date, whereas the seller (writer) is obligated to meet the terms of the option contract if the buyer chooses to exercise it. Electricity options available on exchanges are derived from futures contracts and settled through physical delivery upon maturity if held until that time (Nadarajah, S., *et al.*, 2023)

Swaps

Electricity swaps are financial contracts that allow owners to pay a fixed price for basic electricity, regardless of the fluctuating cost of electricity or vice versa, during the agreed-upon period. These contracts are concluded for a fixed amount of electricity related to a variable spot price at any producer or consumer location. Electricity swaps are widely used to provide short—and medium-term price certainty for up to several years.

Contracts-for-Difference (CfD)

The Contract-for-Difference (CfD) is a purely financial transaction that incentivizes investment in energy production assets with a high upfront cost by providing stable prices over a long period. It can also protect consumers against high electricity prices.

In CfD contracts, an agreement is made between two parties to exchange payments depending on the underlying price. The price movements of the underlying trigger payments between the contract partners, without the actual good, ever-changing hands, and physical delivery of electricity.

Renewable CfDs function as fixed-for-floating swaps, wherein one party exposed to variable prices seeks stability. This party sells its 'floating rate' to a counterparty, which provides a 'fixed rate' in return. In this scenario, renewable producers, facing variable power market prices, act as the sellers of the floating rate. At the same time, a state authority typically serves as the buyer, offering the fixed rate. Throughout the CfD, the fixed and floating rates are compared, and financial settlements are made to determine the net payment obligations for each settlement period (Khodadadi A., 2024).

3.2 HEDGING with FUTURES

Let us proceed to a more in-depth analysis of specific hedging practices, examining their practical applications and effectiveness in managing financial risks. Futures contracts have been used as hedging tools for over a century.

Hedging involves establishing a position in the derivatives market that is equal and opposite to a position at risk in the physical market.

- Generators Use Futures Contracts to Hedge.

In this example, we examine how a generator might use futures contracts to hedge against price volatility in the electricity market. Suppose a generator anticipates selling electricity into the spot market in six months. The generator's cost of production is \$20 per megawatt-hour (MWh), while the current spot price for electricity is \$20/MWh. However, the futures price for delivery in six months

is slightly lower, at \$18/MWh. The generator, as a producer, is "long" on electricity, meaning it benefits if prices rise but faces losses if prices fall. To mitigate this risk, the generator can sell futures contracts at the current \$18/MWh price, thereby hedging against potential price declines in the spot market over the next six months. This hedging strategy involves selling futures contracts now and, after six months, selling electricity at the spot price while simultaneously closing the futures position by purchasing an equivalent futures contract. Assuming the futures price converges with the spot price as the delivery date approaches, the hedge provides stability by offsetting potential losses from adverse price movements in the spot market.

To illustrate, consider two scenarios representing extremes in the spot market price at the end of six months:

- *Scenario 1: Spot Price Falls to \$10/MWh*

If the spot price declines to \$10/MWh, the generator will face a significant loss in its physical position. Selling electricity at \$10/MWh would result in a \$10/MWh loss relative to its \$20/MWh production cost. However, the hedging strategy provides compensation: because the generator originally sold futures at \$18/MWh, it can now buy back those futures contracts at the lower spot-equivalent price of \$10/MWh. This yields an \$8/MWh gain on the futures position, partially offsetting the physical loss. The net result is a combined loss of \$2/MWh, a less severe outcome than a complete \$10/MWh loss without the hedge.

- *Scenario 2: Spot Price Rises to \$30/MWh*

Alternatively, if the spot price rises to \$30/MWh, the generator benefits from a gain in its physical position, as it sells electricity at a \$10/MWh profit (\$30 spot price – \$20 production cost). However, this gain is offset by a \$12/MWh loss on the futures position, as the generator must buy

back futures contracts at the higher spot-equivalent price of \$30/MWh after initially selling them for \$18/MWh. Thus, the net outcome remains a \$2/MWh loss.

In both cases, the generator's total profit or loss after accounting for the physical and futures positions is \$2/MWh. Using futures to hedge, the generator effectively "locks in" a sale price of \$18/MWh (the futures price) for its electricity, reducing the uncertainty of its revenue and limiting its exposure to extreme market fluctuations.

- Marketers Use Futures Contracts to Hedge

Marketer's Long Hedge: Assume that a marketer has guaranteed customers that it will deliver electricity to them in six months.

The marketer buys electricity futures contracts at \$18/MWh and plans to sell electricity to the end user at a slightly marked-up price, \$18.10/MWh. This markup allows the marketer to cover bare costs and ensure a margin on the transaction. To hedge against price fluctuations, the marketer can sell futures contracts at the higher price of \$30/MWh, securing a gain of \$12/MWh over the initial purchase price of \$18/MWh. This transaction guarantees the end user a fixed-price electricity supply at \$18.10/MWh, protecting the customer from potential price increases in the spot market. If the spot price converges to the futures price, the marketer secures a small profit of \$0.10/MWh. This profit results from the slight markup applied to the end user while successfully managing price risk through futures contracts.

Marketer's Short Hedge: Assume that a marketer has agreed to buy electricity from a generator in six months.

The marketer initially buys electricity for \$17.90 per megawatt-hour (MWh) and sells a futures contract at \$18/MWh for delivery in six months. This futures contract locks in a future selling price, reducing the

marketer's exposure to price risk. Six months later, the spot price of electricity has risen to \$30/MWh. The marketer buys the power from the generator at the original \$17.90/MWh and sells it at \$30/MWh on the spot market. This results in a \$12.10/MWh profit on the physical transaction. To close the futures contract, the marketer buys back futures at the current spot price of \$30/MWh, incurring a loss of \$12/MWh on the futures position. By combining the profit from the physical transaction and the loss on the futures position, the marketer achieves a net profit of \$0.10/MWh.

Especially in the oil market, futures contracts can prove to be very useful as they allow for additional hedging strategies and contracts, such as *crack spread contracts*. Refiners' genuine concern lies in the price difference between what they pay for crude oil and what they receive for their refined products rather than the oil prices themselves. Being able to estimate all other costs except oil safely, refiners are primarily concerned about this price spread, and as a result, they are interested in strategies to ensure this spread, on which their potential profits are largely dependent. A popular approach among refiners is to buy futures contracts for oil while simultaneously selling futures for their refined products. The crack spread contract was created to cover these multiple transactions, which incorporates all the above necessary hedging actions to ensure the price spread in just one trade. One well-known version of the crack spread contract involves buying three crude oil futures while selling two gasoline futures and one heating oil future a month later. However, this 3-2-1 ratio might not suit all refiners, especially in over-the-counter markets outside traditional exchanges (Liu, P., *et al.*, 2017).

While useful for managing price risk, hedging with futures contracts involves several inherent risks. First, there is the risk that future prices may not converge with the spot price on the delivery date. This divergence could lead to unexpected financial outcomes, as the effectiveness of a hedge relies on the futures and spot prices aligning closely at settlement.

Another risk is the mismatch between the monthly futures contracts and the daily spot market. If a generator is exposed to daily price fluctuations but uses a monthly futures contract to hedge, the agreement may not adequately cover daily price volatility, leading to residual risk.

Lastly, the risk of miscalculation in the generator's production forecast. If the generator produces more or less electricity than anticipated, the hedge position may not align with the actual output, resulting in an over-hedged or under-hedged position. This discrepancy can create additional financial exposure rather than the desired stability that hedging is meant to achieve.

For hedging with futures contracts to be effective, certain conditions must be met. The futures price must align with the spot price at settlement, ensuring that the forward price converges with the market price. Furthermore, at least one market participant must be willing to enter into the futures contract both when the exposure occurs and at the time of delivery. If no participant is interested in fulfilling the contract at settlement, the hedger becomes exposed to *delivery risk*. In such cases, where no counterparty is willing to buy or sell the futures contract, the effectiveness of the hedge is compromised. This situation would be less problematic in a market where derivatives could be traded freely and at minimal cost, but the lack of market participants can present a significant challenge.

The electricity market presents two key differences that affect how hedging strategies are implemented. Electricity delivery typically occurs over an extended period rather than on a single date. This requires a careful selection of futures contracts to match the exposure period accurately. The second distinction is that to ensure proper exposure coverage, the futures contract must expire at or before the beginning of the delivery period. For example, if the exposure spans November, the appropriate futures contract would be one with a delivery period that ends in October. This ensures the hedge covers the exact time frame needed.

3.2.1 Delivery risk

Delivery risk in the context of futures derivatives in the electricity market refers to the potential mismatch between a futures contract's obligations and the actual ability to deliver or receive electricity as specified. Unlike other commodities that allow delivery on a set date, electricity presents unique challenges due to its non-storable nature. It must be consumed in real time and often requires delivery over a period, adding layers of complexity and risk when using futures contracts for hedging.

A key aspect of delivery risk is the chance that when a futures contract expires, there may not be a market participant willing to meet the obligations of that contract. In more traditional markets, the ability to buy or sell the underlying asset is usually assured. However, in the electricity market, the requirement for an exact match between the contract's delivery period and the actual electricity supply complicates matters. If no counterparty is available to take the opposing position - like a seller refusing to deliver electricity during the specified time or a buyer unable to purchase - the hedger faces exposure, remaining with an open position and no counterparty to engage with.

Electricity delivery is often spread across a defined delivery window - be it a month, a quarter, or certain hours within a day - making the timing and volume of delivery critical. Suppose there's a mismatch between the hedging period and the futures contract's delivery window. In that case, it might result in an inability to fulfill the contract or incur financial losses if market prices diverge from expectations set by the futures contract. For example, if the delivery window does not align perfectly with a generator's production schedule or a consumer's consumption needs, discrepancies may occur, reducing the effectiveness of the hedge (Kemper *et al.*, 2022).

Moreover, the financial settlement of electricity futures—where contracts are settled in cash rather than through the physical delivery of electricity—can help mitigate delivery risk.

However, even with a financial settlement, differences between the futures price and the spot price at the time of settlement may still expose the trader to economic risks, as the hedge might not adequately cover the price fluctuations.

3.2.2 Basis Risk

Basis risk is the primary risk associated with using futures contracts to hedge commodity risks. It is defined as the risk that the forward price and the spot price do not vary by the same amount over time (Kemper *et al.*, 2022).

Basis is the difference between the futures and spot prices of the commodity being hedged.

Basis risk arises from the moment the hedger opens a position in the financial market (t_0) and persists until the position is closed (t' such that $t_0 \leq t' < T$, where T denotes the maturity of the derivative). Throughout the period in which the financial market position remains open, the movements of the spot and forward prices may diverge. Basis risk reflects the risk that offsetting investments in hedging strategies will not experience price changes in opposite directions. The difference between the two prices at various points in time during the remaining life of the future is called the basis, represented by the formula:

$$B_{t,T} = S_{(t)} - F_{(t)}^T$$

The variance of the basis provides a natural measure of basis risk. Indicating with $B_{t_0,T}, B_{t_0+1,T}, \dots, B_{t',T}$ the values of the basis at different points in time, the measure of basis risk takes the form:

$$BRT = Var (B_{t_0,T}, B_{t_0+1,T}, \dots, B_{t',T}) = \sigma_S^2 + \sigma_F^2 - 2\rho\sigma_S\sigma_F,$$

Where:

- $S_{(t)}$ is the spot price at time t
- $F_{(t)}^T$ denotes the forward price at time t for the derivative with maturity at T
- σ_S and σ_F are the standard deviations of the spot and forward prices, respectively
- ρ is the correlation coefficient between the spot and forward prices

for $t = t_0, t_0+1, \dots, t'$ with $t_0 \leq t' < T$.

Basis risk is zero in the case of a perfect correlation between the spot and forward prices.

3.2.3 Liquidity

Both hedgers and speculators share an urgent need to operate with an adequate level of liquidity. A financial instrument is considered liquid if it can be converted into cash quickly and without substantial price changes. The liquidity of a financial market and the instruments traded within it are determined by the interaction of five dimensions: breadth, depth, immediacy, tightness, and resilience. While depth pertains to the total volume at different prices, breadth considers how traded volume affects shifts in the forward price. Immediacy measures the speed of order execution, serving as an indicator of overall market efficiency. Tightness assesses the implicit and explicit costs associated with trading, whereas resilience indicates the market's ability to return to equilibrium following a disruption. Nevertheless, these five factors do not capture all the variables influencing liquidity. The remaining lifespan of a financial instrument is crucial; a futures contract far from its expiration date will attract limited investor interest, resulting in illiquidity.

The traditional approach to hedging emphasizes selecting an instrument with a substantial price correlation to the exposed commodity. The ideal derivative ensures that the forward price at expiration aligns with the spot price and that movements between the two price series correlate. In cases where such an instrument is unavailable, alternative derivatives must be considered.

However, the liquidity of the chosen instrument impacts hedging outcomes as it affects transaction costs and the magnitude of delivery risk. Consequently, both correlation and liquidity should be integral to the development of hedging strategies. The ideal instrument for mitigating exposure combines high liquidity with a solid correlation between spot and forward prices (Frestad, D., 2012).

The impact of liquidity on hedging effectiveness is a very under-researched topic, particularly in the energy sector. The significant volatility of electricity prices complicates this issue, often deterring the inclusion of additional factors in the analysis.

3.2.4 Mis-matching Strategies

In Europe, electricity spot prices exhibit significant volatility, leading to inevitable differences between spot and forward prices, given that the forward price serves as the best available estimate of the future spot price at maturity.

These discrepancies do not inhibit the use of derivatives based on a different country's market to hedge against price risk. The key to effective hedging lies in the correlation between spot and forward prices rather than their levels.

While the ideal futures contract provides a high degree of correlation between prices and is thus the optimal instrument, its limited liquidity can hinder hedging outcomes. Factors such as the time remaining until expiration, the delivery period's duration, and the underlying asset's nature can negatively impact counterparty interest.

Engaging in mis-matching practices often becomes a necessary strategy when the ideal derivative is either unavailable or temporarily out of reach. For example, if the most suitable futures contract expires excessively long, market interest may manifest too late to serve the hedger's needs. In such scenarios, using instruments with shorter maturities that typically offer greater liquidity can present a practical solution (Théate, T., *et al.*, D., 2023).

Aside from using derivatives tied to an underlying asset in a country different from the exposure, combining instruments with shorter maturities is possible. Without holding the derivative to maturity—and thus avoiding exposure to delivery risk—one can close and simultaneously open positions with different delivery dates. For instance, to hedge an annual exposure in Italy, if the ideal instrument proves illiquid, one might combine quarterly or monthly instruments within the Italian or German market until the yearly entire delivery window is covered. It's important to note that mis-matching regarding the delivery period incurs higher costs due to the necessity of managing and transacting multiple positions.

3.3 HEDGING with OPTIONS

Options on futures provide added flexibility in hedging by allowing hedgers to protect against unfavorable price movements while benefiting from favorable ones. Power generators and end users can use combinations of call and put options to establish a price range for electricity.

A put option, "floor," grants the buyer, such as a power generator, the right—but not the obligation—to sell electricity at a set strike price at a specific time. This ensures a minimum sale price, protecting the generator from low market prices. For example, if the electricity futures price is \$25/MWh, a generator aiming to secure at least \$25/MWh might buy a put option at that strike price for a premium of \$1/MWh. In this scenario, if the market price rises, the generator can sell at the higher spot price, benefiting from the price increase. If the price falls below \$25/MWh, the generator can exercise the put option, selling at the strike price to maintain the targeted minimum revenue.

A call option, "cap," serves as a ceiling price for end users, limiting the maximum price they pay relative to an indexed price. This enables end users to manage costs by ensuring they are not exposed to extreme price increases.

The stochastic models used to determine the theoretical value of options (Black-Scholes, binomial models, which are effective as they rely on arbitrage opportunities rather than Geometric Brownian Motion, etc.) have proven poorly suited for the electricity market. This is because these models assume the underlying asset follows a probability distribution that cannot be reasonably applied to electricity. The high historical volatility of electricity markets tends to make options on these instruments excessively costly.

- *Swing options*

Commonly known as flexible nomination options, these have specific characteristics that define them. First, these options can be activated on a daily basis or within a limited number of days throughout the allowed exercise period. Secondly, when exercising a swing option, the daily quantity may vary (or swing) between a minimum daily volume and a maximum volume. However, the total volume taken during a specified timeframe, like a week or a month, needs to be within certain minimum and maximum volume levels. Additionally, a swing option's strike price may stay constant throughout its entire duration or be established at the beginning of each period using a defined formula. Lastly, suppose the buyer fails to fulfill the minimum quantity requirements within a given contract period. In that case, they must pay a lump sum penalty or compensate for the seller's revenue loss (commonly referred to as take-or-pay).

3.4 HEDGING with SWAP

Swap contracts are over-the-counter (OTC) financial derivatives that allow two parties to exchange cash flows based on the price changes of an underlying asset or commodity without requiring physical delivery. These contracts are set on a notional amount, determining the basis for cash flow settlements tied to market price movements. Unlike exchange-traded derivatives, swaps offer significant customization and flexibility to meet specific hedging needs. However, they lack clearinghouse

guarantees, which increases counterparty and credit risk, often making them less liquid and sometimes requiring renegotiation before contract expiration.

- *Fixed-for-Floating Price Swap (Energy Swap)*

A Fixed-for-Floating Price Swap is a financial contract that allows one party to pay a fixed price for electricity over a specified period, regardless of fluctuations in the floating market price, while the counterparty pays the floating spot price. This swap is structured for a fixed quantity of power, referencing the spot price at a generator or consumer's location. The fixed rate remains constant across the contract duration, providing the buyer with price certainty and a hedge against volatility in electricity prices. These swaps function like a strip of electricity forwards, meaning they comprise a series of forward contracts with multiple settlement dates but an identical fixed price for each settlement. Each settlement reflects the difference between the fixed and spot market prices on that date (Kemper *et al.*, 2022).

Fixed-for-Floating Price Swaps are widely used in the energy sector by both producers and consumers looking for short- to medium-term price certainty by locking in a specified price level, hedging against electricity price fluctuations and securing predictable cash flows.

- *Basis Swap*

A basis swap in the energy market enables counterparties to effectively manage the differences between a local market price—such as a specific regional rate—and a widely recognized benchmark index, like the PUN (Italian National Single Price).

In Italy, where electricity prices vary significantly due to transmission limitations and localized supply-demand imbalances, basis swaps become particularly beneficial. By employing these swaps, participants can hedge against the risks associated with these price differences, creating a closer alignment between local and national market exposures. A basis swap modifies the basis or benchmark of variability rather

than eliminating price fluctuations. This means that although price risk remains, it shifts to reflect the differential from a major index, reducing the mismatch between regional and broader market dynamics.

- *Spark Spread Swap*

A spark spread swap is a specialized swap that focuses on the difference, or spark spread, between the electricity price (often the PUN in Italy) and the cost of generating that electricity, primarily the cost of natural gas, which is a significant input in Italy's energy mix.

The spark spread measures the profitability of generating electricity based on current fuel costs. For gas-fired plants, the spark spread swap is vital in locking in profitability by fixing the difference between electricity sale prices and fuel costs.

A positive spark spread for a generator indicates that the electricity market price covers production costs, making generation profitable. A negative spark spread, however, suggests production at a loss. By entering a spark spread swap, generators can protect themselves from the risk of this spread decreasing or becoming negative, as the contract provides compensation for unfavorable shifts in fuel or electricity prices (Smith A., *et al.*, 2011).

For example, if the PUN is €60/MWh and the cost of natural gas for generating electricity is €40/MWh, the spark spread would be €20/MWh. The generator can secure this spread through a swap, stabilizing its profit margin. If the PUN decreases or gas prices increase, thereby reducing or negating the spark spread, the swap will ensure the generator maintains a consistent margin.

- *A Peaking Swap* applies to trade only during a specific time—from 7 a.m. to 10 p.m. — and only on working days.
- *A Flat Cap*, a contract that gives the holder the option to buy a given amount of electricity at an agreed price.

There are also a wide range of exotic contracts that are used by parties to manage risk, including:

- *Weather contingent options:* These can only be used if a particular weather outcome occurs, such as above-average temperatures over a given period.
- *Asian options:* an option contract that can be called on if the average price of electricity is high over a predetermined period.
- *Outage protection contracts:* a product that allows generators to protect themselves against the risk of being unable to sell electricity in the spot market.
- *Load following contracts:* a hedging product that follows the usage of the electricity consumer.
- *Collar contracts:* A combination of a cap and floor contract that limits both upward and downward price movement.

CHAPTER 4

INSIDE

4.1 Italy's Electricity energy market

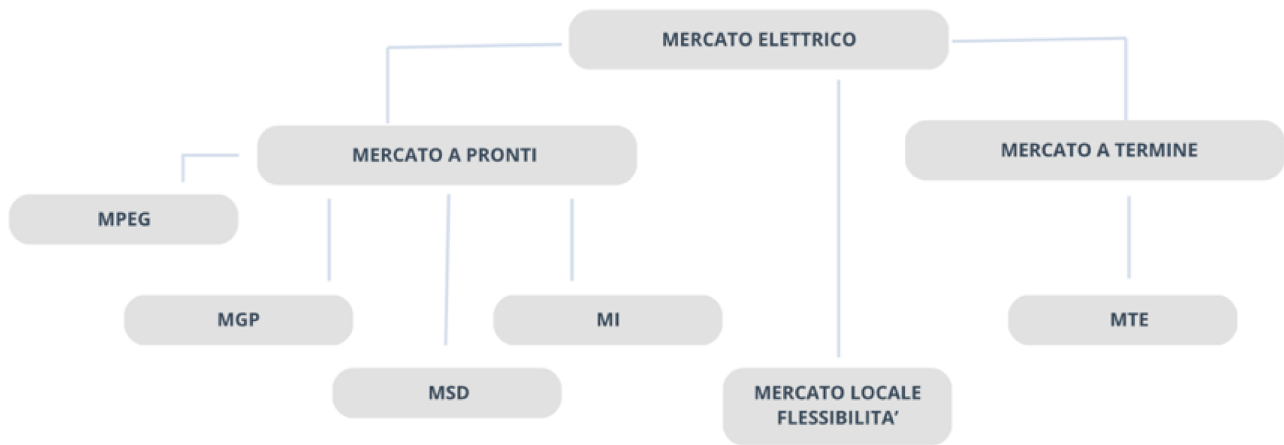
Following the liberalization process of the European energy sector, initiated by the EU Directive 96/92/EC in 1996, member states of the Union undertook a series of reforms aimed at promoting free competition and market transparency.

In Italy, energy sector liberalization started on March 16, 1999, transforming the electricity market previously dominated by a monopoly controlled by ENEL, the sole supplier for all consumers. The process was initiated with the approval of Italian Legislative Decree No. 79, known as the *Bersani Decree*, in response to the EU Directive on the internal energy market (Directive 96/92/EC, later replaced by Directive 2003/54/EC). The decree mandated the separation of ownership and management of each supply chain segment, effectively promoting greater efficiency and leading to lower prices. Specifically, it established that "starting from 2003, no entity could produce or import more than 50% of the total electricity produced and imported" (Terna S.p.A, 2024).

The transmission network transferred from ENEL to Terna S.p.A., under the oversight of the Ministry of Economy and Finance, was completed in 2004 with Terna's listing on the Milan Stock Exchange.

One of the most significant innovations introduced was the launch of the Italian Electricity Market (ME), described as "an electronic marketplace for wholesale electricity trading, where energy prices are determined by the equilibrium price formed by the intersection of the quantities of electricity demanded and those supplied by participating operators." (Gestore dei Mercati Energetici).

Figure 4.1 Structure of the Electricity Market (Source: Terna)

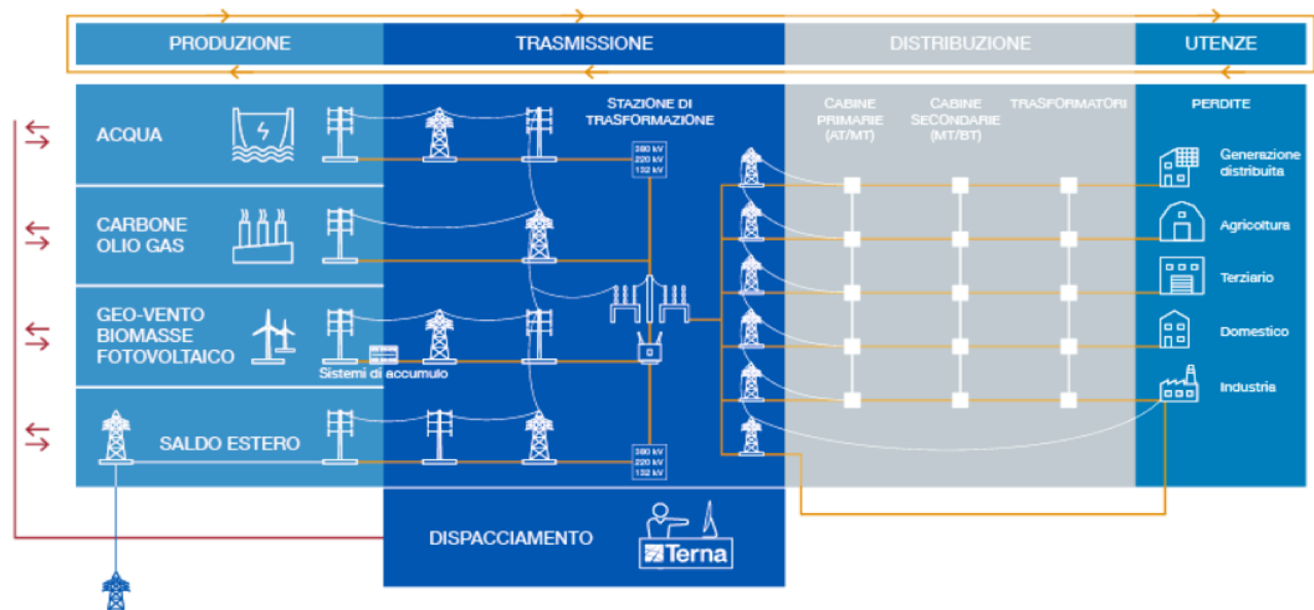


Currently, the ME is structured into two primary segments: the *Spot Market*, which handles short-term transactions, and the *Forward Market for Energy*, which handles long-term contracts hedging price volatility.

The so-called *Spot Market* is organized into the following key segments, organized progressively approach real-time delivery:

- THE DAY-AHEAD MARKET (MGP) is where producers, wholesalers, end customers, the Acquirente Unico (AU), and the Gestore dei Servizi Energetici (GSE) buy and sell quantities of electricity for the following day. Prices and quantities are determined by supply and demand, with outcomes aggregated into the *National Single Price (PUN)*.
- THE INTRA-DAY MARKET (MI) allows operators to adjust the schedules established in the MGP.
- DISPATCHING SERVICES MARKET (MSD) is where Terna S.p.A. purchases the necessary energy to maintain system control and security. This includes addressing congestion issues and ensuring a real-time balance between electricity injection and withdrawal.

Figure 4.2 Structure of the Electricity System (Source: Terna)



- BALANCING MARKET (MB) is a subset of the MSD, where Terna selects offers to address grid congestion and reserve requirements further.
- TRANS EUROPEAN REPLACEMENT RESERVES EXCHANGE (TERRE) enabling European system operators procure reserves to correct imbalances in their respective electricity grids.

Operators also have the option to enter into bilateral agreements in the unregulated Over-the-counter (OTC) market.

The organization and management of the ME fall under the responsibility of the Gestore dei Mercati Energetici (GME), while Terna S.p.A. ensures a continuous supply of electricity throughout the national territory. The electricity supply chain covers several key activities: production, transmission, dispatching, distribution, and ultimately, consumption. Each activity functions under distinct market regimes. While production and distribution are competitive, transmission and dispatching operate as a state monopoly controlled by Terna S.p.A. (GME, 2025).

To promote competition, all operators receive uniform prices for medium—and high-voltage electricity transmission. The same principle applies to dispatching, which involves maintaining a real-time balance between production and consumption.

The electricity transmission network is subject to various technical constraints, the most significant of which is the balance between incoming and outgoing energy. At any given moment, the amount of electricity supplied by producers must equal the amount consumed by users; any deviation from this

equilibrium condition could lead to a crisis within the system.

To facilitate dispatch management and comply with regional structural constraints, the distribution network is divided into zones. The Italian electricity market currently consists of *seven territorial "market zones"*, where energy can be bought and sold without restrictions at a specific "zonal price". These zonal prices only affect producers, as consumer costs remain uniform nationwide, thanks to the *Prezzo Unico Nazionale (PUN)*.

Figure 4.3 The 7 Market Zones (Source: Terna)



This PUN represents the weighted average of zonal prices, traded in the Mercato del Giorno Prima (MGP), a segment of the Spot Market, reflecting the quantities of electricity negotiated, including any exchanges with neighboring countries. As the spot price of electricity, the PUN serves as the benchmark for immediate settlement in electricity transactions.

With its zonal organization and PUN pricing mechanism, the Italian electricity market structure represents a sophisticated attempt to manage domestic electricity distribution and pricing. However, this

internal market framework operates within a broader context of significant external dependencies that create substantial financial vulnerabilities. At the heart of this challenge lies Italy's fundamental reliance on energy imports to meet its domestic electricity needs. While Terna S.p.A. efficiently manages the internal transmission and dispatching of electricity, the reality is that much of this electricity originates from imported energy sources (GME, 2025).

This heavy dependence on foreign energy sources creates a critical intersection between Italy's domestic electricity market and international currency markets. The PUN mechanism, while effectively providing uniform prices for Italian consumers, cannot shield the system from the underlying currency risks associated with energy imports. When Italian energy companies purchase the fuel needed for electricity generation, they must conduct these transactions in US dollars, following global energy market conventions. However, their revenue stream, governed by the PUN, comes in euros. This currency mismatch creates a fundamental exposure to exchange rate fluctuations affecting the electricity supply chain.

The significance of this currency exposure becomes even more pronounced when considering Italy's position as one of Europe's largest energy importers, with over 75% of its energy requirements met through imports. This means that any fluctuation in the EUR/USD exchange rate amplifies the country's energy costs, potentially straining both the financial stability of energy companies and the effectiveness of the PUN pricing mechanism in maintaining stable consumer prices.

4.2 Europe's Energy Sector

The European Union is the world's leading energy importer, satisfying 70% of its natural gas needs and 90% of its oil consumption through imports, totaling over €40 trillion per year, with 90% of these transactions conducted in currencies other than euros, primarily U.S. dollars.

The impact of this currency exposure has drawn significant academic attention.

Various analyses investigate the connection between the market value of energy firms in the Eurozone and the changes in the prices of raw materials, such as oil, natural gas, coal, and uranium, as well as their trading values, denominated in U.S. dollars. The pricing of raw materials in dollars is the main factor contributing to business exposure, with an impact that exceeds the raw material price itself (Lado-Sestayo, R., *et al.* 2023).

This USD dependence is reflected even in European benchmarks like Brent crude oil from the North Sea. Although Brent is a European marker, its pricing is denominated in US dollars rather than euros. This situation reflects the limited role of the euro in global energy markets, where the US dollar continues to dominate.

For years, there has been advocacy for linking fossil fuel pricing to the euro instead of the US dollar, an idea that has often been viewed through a political lens. The European Commission's recommendations on strengthening the euro's international role in the energy sector include measures to reduce the dollar's overwhelming dominance in transactions and lessen the impact of protectionist policies, such as those seen during President Donald Trump's administration. Although the word "dollar" is never explicitly mentioned in the Commission's document, it is clear that the push to enhance the euro's role stems from frustration, justified by the EU's absence from what is one of the most crucial markets in the global financial system: the oil market, where the US dollar dictates the terms (European Commission, 2024).

To this end, the European Commission recently approved proposals to encourage market players in the Old Continent to expand the use of "Eurocentric" contracts, focusing on currency denomination.

From a technical perspective, the current dominance of dollar-denominated contracts stems largely from market inertia and long-term agreement structures.

A monetary perspective reveals that re-denominating contracts could increase euro demand in foreign exchange markets, potentially shifting economic authority to Frankfurt (European Commission 2024).

Imposing the euro as the reference currency for fuel supplies would lower transaction costs in foreign exchange markets. Sufficient competition could reduce energy production costs, resulting in more transparent and stable wholesale electricity prices, such as Italy's PUN (Prezzo Unico Nazionale). The wholesale electricity price would benefit in terms of transparency, more accurately reflecting the cost of the resource, and being free from speculative currency fluctuations.

Research by Aline Muller and Willem F. C. Ve reveals that euro depreciation against foreign currencies, particularly the U.S. dollar, negatively affects stock returns, while appreciation yields positive outcomes. While short-term exposures are often effectively hedged, long-term vulnerabilities remain, particularly for firms with weaker liquidity positions (Muller, A., *et al.*, 2006).

A companion study by Rubén Lado-Sestayo *et al.* provides deeper context, examining the vulnerability of utility to shifts in the prices of energy raw materials (oil, liquefied natural gas, coal, and uranium) and how this vulnerability interacts with the euro's role in global energy markets.

Of the 40 companies evaluated, an overwhelming 77.5% (31) displayed a statistically significant exposure to changes in energy prices and exchange rates. These companies conduct their operations in euros while needing to purchase energy commodities in U.S. dollars. The research shows that the effects of energy price fluctuations are not uniform across various economic conditions. The behavior of firms during periods of market growth is markedly different from their behavior in downturns, indicating that the risk profiles of these companies are sensitive to macroeconomic cycles. Some companies may find advantages in rising energy prices under particular conditions. For instance, Italian utility companies showed a positive relationship with increasing uranium prices, which may be attributed to the country's nuclear moratorium. German companies, heavily reliant on imported gas and transitioning toward renewable energy sources, exhibited a strong positive correlation with rises in gas prices. Similarly,

Spanish companies displayed a positive association with coal prices, suggesting that regional market dynamics and energy mix play a vital role in shaping financial outcomes.

The situation is further complicated by the absence of a unified energy policy for negotiating supply contracts for raw energy materials (Lado-Sestayo, R., *et al.* 2023).

Despite the EU being a single economic block, energy supply agreements remain largely bilateral, meaning that each country faces distinct levels of exposure to the U.S. dollar. This bilateral structure weakens the Eurozone's collective bargaining power. Acting with “a single voice” could improve contract negotiation outcomes for energy purchases. Nevertheless, national sovereignty and competing interests among member states continue to hinder the implementation of a cohesive energy policy.

Addressing foreign exchange risk in Europe’s energy sector demands a multi-pronged approach.

Policymakers should focus on fostering financial markets capable of supporting advanced hedging instruments. In the short term, public financial institutions—such as central banks, development banks, and dedicated funds—can provide the necessary liquidity and mitigate market failures. These temporary interventions will reduce currency risk while private financial markets mature.

Aligning monetary and fiscal policies to facilitate FX derivative markets is critical over the long term. Boosting the availability of currency hedging tools would improve market depth and competitiveness while reducing transaction costs.

At a “regional” level, the European Union must adopt a cohesive negotiating strategy to encourage euro-denominated energy import contracts, seeking to shield the EU from external monetary policies and stabilize energy pricing mechanisms.

Developing tailored financial products, such as currency swaps and long-term energy contracts in euros, can help mitigate the risks. Multilateral development banks can support this transition by offering expertise and funding to help scale up the use of such financial solutions.

Achieving a more resilient and stable energy sector requires both immediate actions to mitigate current vulnerabilities and a long-term commitment to structural reforms (IEA Report, 2024).

4.3 ENI

“WHAT's good for ENI is good for Italy.”

Although Enrico Mattei, the dynamic head of Italy's largest and most influential business empire, never coined this dictum, it would no doubt precisely express his feelings. ENI is Mattei's dream, his creation, his world. It is Italy's proudest post-war development and her most significant stake in world economics. It also sparked some of the most heated debates in Italy since the era of fascism. Like fascism, ENI was a bold and uniquely Italian concept. It was a new form of state capitalism that the world had never seen before.

But what do the letters ENI mean? ENI stands for Ente Nazionale Idrocarburi, which translates to National Hydrocarbons Authority. Like other big business corporations, it has become known by its initials.

Today, ENI operates as a global energy powerhouse across 68 countries and employs over 30,000 people. Initially rooted in the oil and gas sector, ENI has transformed into an integrated energy technology firm, playing a key role in ensuring energy security while leading the energy transition. Its comprehensive operations cover the entire energy value chain—from oil and natural gas exploration and extraction to electricity generation through traditional and renewable sources.

The company's integrated model serves a wide range of markets, offering products like gas, electricity, and energy efficiency solutions. ENI is also pioneering efforts in sustainable mobility by blending traditional energy practices with modern approaches to meet changing customer needs. Leveraging its vast expertise and geographic reach, ENI aims to maintain economic stability while minimizing its environmental footprint (carbon neutrality by 2050).

Operational excellence is at the heart of ENI's strategy, which is also committed to safety, environmental protection, and financial resilience.

ENI's integrated business model combines proprietary technologies with forward-thinking financial structures, blended with transparent company governance and supported by effective risk management practices that facilitate sound decision-making (ENI Annual Report, 2024).

Over the last few years, despite lower oil and gas prices in 2024 (Brent down 18% and European gas down 65% from 2023), ENI has delivered strong financial results driven by robust operational performance, safeguarding the Group's production goals and upholding financial discipline.

4.3.1 ENI's Market position and Financial performance

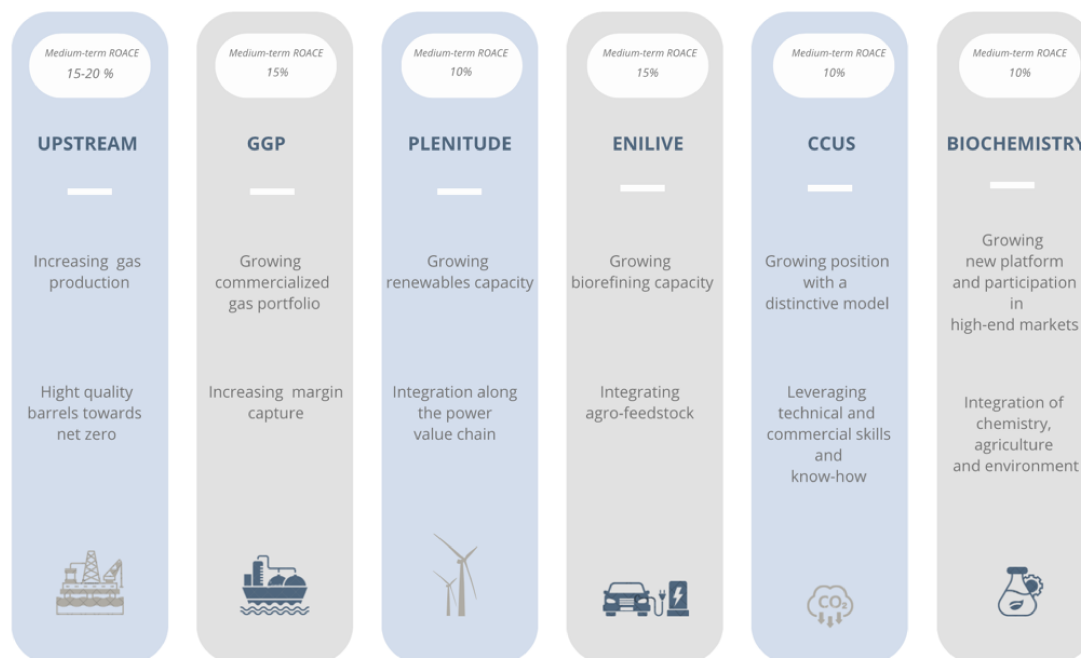
Not only is Eni Italy's most profitable company, but it is also one of the best-performing international oil and gas majors, with a ROCE close to that of Exxon Mobil, the leading oil and gas major in terms of financial performance.

But what are the sources of Eni's outstanding financial performance? Eni's profits are generated primarily by two of its divisions: E&P and Gas and Power. Not least, Eni's transformation toward renewable energy and sustainability has also begun to bear fruit through its Plenitude and Enilive subsidiaries.

In the case of E&P, the company maintains robust growth with projected 3-4% production increases through 2027, supported by strategic developments in Congo, Cote d'Ivoire, Indonesia, and Libya. Stable production volumes have supported profitability despite oil prices remaining relatively flat or experiencing slight declines due to macroeconomic challenges, slower global growth, and subdued demand in major markets like China and Europe (Eni S.p.A).

The company's traditional upstream business remains robust, but what's notable is how Eni has evolved this segment. Rather than simply maintaining its oil and gas operations, it's integrating them with new

Figure 4.4 Eni's Activities (Source: ENI)



technologies like Carbon Capture and Storage (CCS), particularly in strategic locations like the UK, Italy, and North Africa. This approach allows Eni to maintain lucrativeness while preparing for a lower-carbon future (ENI, Annual report, 2024).

In the case of Gas and Power, Eni's profits derive primarily from its near-monopoly position in the Italian gas market, a strong position further bolstered by its adept navigation of the European energy crisis, diversification of supply sources, and long-term LNG contracts that ensure stability and reliability.

While maintaining its traditional downstream dominance in Italy, where most sales still benefit from market position and distribution density advantages, ENI has successfully expanded its renewable energy portfolio. This expansion includes significant solar and wind power developments, innovative energy storage solutions, and pioneering projects in green hydrogen. As a latecomer to the oil and gas business, Eni's journey began with a strategic necessity: finding unconventional paths to energy resources when traditional routes were already claimed. This challenge sparked an impressive trajectory of international

expansion, carrying significant financial complexities – particularly in managing exchange rate exposures across its global subsidiaries.

Over the years, Eni has demonstrated remarkable adaptability in accessing oil and gas reserves, venturing into physically and politically challenging locations. Its operations span multiple currency jurisdictions – from offshore developments to politically complex regions like Nigeria, Libya, Algeria, Russia, and Kazakhstan. This geographic diversity, while opening access to valuable resources, has created a sophisticated web of subsidiary-level currency exposures that require careful management, particularly in dealing with the significant currency affecting its operations: the Dollar.

The company's downstream evolution reflects an ambitious international agenda. Moving beyond its euro-anchored Italian base, Eni has embarked on a bold expansion that amplifies its currency exposure. Recent investments include dollar-denominated biorefinery operations in Louisiana, won-based partnerships in South Korea, and projects in Malaysia (Eni S.p.A.).

This international growth trajectory has elevated the importance of managing complex currency relationships, particularly across its USD, GBP, and WON exposures.

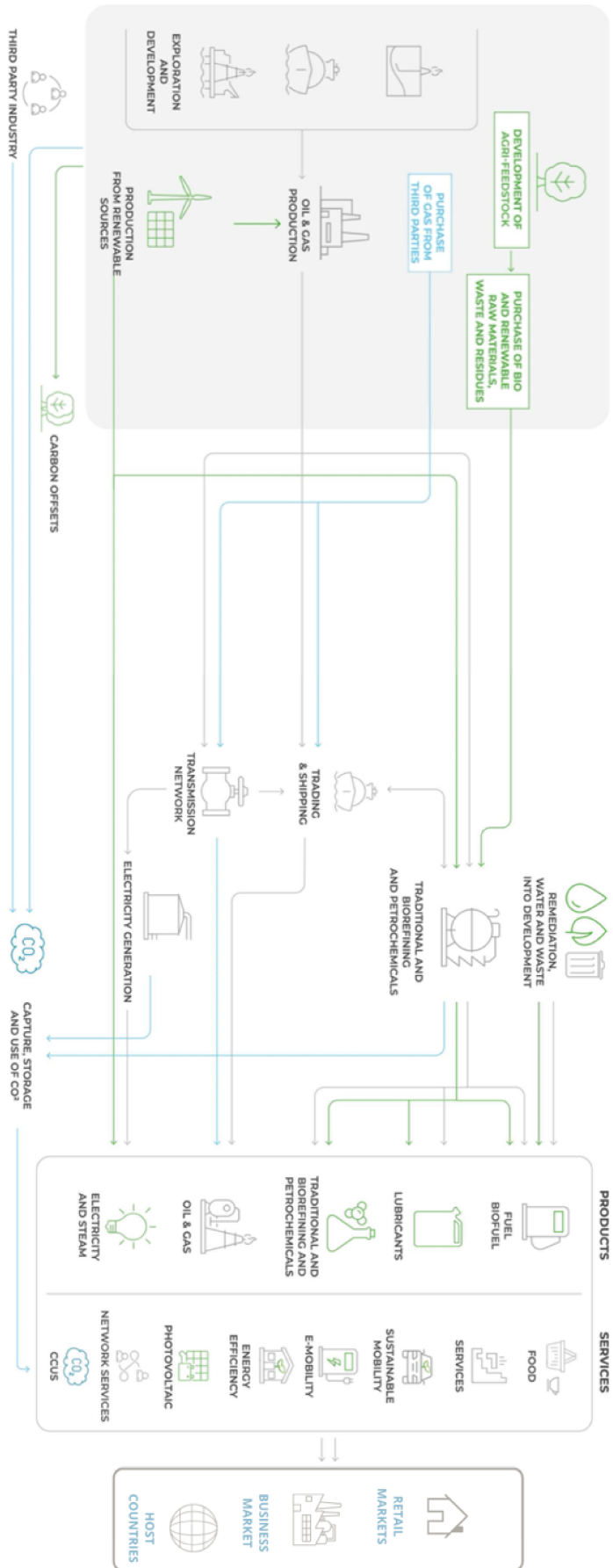


Figure 4.5 Eni Value Chain (Source: ENI)

4.3.2 Emerging Challenges

Descalzi's (ENI's CEO) intended strategy over the next four-year period may be summed as "More of the same, with a cheeky wink to sustainable growth!" – a clear focus on navigating the energy transition while maintaining strong financial performance. The core objectives emphasize delivering robust financial results, optimizing investments across traditional and renewable sectors, and maintaining disciplined capital allocation. Given Eni's successful performance, it is difficult to argue that Eni should be pursuing a radically complex strategy; at the same time, it is essential to consider the potential pitfalls of the approach. A few issues appear to be particularly important:

- *Competition in the Energy Transition Era.* While Eni has historically dominated the Italian gas market, the current competitive landscape is markedly different. The company faces dual pressures: maintaining competitiveness in traditional markets while building strength in new energy sectors. European rules on competition in natural gas and electricity production place ceilings on Eni's market share in distribution in Italy. As a result, Eni has sought to grow into other European markets (mainly through acquiring local energy distribution companies). How well-equipped is Eni to prosper in competitive markets? Eni's downstream gas heritage is as a monopolist; it has little experience in competitive marketing. The current competitive environment in which Eni operates is characterized by volatile prices and margins of energy commodities, limited product differentiation, and complex relationships with state-owned companies and national agencies of the countries where hydrocarbon reserves are located (Cheung, A., 2025).

As commodity prices are beyond the Company's control, Eni's ability to remain competitive and profitable requires continuous focus on technological innovation, achieving efficiencies in operating costs, effective management of capital resources, and delivering valuable services to energy buyers. Eni's success will depend on securing access to new investment opportunities.

- *Green Investment Returns and Integration Challenges.* Eni's ambitious engagement in renewable energy (Plenitude), biorefining (Enilive), and carbon capture projects represents a significant challenge. This expansion will involve acquisitions and partnerships, with success dependent on realizing synergies from combining resources, developing new processes, and creating distribution channels. This may require time to develop, including retraining its workforce and recruiting for necessary new skills, and it could take longer than expected to achieve returns. The operating margins for low-carbon products and services may not be as high as those historically experienced in its oil and gas operations. As a result, challenges in developing these services could materially adversely affect Eni's future results of operations, cash flow, liquidity, business/financial prospects, shareholder returns, including dividends, the amount of funds available for stock repurchases, and the price of Eni's shares.
- *Digital Talent Gap and Workforce Transformation.* Eni faces a critical challenge in transforming its workforce to meet the demands of an increasingly digitalized and sustainable energy future. While the company has historically excelled in traditional oil and gas expertise, the rapid shift toward advanced technologies, renewable energy systems, and digital operations requires a fundamentally different talent profile. This challenge is particularly acute as Eni expands Plenitude and Enilive, which demand skills in AI, smart grid management, and advanced data analytics. The company must simultaneously manage multiple workforce transitions: upskilling its existing talent pool, attracting digital natives who might traditionally gravitate toward tech companies rather than energy firms, and maintaining crucial legacy knowledge (Lv, Yongjun, 2023).

The risk is amplified by intense competition for digital talent from traditional competitors and new market entrants, particularly in emerging fields like innovative energy management and renewable technology optimization. Eni's ability to build and maintain this next-generation

workforce will be crucial for executing its strategic renewable energy and digital transformation initiatives, especially given its ambitious targets for green business growth.

While these three strategic challenges are particularly pressing for Eni, they represent the tip of the iceberg. The broader scope of risks and uncertainties that Eni faces has been thoroughly analyzed in Chapter 2 "HIGH VOLTAGE RISK: DECODING ELECTRICITY ENERGY MARKET" specifically in section 2.2, "Risks in Energy Markets: Challenges and Uncertainties." From cybersecurity threats to regulatory compliance, from market volatility to geopolitical tensions - these challenges keep energy executives up at night and are worth contemplating before their morning espresso.

4.3.3 Exchange Risk Exposure in ENI's Business Model

In the complex landscape of global energy markets, ENI's exposure to market risk is a critical aspect of its financial profile, deeply intertwined with its core business operations across the hydrocarbon value chain. ENI must maintain its balance while facing the winds of commodity price fluctuations, interest rate risks, and foreign exchange. A single misstep could result in substantial losses that echo through its global operations.

The plot thickens when we consider ENI's business model a double-edged sword - while its integrated nature provides certain natural hedges, it also exposes the company to the full fury of volatile hydrocarbon prices in its core business. In a bold strategic move that might raise eyebrows among the risk-averse, ENI deliberately chooses not to hedge certain fundamental exposures, including its hydrocarbon production business and specific commodity risks like refining margins and portions of its gas supply portfolio (ENI Annual Report, 2024).

At the heart of ENI's risk profile lies a structural challenge: while its financial reporting is denominated in euros, its primary revenue-generating activities and costs speak the language of U.S. dollars. This

creates a natural currency mismatch that delves deeply into the company's financial architecture: any depreciation of the euro against the dollar increases the cost of imports in local currency terms, eroding profitability (European Commission, 2024).

ENI's global operational footprint amplifies the significance of this vulnerability; the company's upstream activities operate across multiple currency zones. The materiality of this exposure is evidenced in its 2023 risk metrics, where exchange rate Value at Risk (VaR) volatility ranges from a low of €0.04M to a high of €0.62M while maintaining an average of € 0.21M.

Energy contract structures amplify FX risks through payment delays of 30–70 days between invoicing and settlement. During this time, exchange rate fluctuations can significantly alter costs. Simulations have shown that more extended invoicing periods increase transaction costs linked to FX risk, leaving importers vulnerable to the depreciation of local currencies against the dollar, a trend made worse by the bargaining power weakness of energy-importing economies (Martinez Alvarez A., *et al.*, 2024).

During geopolitical and economic instability, the EUR/USD exchange rate fluctuates several percentage points within weeks. Macroeconomic dynamics and European Central Bank (ECB) policies worsen this scenario. Tighter monetary policies in the U.S. or looser ones in the Eurozone weaken the euro, increasing USD-denominated energy import costs. Inflationary pressures and changing regional economic conditions add to the complexity of managing FX risk, forcing energy companies to focus on solid risk mitigation strategies.

To address these multifaceted market risks, ENI implements a comprehensive derivative strategy across both organized markets (MTF and OTF) and over-the-counter platforms, their hedging portfolio as of December 31, 2023, includes currency swaps (€70M in assets against €168M in liabilities) and interest-currency swaps (€84M) (ENI Annual Report, 2024).

The company's approach to exchange risk addresses three distinct risk channels: economic risk arising from temporal gaps between transaction execution and contractual term definition, transactional risk from foreign currency-denominated trade and financing positions, and translation risk affecting consolidated financial statements.

The framework defined by Eni's policies and guidelines provides that the valuation and control of exchange currency risk are performed based on the maximum tolerable levels of risk exposure, which are defined in terms of the limits of stop loss, which express the maximum tolerable amount of losses associated with a specific portfolio of assets; the limits of revision strategy; and VaR measurements for the maximum potential portfolio loss.

Eni's advanced monitoring system is managed primarily through its subsidiary, Eni Global Energy Markets SpA, by employing sophisticated VaR methodologies based on variance/covariance simulation models with a 99% confidence level and a 20-day holding period. The company accurately tracks potential market value fluctuations over a 24-hour horizon. The effectiveness of this strategy is further evidenced by Eni's successful hedging of a substantial US dollar-denominated securities portfolio worth €2,562M, which generated positive exchange differences of €75M through fair value hedge relationships on US dollar-denominated bonds. This rigorous approach also contributed to a notable improvement in year-end VaR positions, declining from €0.34M in 2022 to €0.30M in 2023 (ENI Annual Report, 2023).

Taking our cue from Deloitte's "Optimizing the hedging strategy for oil and gas companies" (2017), it is interesting to analyze ENI's exchange risk management approach through the lens of Deloitte's comprehensive report on optimizing hedging strategies. While ENI has established a sophisticated risk monitoring framework with its VaR methodology and comprehensive derivative strategy, there are several areas where its approach could be strengthened.

The key challenge lies in what Deloitte identifies as a fundamental issue in the industry: "The evolution in accounting standards didn't always keep pace with innovation in hedging strategies and instruments, [causing] the dual objectives of cash flow protection and reported earnings protection [to] tend to be at cross purpose." ENI's sophisticated VaR monitoring system and derivative portfolio demonstrate strong operational risk management but show less clear integration with financial reporting objectives.

Specifically, ENI could enhance its approach by implementing Deloitte's recommendation to "designate USD-denominated short-term liabilities as a hedge against the USD-EUR valuation risk in inventory, thereby reflecting appropriately the underlying strategy of funding dollarized inventory with USD-denominated working capital borrowings." This would create a simultaneous and offsetting restatement of foreign currency liabilities and inventory valuation, thereby reducing earnings volatility.

As Deloitte points out, synchronizing USD borrowings servicing with dollarized earnings timing would better "balance between the cash flow, accounting, and regulatory objectives" while optimizing hedging costs. This temporal alignment seems to be an area where ENI's strategy could be refined.

I suggest using and developing the Risk Management Triangle approach, as it appears better suited to their risk profile and would provide a more comprehensive framework for managing their exposures. This framework emphasizes the critical interplay between risk mitigation, cost efficiency, and regulatory compliance. Incorporating an earnings-at-risk (EaR) framework could strengthen the integration of operational and financial objectives. Such a framework evaluates the potential variability in earnings due to market risks, enabling ENI better to assess the trade-offs between hedging costs and earnings protection.

In essence, there's still room to polish this gem. In today's turbulent energy markets, mastering the art of hedging could make the difference between riding the waves and being swept away by them!

Conclusion

In the contemporary global economic landscape, energy commodities have emerged as pivotal assets, with continuous access and price stability becoming paramount concerns for economic agents worldwide. The remarkable complexity of energy markets—with their varied price formation mechanisms and high-volatility contexts—necessitates risk mitigation approaches of extraordinary sophistication. Derivatives emerge as uniquely positioned instruments capable of addressing these multifaceted challenges with remarkable efficacy.

This research comprehensively examines derivative instruments within energy markets, elucidating their sophisticated architectural role in financial risk management. The intellectual discourse surrounding energy derivatives extends beyond conventional financial paradigms, positioning these instruments as strategic mechanisms designed to navigate the complex uncertainties in diverse market environments.

It is crucial to challenge prevalent misconceptions: derivatives are not fundamentally problematic tools but rather strategic instruments demanding nuanced understanding and precise implementation.

From an analytical perspective, the strategic advantages of derivatives are extensive: they facilitate precise price signaling, enable robust risk management, catalyze capital formation, provide volumetric risk hedging, and generate investment opportunities. Corporate practices reveal the dynamic complexities within hedging strategies, highlighting scenarios where delayed hedging might prove strategically more advantageous than continuous positional adjustments.

However, substantial implementation challenges exist. The complexity, potential for misinterpretation, high transactional costs, resource constraints, and stringent regulatory frameworks demand a critically informed and intellectually rigorous approach. This research deliberately challenges prevailing narratives that summarily demonize these financial mechanisms, demonstrating that perceived weaknesses often stem from incorrect evaluation or imprudent implementation rather than fundamental structural flaws.

This study proposes a comprehensive numerical analysis that systematically interrogates hedging strategies across diverse methodological landscapes to advance the understanding of these instruments. This analysis evaluates their effectiveness and profitability across multiple temporal horizons and varied energy commodity contexts while investigating alternative derivative strategies through sophisticated combinations of derivatives or strategically alternating financial instruments based on liquidity dynamics.

Derivatives in energy markets represent more than financial instruments; they are strategic mechanisms for navigating complex economic landscapes. Their intrinsic value resides not in the complete elimination of risk but in providing intelligent, adaptive frameworks capable of responding to the profound complexity of modern economic environments. Through this approach, researchers can develop increasingly robust and flexible risk management approaches that transform market uncertainties into manageable opportunities.

Bibliography

- AKYILDIRIM, E., CEPNI, O., MOLNÁR, P., & UDDIN, G. S. (2022). *Connectedness of energy markets around the world during the COVID-19 pandemic*. *Energy Economics*, 112, 106127. <https://doi.org/>
- ALEXANDRIDIS G., Z. CHEN, Y. ZENG, “Financial hedging and corporate investment”, *Journal of Corporate Finance*, Volume 67, April 2020, 101887. <https://doi.org/>
- ANGELETOS, G.-M. (2007). Uninsured idiosyncratic investment risk and aggregate saving. *Review of Economic Dynamics*, 10(1), 1–30.
- ARETZ, KEVIN, BARTRAM, SÖHNKE M., “Corporate Hedging and Shareholder Value”, Lancaster University Management School.
- ASH, J. S. (2008). *Energy supply, risk and justice: Regulatory strategies for an era of limited trust* (Working Paper 0807). University of Cambridge, Energy Policy Research Group. <https://www.jbs.cam.ac.uk/>
- ASSOCIAZIONE ITALIANA DI GROSSISTI DI ENERGIA E TRADER (AIGET). (2011, November 28). *Smart future e non solo smart grid*. Workshop, Milano, Italia.
- ASWATH DAMODARAN, “Applied corporate finance”, *Fourth edition*, Wiley, October 2014, ISBN: 978-1-118-91857-9.
- BAO, M., DING, Y., ZHOU, X., GUO, C., & SHAO, C. (2021). Risk assessment and management of electricity markets: A review with suggestions. *CSEE Journal of Power and Energy Systems*, 7(6), 1322–1333. <https://doi.org/>
- BECHERER D., “Rational hedging and valuation of integrated risks under constant absolute risk aversion”, 2003.
- BEVILACQUA, M., GRÜNEWALD, T., OVERLACK, S., ROLSER, O., SCHRUM, A., & THERKELSEN, C. (2024, January 16). *Global energy perspective 2023: Energy value pools outlook*. McKinsey & Company. <https://www.mckinsey.com/>
- BOHMANN, M. J., MICHAYLUK, D., & PATEL, V. (2019). Price discovery in commodity derivatives: Speculation or hedging? *Journal of Futures Markets*, 39(9), 1107–1121. <https://doi.org/>
- BROKER, T., DURR, D., & SMITH, M. (2019). Analysis of the global energy industry, climate change, and financial matters: The need for effective corporate governance. *International Journal of Corporate Governance*, 10(3-4), 185. <https://doi.org/>
- BUTNARIU A., FLORIN-ALEXANDRU, A. APETREI, “Mitigating financial risk by using hedging strategies”, *SEA Practical application of science*, Volume IV, Issue 16 (1/2018).
- CAPARRELLI F. (2001). *I Derivati*. McGraw-Hill.
- CAPUTO NASSETTI F. (2007). *Contratti derivati finanziari*. Egea. Milano.
- CASTRO A- Deloitte. *Optimizing hedging strategy for oil refining companies*. Retrieved from <https://www2.deloitte.com/>
- CASTRO, R., CLEMENTI, G. L., & MACDONALD, G. (2004). Investor protection, optimal incentives, and economic growth. *Quarterly Journal of Economics*, 119(4), 1131–1175.
- CASULA, L., & MASALA, G. (2022). *Electricity derivatives: An application to the futures Italian market*. *Empirical Economics*, 61(2), 637–666.
- CFA Institute. (2022). *User perspectives on financial instruments under IFRS*. Retrieved from <https://www.cfainstitute.org/>
- CHEUNG, A. (2025, January 9). *Five energy transition lessons for 2025*. BloombergNEF.
- CLIFFORD W. SMITH JR., “Managing corporate risk”, University of Rochester, *Handbook of corporate finance: empirical corporate finance*, Volume 1, North-Holland.
- CLIFFORD W. SMITH, R. M. STULZ, “The determinants of firm’s hedging policies”, *Article in Journal of Financial and Quantitative Analysis*, DOI: 10.2307/2330757 · Source: RePEc.

- CONEJO, A. J., BARINGO, L., KAZEMPOUR, S. J., & SIOSHANSI, R. (2018). *Optimization models in electricity markets*. Cambridge University Press. Retrieved from <https://www.cambridge.org/>
- DAMODARAN, ASWATH. "Value and Risk: Beyond Betas", *Financial Analysts Journal*, vol. 61, no. 2, 2005, pp. 38–43. *JSTOR*.
- DENG, S. J., & OREN, S. S. (2006). Electricity derivatives and risk management. *Energy*, 31(6-7), 940–953.
- DUFFY J., L. PORRE, "Hedging: A Hot Commodity Right Now - Performance Improvement," Deloitte, 2020
- ENI. (2024.). *Financial results and reports*. Retrieved from <https://www.eni.com/>
- ERNST & YOUNG, Financial reporting developments – Derivatives and hedging. *EY Insights*. Retrieved from <https://www.ey.com/>
- ESPAS, *European strategy and policy analysis system*, "2030, Tendenze globali fino al 2030: l'UE sarà in grado di affrontare le sfide future?", 2024.
- EUROPEAN COMMISSION. (2018). *Commission Recommendation of 5.12.2018 on the international role of the euro in the field of energy (SWD(2018) 483 final)*. <https://ec.europa.eu/>
- EUROPEAN COMMISSION. (2018). *Communication from the Commission to the European Parliament, the European Council (Euro Summit), the Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions: Towards a stronger international role of the euro (COM(2018) 796 final)*. <https://eur-lex.europa.eu/>
- EUROPEAN COMMISSION. (2021). *Commission Staff Working Document: Promoting the international role of the euro in the field of energy (Accompanying the document Commission Recommendation on the international role of the euro in the field of energy)* <https://ec.europa.eu/>
- EUROPEAN COMMISSION. *Commission staff working paper*, Key facts and figures on the external dimension of the EU energy policy. 2024
- EUROPEAN COMMISSION. Communication from the commission to the European parliament and the council. *European energy security strategy*. 2020. SWD (2020)
- EUROPEAN COMMISSION. *Roadmap of the EU-Russia energy cooperation until 2050*.
- EUROPEAN COMMISSION. *Market analysis – Energy*. Retrieved from <https://energy.ec.europa.eu/>
- EUROPEAN EXTERNAL ACTION SERVICE. (n.d.). *Europe's energy balancing act*. Retrieved from <https://www.eeas.europa.eu/eeas/>
- EUROSTAT. *Energy imports dependency*, online data code: <https://ec.europa.eu/>
- EY Inside - ERNST & YOUNG LLP. (2024, July). *Financial reporting developments: A comprehensive guide – Derivatives and hedging*. <https://www.ey.com/>
- FALBO, P., FELLETTI, D., & STEFANI, S. (2014). *Electricity futures*. In *World Scientific Handbook of Futures Markets* (Chap. 18, pp. 635–xxx). World Scientific.
- FLORACKIS C., A. KANAS, A. KOSTAKIS, S. SAINANI, "Idiosyncratic risk, risk-taking incentives and the relation between managerial ownership and firm value", *European Journal of Operational Research* 283 (2020), 748-766.
- FRESTAD, D. (2012). Liquidity and dirty hedging in the Nordic electricity market. *Energy Economics*, 34(5), 1341–1355. <https://doi.org/>
- FUSARO, P. C. (2001). *Energy risk management: Hedging strategies and instruments for the international energy markets* (1st ed.). McGraw-Hill.
- GESTORE DEI MERCATI ENERGETICI (GME). *Italian power market operator*. Retrieved from <https://gme.mercatoelettrico.org/en-us/>
- GESTORE DEI MERCATI ENERGETICI. *Vademecum della borsa elettrica*, 2025, <https://www.mercatoelettrico.org/>
- GORDON M. BODNAR, C. CONSOLANDI, G. GABBI, A. JAISWAL-DALE, "A survey on risk management and usage of derivatives by non-financial Italian Firms", working paper, *center for applied research in finance*, Bocconi, 07/08.

- GUPTA A., C. REISINGER, A. WHITLEY, “Model uncertainty and its impact on derivative pricing”, University of Oxford.
- HALKOS, G., & TSIRIVIS, A. S. (2019). Energy commodities: A review of optimal hedging strategies. *Energies*, 12(20), 3979. <https://doi.org/>
- HAN, C., HILGER, H., MIX, E., RYDIN GORJÃO, L., & OTHERS. (2021, December). *Complexity and persistence of price time series of the European electricity spot market*. arXiv. <https://doi.org/>
- HARRISON, M., & DAVIS, P.- CFA Institute Enterprising Investor. (2018, June 12). *In practice summary: Reassessing the drivers of commodity futures returns*. <https://blogs.cfainstitute.org/>
- HILL, C. W. L., & JONES, G. R. (2008). *Essentials of Strategic Management* (3rd ed.). Mason, OH: South-Western Cengage Learning
- HOROBET, A. A. DRAGHICI, L. G. CONSTANTIN, “Hedging currency risk in European stock markets: evidence from the current financial crisis”, *Banking, accounting and financial systems from 21st century perspective*.
- HULL J.C. (2006). *Options, Futures, and other derivatives*. Pearson. USA.
- IEA (2024), World Energy Investment 2024, IEA, Paris <https://www.iea.org/> Licence: CC BY 4.0
- INTERNATIONAL ENERGY AGENCY. (IEA) (2024). *World Energy Outlook 2024*. Retrieved from <https://www.iea.org/>
- ITALIAN MINISTRY OF ECONOMIC DEVELOPMENT. (2018). *National energy strategy: For a more competitive and sustainable energy*. Retrieved from <https://www.mimit.gov.it/>
- JOSHI, N.- CFA Institute (2013, May). *A new perspective on the validity of the CAPM: Still alive and well (Digest Summary)*. <https://rpc.cfainstitute.org/research/>
- KATZENSTEIN J. AND STEPHEN NELSON, “Worlds in Collision: uncertainty and risk in hard times”, *Stato e Mercato*, 2011, issue 3, 369-394.
- KEMPER, A., SCHMECK, M. D., & BALCI, A. K. (2022). The market price of risk for delivery periods: Pricing swaps and options in electricity markets. *Energy Economics*, 113, 106221. <https://doi.org/>
- KHODADADI, A. (2024, November). *Contracts for difference (CfDs) in the energy transition: Balancing market efficiency and risk mitigation* (OIES Paper EL No. 56). Oxford Institute for Energy Studies. <https://www.oxfordenergy.org/>
- LADO-SESTAYO, R., DE LLANO-PAZ, F., VIVEL-BÚA, M., & MARTÍNEZ-SALGUEIRO, A. (2023). Commodity exposure in the eurozone: How EU energy security is conditioned by the Euro. *Energy*, 277, 127528. <https://doi.org/>
- LEROY, STEPHEN F., AND LARRY D. SINGELL. “Knight on Risk and Uncertainty.” *Journal of Political Economy*, vol. 95, no. 2, 1987, pp. 394–406. *JSTOR*, www.jstor.org/stable/1832078.
- LIU, P., VEDENOV, D., & POWER, G. J. (2017). Is hedging the crack spread no longer all it's cracked up to be? *Energy Economics*, 63, 31–40. <https://doi.org/>
- LV, Y. (2023). Transitioning to sustainable energy: Opportunities, challenges, and the potential of blockchain technology. *Frontiers in Energy Research*, 11. <https://doi.org/10.3389/fenrg.2023.1258044>
- MARTINEZ ALVAREZ J., S. FERNANDEZ-VAZQUEZ, S. V. MACEDO, A. ORTEGA-ANDRADE, “Commodity exposure in the eurozone: How EU energy security is conditioned by the Euro”, *Journal of Political Economy*
- MARTINEZ ALVAREZ, J., FERNANDEZ-VAZQUEZ, S., VARGAS MACEDO, S., & ORTEGA-ANDRADE, A. (2024). Enhancing energy security and efficiency through a regional integration policy: The case of the Southern Cone. *Energy Policy*, 195, 114384. <https://doi.org/>
- MCKINSEY & COMPANY. *Global energy perspective*. Retrieved from <https://www.mckinsey.com/>
- MCQUARRIE, E. F.- CFA Institute Enterprising Investor. (2024, April 24). *What price risk? Unpacking the equity risk premium*. <https://blogs.cfainstitute.org/investor/2024/>

- MICHELACCI, C., & SCHIVARDI, F. (2008, July 10). *Does idiosyncratic business risk matter?* CEMFI; University of Cagliari and EIEF. Retrieved from <https://www.bancaditalia.it/>
- MULLER, A., & VERSCHOOR, W. F. C. (2006). Foreign exchange risk exposure: Survey and suggestions. *Journal of Multinational Financial Management*, 16(4), 385–410. <https://doi.org/10.1016/j.mulfin.2005.09.001>
- NADARAJAH, S., & SECOMANDI, N. (2023). A review of the operations literature on real options in energy. *European Journal of Operational Research*, 309(2), 469–487. <https://doi.org/>
- NESTICÒ, A., HE, S., DE MARE, G., et al. (2018). *Cost-Benefit Analysis and Investment Risk Assessment: Threshold Values According to the ALARP Logic*.
- NOVALES, A., ALVARO CHAMIZO, “Splitting credit risk into systematic, sectorial and idiosyncratic components”, *Journal of risk and financial management*, 2 August 2019.
- OECD. (2021). *Global insurance market trends 2021*. Organisation for Economic Co-operation and Development. <https://www.oecd.org/>
- PEAKE, C. F.- CFA Institute Journal Review. (2005, May 1). *The capital asset pricing model: Theory and evidence (Digest Summary)*. <https://rpc.cfainstitute.org/research/>
- PHAM, C. D., & LE, P. T. (2020). *Is estimating the capital asset pricing model using monthly and short-horizon data a good choice?* *Heliyon*, 6(7), e04339. <https://doi.org/>
- POLLITT, M. (2023). *Electricity markets in transition: A proposal for reforming European electricity markets*. CEPR VoxEU. Retrieved from <https://cepr.org/>
- PWC. (2024.). *Power and utilities trends*. Retrieved from <https://www.pwc.com/>
- PWC. (n.d.). *Energy sector insights*. Retrieved from <https://www.pwc.de/en/energy-sector.html>
- PWC. *The energy industry balances risks and rewards as it embraces the energy transition*. <https://www.pwc.com/>
- REEVES, M., KOEHN, N., NEELEY, T., & BERINATO, S.- HARVARD BUSINESS REVIEW, (2021). *Coronavirus: Leadership and recovery: The insights you need from Harvard Business Review*. Harvard Business Review Press. <https://books.google.it/>
- REINHARDT, F., & VIKLUND, C. (2017). Energy strategy for the C-suite. *Harvard Business Review*. Retrieved from <https://hbr.org/2017/01/energy-strategy-for-the-c-suite>
- SMITH, A. D., FUMO, N., & MAGO, P. J. (2011). Spark spread – A screening parameter for combined heating and power systems. *Applied Energy*, 88(5), 1494–1499. <https://doi.org/>
- SURYANARAYANA, K., SANJEEVIKUMAR, P., & NAGESH PRABHU. (2021). *Advances in Renewable Energy and Electric Vehicles*.
- TERNA S.P.A. (2024). *Integrated Report 2023*
- THÉATE, T., SUTERA, A., & ERNST, D. (2023). Matching of everyday power supply and demand with dynamic pricing: Problem formalisation and conceptual analysis. *Energy Reports*, <https://doi.org/>
- UNIVERSITY OF CAMBRIDGE. (2023). The study finds that electricity prices across Europe will stabilise if the 2030 renewable energy targets are met. Retrieved from <https://www.cam.ac.uk/research/>
- VALDÉS, L., & CALDENTEY, R. (2024). *Financial hedging of operational risk constraints: A general framework*. *Production and Operations Management*, 33(9), 1912–1930.
- WERNER, D. (2014). *Electricity market price volatility: The importance of ramping costs*. Paper presented at the 2014 Annual Meeting of the Agricultural and Applied Economics Association, Minneapolis, MN
- ZHILKINA, Y., & AKHMETSHIN, A. (2019, January). *Risks in the energy sector: The analysis of management practices in the electricity market*. E3S Web of Conferences, 124, 05051