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FORRSight

Interview with Gerhard Stahl on Leadership and Risk Management

Bridging Finance and Risk: CFOs & CROs in Sync

Ron Dembo on the Evolution of Data

Why Stochastic Data is Key to Measuring Climate Risk

Kirat Singh Explains New Dynamics in Energy Trading

Mastering Risk in a World of Exotic Instruments

Navigating the Next Frontier

Enterprise Risk Management in Today's Energy Markets

FORRS

Content

Dear Readers,

In recent years, the energy sector is facing global upheaval, driven by political shifts worldwide and rapid technological changes in both generation and consumption.

Societal pressures to decarbonize industry, along with digital transformation and AI, are adding further momentum to this rapid development. Moreover, the eruptive changes in global energy supply due to geopolitical shocks and changing international trade relations are pushing "energy" to the top of the agenda for every major European economy. All those developments are impacting energy markets enormously, reshaping risks across the entire energy trading value chain.

The surge in uncertainty and the growing number of influencing factors demand more than just a change in existing risk management. Instead, they require a transformation towards a more interconnected and resilient risk framework, plus advanced methods to guide tomorrow's decisions.

The long-standing shift from price-taking to risk-taking has progressed, yet there is a need for even stronger guardrails to navigate future risks. For example, the growing number of prosumers in retail portfolios poses new challenges for precise forecasting, creating physical volume risk. At the same time, supply flexibility as a hedge (such as BESS) requires intraday and even real-time risk management capabilities more than ever. Strategies that proved successful in the past may no longer guarantee future outcomes. Proactive portfolio management across the entire trading value chain, combined with disciplined risk oversight, is essential to remain competitive.

This edition of FORRSight Magazine advocates forward-looking and preventive risk-thinking, designed to limit substantial losses and preserve resilience in turbulent markets.In a landscape where risk-adjusted decisions matter more than ever, organizations that couple agility with resilient risk controls will be better positioned to master increasing uncertainty and high volatility. It is imperative to embed resilient and new risk controls into strategy, governance, and operations, so that value creation remains sustainable, even in times of structural transformation in the energy market.

Martin Hiller
Partner at FORRS

Dear Friends,

As innovative products and new technologies trigger a transformation of energy markets at ever increasing speeds, risk management must evolve from a static measurement tool to an organization-shaping concept.

It is apparent that risk numbers based on historical data or traditional stress scenarios fail to capture the disruptive nature of contemporary changes. Take, for example, the systemic risk cascade triggered by the 2022 energy crisis. As gas flows to Europe collapsed, the market experienced unprecedented price spikes and extreme volatility. Almost instantly, standard hedging procedures carrying large open positions required a sharp increase in collateral raising – almost tenfold within days – which created liquidity stress even for otherwise solvent companies.

Another risk layer is generated by the reliance on AI for trading and risk monitoring. Despite the proactive nature of AI-driven algorithms, their potential herd behavior may trigger simultaneous large trades, which increase volatility and trigger margin calls. Thus, AI model risk, together with cybersecurity threats that can manipulate data or distort predictions, need to be integrated within a risk management framework. The ability to explain these algorithms is key to active risk management. In addition, the reason for trading or establishing hedge positions, together with the relevant implication must be understood.

Along with market innovations and digital transformation, risk management faces climate uncertainty and global disruptions. Clearly, just trying to manage price and physical risks will be insufficient. Instead, risk management must be embedded in every aspect of the value chain and all business activities.

Proactive leadership needs to establish and enforce a company-wide risk culture. This will lead to disciplined decision-making that will establish the resilience needed to face the multiple structural challenges of current times.

Prof. Dr. Rüdiger Kiesel
Professor for Energy Trading and Financial Services
at the University of Duisburg-Essen

Technical University of Munich

PROF. DR. SVETLANA IKONNIKOVA
Professor for Resource Economics

Earthquakes and Tectonic Shifts in Energy Markets

Digitalization, AI, decentralization, and decarbonization are fundamentally reshaping energy markets, triggering structural breaks in prices, volatility, and correlations. Risk leaders must move beyond cycle-based, history-biased models toward multi-horizon approaches that incorporate geopolitical and climate risks, as well as AI-driven spillovers.

The production, trade, and infrastructure of energy across power generation, heat, fuels, and natural resources have long been fundamental drivers of economic growth. However, over the past decade, exposure to energy market shocks has become broader, faster-moving, and tightly interlinked with the rest of the economy.

Energy risk is no longer confined to utilities or heavy industries. It is now affecting households, supply chains, financial markets, and public budgets in every major economy. This article outlines the **risks to watch, questions to consider,** and **decisions to make** for risk managers, traders, and corporate leaders.

Three Tectonic Shifts

1. Digital Transformation and AI

The first major structural shift is digital transformation. Energy systems have moved from analog and paper-based processes to digital records, automated workflows, and data-driven decision-making. Smart meters, real-time sensors, and cloud-based platforms have dramatically increased the volume and granularity of operational and market data.

Building on this foundation, artificial intelligence (AI) has emerged as a more powerful wave within digitalization. Over only a few years, particularly in the last 12–24 months, AI applications in forecasting, dispatch optimization, algorithmic trading, and risk analytics have moved from pilot projects into daily operations across many energy and trading organizations. This creates clear advantages for firms that can effectively deploy and govern these tools. However, AI also creates new risks, including model uncertainty, feedback loops in algorithmic markets, cyber vulnerabilities, and the danger of overreliance on systems that learn from non-stationary data.

2. Decentralization and Democratization

The second shift is the decentralization and democratization of the power system. Technological advances have enabled households, communities, and industrial consumers to become active participants in energy supply, rather than passive off-takers. Rooftop solar, small-scale wind turbines, behind-the-meter batteries, and demand response programs now allow consumers to generate, store, and actively manage their own energy use.

In many regions, local energy platforms and community schemes facilitate peer-to-peer trading, shared assets, or aggregation of small units into market-relevant portfolios. While each installation is local, their aggregate impact is not. Distributed assets now influence wholesale price formation, grid stability, and cross-border flows. For traders and risk managers, this proliferation of small, data-intensive actors complicates load forecasting, increases the importance of locational risks, and changes the patterns of intraday and seasonal price dynamics.

3. Sustainability, Regulation, and Decarbonization

The third major force reshaping energy markets is the sustainability and climate policy agenda. Decarbonization targets and environmental regulations have evolved from niche constraints into core principles of energy and industrial policy. In the European Union, for example, the “Fit for 55” package aims to cut net greenhouse gas emissions by 55% by 2030, through a comprehensive overhaul of emissions trading, carbon border adjustment, energy taxation, efficiency standards, and renewable targets.

Policies like this affect every stage of the energy value chain, production, processing, transport, and consumption, whether energy is used directly as fuel, converted into electricity, or embedded in materials.

Regulatory measures introduce explicit price signals, caps, and incentives that, when combined with digitalization and decentralization, lead to complex, path-dependent market behaviors. For firms, this means that compliance, carbon exposure, and long-term policy credibility now directly influence asset valuation, hedging strategies, and capital allocation.

Shaken Fundamentals: New Patterns in Demand and Supply Behavior

These three tectonic shifts are not just adding layers to existing markets. They are altering the underlying behavioral patterns on both the demand and supply side. As opportunities, constraints, and objectives change, the energy system exhibits correlation patterns in trends, volatility regimes, and correlation structures that challenge traditional models and heuristics.

On the demand side, households, commercial users, and industrial consumers are increasingly forced to re-evaluate their options across multiple dimensions. These include:

- Fossil fuels versus electrification in heating, mobility, and industrial processes
- Grid-supplied electricity versus local self-generation and storage
- Long-term contracts and delegated portfolio management versus direct participation in wholesale or local platforms

Each of these choices is shaped by technology costs, regulatory incentives, and digital access to information and markets. This results in greater optionality and flexibility in demand, along with greater complexity in forecasting load profiles and price responses.

On the supply side, traditional beliefs about the optimal energy mix and technology portfolio have changed. The COVID19 pandemic and the Russian invasion of Ukraine exposed vulnerabilities in gas supply, pipeline infrastructure, and global commodity chains, pushing security of supply and diversification back to the top of the agenda. Market participants must plan for daily and weekly balancing risks, as well as for seasonal and multiyear shocks.

In this context, commercial storage, both short-term and seasonal, has gained strategic importance, serving not only as a tool for intraday arbitrage but also as insurance against prolonged disruptions. At the same time, limitations on infrastructure and access to critical materials such as copper, aluminum, and lithium have become essential risk factors for power grids, battery deployment, and renewable expansion. These constraints shape the speed, cost, and geographic distribution of the energy transition.

What emerges is a risk landscape that is more volatile, more interconnected, and more strongly influenced by forces outside of traditional supply and demand. Weather patterns and fuel prices still matter, but they now interact with technology adoption, regulatory change, infrastructure bottlenecks, and geopolitics in ways that make simple extrapolation from history increasingly unreliable.

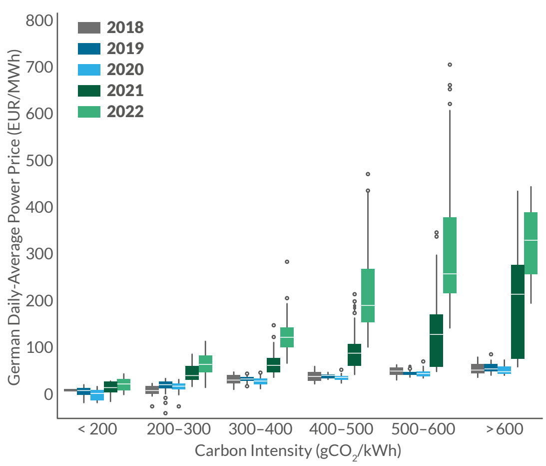
For energy companies, traders, and end users, this means that risk management can no longer focus solely on short-term price fluctuations. It requires multi-horizon approaches that integrate:

- Physical flexibility (generation, demand response, storage)
- Contractual optionality (structured products, long-term offtake, capacity rights)
- Advanced analytics and AI-enabled monitoring
- Scenario-based assessment of structural shifts in policy, technology, and geopolitics

In other words, energy markets are undergoing tectonic changes, and risk management frameworks must evolve from managing cycles to managing structural transformation.

Literature

Madadkhani, Shiva and Ikonnikova, Svetlana, Regime Detection in Day-Ahead Power Markets: Implications for Electricity Price–Emissions Dynamics. Available at SSRN



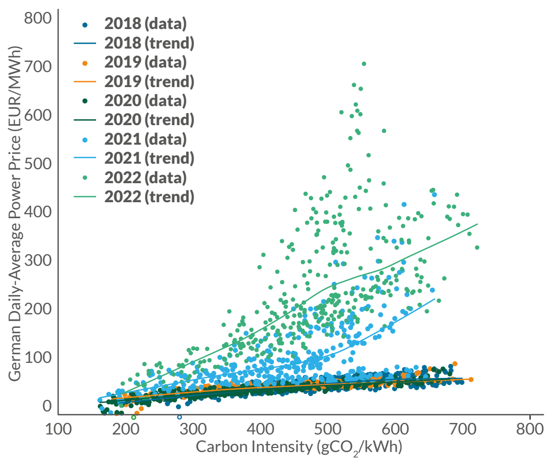


Figure 1: Power Prices and Carbon Intensity in the German Electricity Market from 2018 to 2022. (Graphics modified from Madadkhani & Ikonnikova, 2025)

Market Whiplash: Turning Risk into Resilience in Energy Trading

While today's energy markets have been rocked by unprecedented volatility, from the COVID19 pandemic to the Russia-Ukraine war, these disruptions have also accelerated innovation and transformation. For Europe and Germany, the lesson is clear. Robust Enterprise Risk Management (ERM) is more than just protection – it is a strategic enabler of growth and competitiveness. By adopting advanced risk management methodologies, integrated systems, and resilient governance, energy traders can turn volatility into long-term success.

Global and European Energy Market Dynamics

The energy sector stands at an inflection point. Three converging forces are fundamentally reshaping how energy is produced, distributed, and consumed worldwide:

1. Decarbonization is driving a rapid shift from fossil fuels to renewables and low carbon alternatives, creating new opportunities and disrupting traditional markets.
2. Digitalization is transforming energy systems through integrated, end-to-end value chain automation, real-time monitoring, and AI, enabling smarter, more efficient operations across supply chains.
3. Decentralization is empowering consumers, businesses, and communities through distributed generation, storage, and peer-to-peer trading, turning them into active market participants.

Europe's ambitious climate goals and its leading role in renewable integration, infrastructure modernization, and energy security underline the scale of this transition. Energy supply chains and market structures are being fundamentally reshaped, and organizations that adapt to these shifts will lead the next decade.

Liberalized markets encourage innovation and competition. Integrated risk strategies help companies manage volatility and integrate new products such as Power Purchase Agreements (PPAs), structured products, and Battery Energy Storage Systems (BESS) into their portfolios.

The interplay between physical and financial markets, once a challenge, is now a catalyst for smarter, more active trading. Consequently, ERM is evolving from a reactive function into a proactive discipline. Once embedded as a forward-looking, value-creating function throughout the enterprise, risk management allows organizations to scale new products and value pools within their portfolios, while staying within their risk tolerances.

Learning from Recent Crises

The past five years have tested both the resilience and the adaptability of energy markets. During the COVID-19 pandemic, demand shocks and price swings exposed the limits of static risk models and highlighted the need for dynamic approaches. As economies reopened, companies with flexible strategies seized opportunities and strengthened their positions.

The Russia-Ukraine war marked a turning point for European energy security. Germany's rapid diversification away from Russian gas highlighted the sector's ability to innovate under pressure, including accelerating LNG infrastructure, expanding renewables, and reinforcing proactive risk management. These experiences underline a powerful truth: volatility can drive progress when managed effectively, and risk is now central to both operational and strategic decision making.

A key lesson learned is that the spectrum of relevant risk factors is far broader than anticipated. For energy trading companies, activities once considered routine, such as onboarding customers or counterparties, extending credit, and funding transactions, suddenly became more complex and resource-intensive. Entering new markets, such as short-term or algorithmic trading, requires much more automation and technology infrastructure.

Future winners will be those that account for this wider range of risks and equip themselves with robust technology setups for new markets.

Beyond Market Risk: A Holistic Framework

Traditional risk management in energy markets focused on market risk. Today, success requires a holistic view that covers geopolitical, climate, liquidity, credit, and operational risks.

Geopolitics reshapes supply chains overnight. Liquidity demands agile funding strategies. Climate risks require scenario analysis, stress-testing, and new hedging strategies. Credit exposures call for rigorous counterparty and collateral management. And operational risks, from cyber threats to system outages, depend on secure, reliable platforms.

These risks are all interlinked, so they must be managed with integrated methodologies, real-time analytics, and governance structures that enable rapid, coordinated responses. A fragmented approach is no longer viable. Only a unified, enterprise-wide framework can deliver resilience and agility.

The Imperative for Advanced Methodologies and Systems

Modern ERM is proactive and performance driven. Scenario analysis and stress testing prepare firms for extreme but plausible events, while real-time analytics powered by AI provide actionable insights. Integrated platforms break down silos, so market, credit, and operational risks are managed cohesively, and strong governance delivers clarity, transparency, and speed.

Technology is the key enabler. Automated controls, dynamic margining tools, and intelligent dashboards empower decision makers to act swiftly and strategically. The ability to seamlessly integrate new data sources, models, and processes is becoming a critical differentiator in an increasingly competitive market.

Building Resilient Systems for the Future

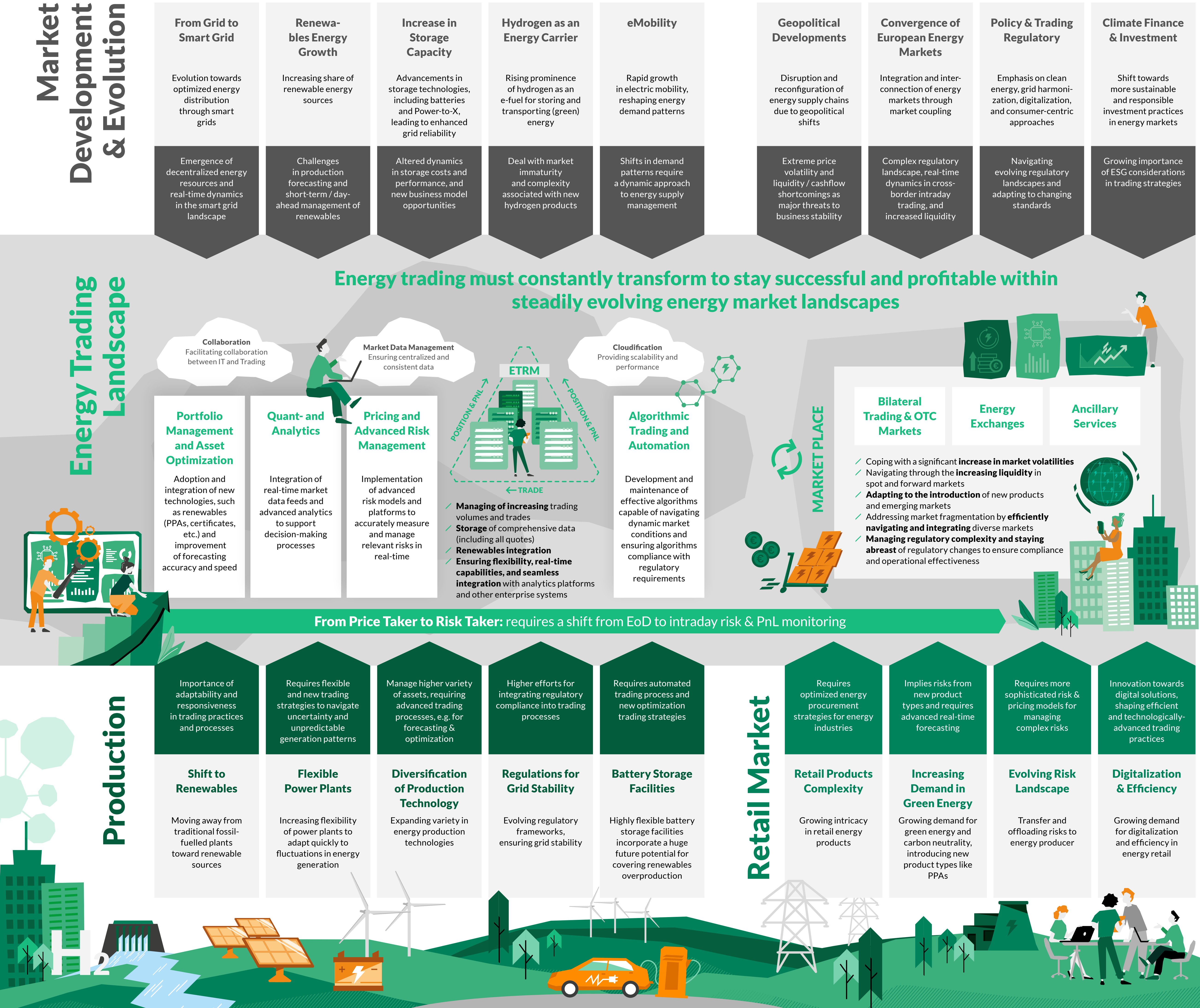
Resilience is quickly turning into a core capability. Systems must handle high transaction volumes, deliver accurate data, withstand cyber threats, and adapt flexibly to new products and regulations. As portfolios add renewables, complex PPAs, and carbon instruments, risk platforms must evolve to capture new exposures and valuation complexities.

These enhancements unlock efficiencies and create a competitive edge. Organizations that invest in scalable architectures and advanced automation will mitigate risks, while accelerating time-to-market for new products and strategies.

Conclusion: From Risk to Advantage

As the world advances towards decarbonization and digitalization, energy markets remain dynamic. For energy traders, ERM has become a strategic differentiator. By investing in advanced methodologies, resilient systems, and strong governance, firms can transform volatility into value and position themselves as leaders in the energy transition.

The New Energy Trading Landscape: Keeping Pace with Recent Advancements



As the energy landscape evolves, fast adaptability is becoming even more essential for success. Three major forces are currently shaping the energy trading landscape: **Market Evolution, Retail Transformation, and Production Progression**.

These forces collectively redefine trading practices, requiring organizations to quickly adapt to new challenges and seize emerging opportunities.

Energy trading is evolving beyond traditional methods, and not only traders need to adapt to these challenges. As trading becomes increasingly sophisticated, risk management practices must take the next steps quickly. More exotic products require advanced valuation and risk measurement. The increased pace of trading and reduced lead times make frequent risk assessment essential to stay in control in the face of market volatility. Success in this changing playing field is determined by agile, automated, and highly technological approaches to modern risk management.

This FORRS's infographic takes a deep look into the rapidly evolving energy trading landscape. It explores how advancements, such as real-time forecasting, sophisticated risk models, and innovative Energy Trading and Risk Management (ETRM) systems are reshaping the industry. Key trends, such as the rise of inflexible renewables, the impact of geopolitics, and the surge in green energy products, are highlighted.

Discover how energy professionals like you can turn volatility into opportunity by adopting innovative approaches and embracing digital transformation. This shift is vital for thriving in a market defined by rapid change, increasing complexity, and unprecedented opportunities.

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Market Trends: New Drivers for Higher Demand in Risk Management

Anyone who still thinks that risk management in energy trading is primarily about matching long-term positions against a stable book should think again. The recent energy transition has altered the physics of the market. Speed and volatility are now the new constants. Yet, while trading desks are upgrading their arsenals, risk methodologies often lag behind, with serious consequences.

The Liquidity Trap: When Profitability Does Not Protect Against Insolvency

The energy crisis taught us a brutal lesson: Solvency does not equal liquidity. In the "old world", market risk was mostly a Profit and Loss (PnL) issue. Today, driven by extreme volatility, market risk impacts cash flow directly.

The mechanism is merciless: If prices explode, clearinghouses and exchanges demand immediate initial and variation margins. Even economically sensible hedges, such as selling electricity forward against one's own generation, become deadly traps. While the power plant theoretically gains value, the company bleeds out liquidity because hedging profits are only realized upon delivery, whereas margins are due now.

Therefore, risk management must no longer view liquidity in isolation. The solution lies in integration. Market movements must be translated directly into cash effects. Thus, better metrics are needed, such as liquidity at risk, that simulate: "How much cash must be posted tomorrow morning if the market moves 20% in the wrong direction?". This is analogous to banking ratios like Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR). Anyone calculating stress tests solely on Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) while ignoring the liquidity line is flying blind.

Figure 1: Risk Dimensions of the Future Energy Trader

Rethinking Credit Risk: Why Limits Are Yesterday's News

The classic credit system, "Partner A has a limit of 10 million euros", stems from an era of stable prices and is dangerously naive today. In a volatile market, replacement risk fluctuates massively. If a counterparty defaults, the position must be covered anew in the market, usually when prices are extremely unfavorable (wrong-way risk).

Those who only look at the current Mark-to-Market (MtM) value drastically underestimate the risk. More relevant is the Potential Future Exposure (PFE), which highlights where the value of the deal could stand in the future if the partner defaults.

To reflect this risk correctly, there is no way around Credit Valuation Adjustment (CVA), which is a well-known term from banking. CVA is nothing other than pricing the probability of default directly into the deal.

Specifically, this means that a deal with a counterparty with a weak credit rating must have a different price than one with a top-rated player. Introducing CVA often hurts sales, but it is necessary to avoid taking hidden risks onto the books that are not covered by margins in a crisis.

Model Risk: The Illusion of the Average Price

The asset class of renewables and storage forces a radical break with traditional models. A wind farm cannot be valued like a gas power plant because it has a volume risk. If the wind does not blow, the highest price is useless.

Worse still is the cannibalization effect. If all wind turbines produce simultaneously, the price often crashes through the floor. Here, anyone valuing assets with simple average prices (baseload) is fooling themselves. One must model the Capture Rate – a metric showing how much the asset's specific earnings deviate from the standard baseload price. This requires stochastic models that cleanly map the correlation between "high wind" and "low price".

It gets even more complex with battery storage. Its value lies not in continuous operation, but in optionality, the ability to flexibly utilize volatility peaks (spreads). Conventional discounted cash flow models fall short here. To determine the value of storage, complex optimization algorithms are needed that simulate thousands of price paths. Ignoring these model risks means making investments based on phantom numbers.

Operational Risk: Speed Kills

With the shift to intraday and algorithmic trading, the nature of operational risk changes fundamentally. Where a trader could correct a typo in seconds, today, the algorithm decides in milliseconds. A wrong parameter ("fat finger") or a logical error in the code can lead to an order being executed thousands of times before a human has even refreshed the screen. Such "runaway algos" can destroy a year's profit within minutes.

Therefore, the focus must shift away from manual "four-eyes" principles toward hard IT control mechanisms. Kill switches that immediately stop trading in case of anomalies and automated pre-trade checks are indispensable. Likewise, governance becomes a mandatory exercise, where no algorithm may go to market without rigorous backtesting. One must be able to historically prove how the code would have behaved in stress phases.

In the age of machines, operational risk is no longer a "back-office topic", but a question of IT architecture and system stability.

The Implementation Headache: Where Theory Meets IT Reality

Designing fancy risk metrics on a whiteboard is one part. The real headache starts when trying to force those ideas into an IT landscape that was not built for speed. In most energy companies, the infrastructure is not a sleek machine but rather a patchwork of legacy ETRM systems and fragile Excel sheets with VBA macros.

One huge obstacle is data fragmentation. To see liquidity risk, three isolated worlds must be stitched together:

1. Open trades in the ETRM
2. Actual cash position in the treasury system
3. Live margin calls coming from brokers

In the real world, these systems rarely talk to each other. They sit in silence until a nightly batch job runs. The result is trying to navigate a volatile morning market using a map drawn last night.

This creates a dangerous intraday blind spot. We are not even talking about the need for high-frequency, millisecond-perfect calculations here. The frustration is far more basic. Most legacy systems are incredibly rigid. They were designed to close the books exactly once, at night.

Conclusion:

Looking at the four outlined pain points, from the liquidity trap to the algorithmic black box, makes one thing clear: The transformation from a classic utility to a technology-driven trader is not an option, but a condition for survival. However, those who view these challenges merely as a defensive compulsory exercise fail to recognize the enormous potential of the new risk world.

Here, the circle closes back to the introduction. In a market characterized by intraday speed and extreme volatility, the winner is not the one with the most assets, but the one with the best control. Excellent risk management transforms from a pure cost factor into a decisive competitive advantage.

Transformation of Risk Management – From Price Taker to Risk Taker

The energy industry is undergoing a transformative phase, where effective risk management (RM) is essential for navigating challenges and achieving success. This article explores the dynamic landscape of RM, emphasizing its vital role and the necessity for continuous enhancement.

In energy trading companies, RM is increasingly under scrutiny, particularly following events like the German energy crisis and "Dunkelflaute" periods. These incidents have driven management to reevaluate their RM strategies' readiness for future challenges. To succeed, energy trading companies must align their RM practices with their business objectives.

Status of Risk Management

Today, RM practices in energy markets vary significantly, from basic approaches to those on par with financial institutions' standards. At the fundamental level, RM involves simple metrics like Value at Risk (VaR) for assessing market risk, often using manual Excel reporting. This approach typically uses historical data, at best from the previous day's end. More advanced firms utilize databases to enhance metric calculations and improve reporting timeliness, yet they often lack capabilities for real-time intraday risk decisions. To bridge this gap, some companies adopt dynamic strategies with near-real-time and event-driven reporting, leveraging semi-automated software or coding languages like Python. At the advanced end, a wide array of risk metrics, including credit, liquidity, and operational risks, undergo rigorous evaluation and audits. Here, RM is an integral part of business strategy, focusing on risk-adjusted returns and suitable risk capital allocation, elevating energy trading companies' RM to that of financial institutions.

Tackling Energy Market Challenges

An effective RM framework should identify, measure, monitor, and mitigate risks to prevent financial losses and existential threats. Trading organizations face numerous external and internal risks from both anticipated and unforeseen events. Unpredictable shocks like global pandemics or geopolitical conflicts heighten price volatility, disrupt the supply-demand equilibrium and intensify market, margin, and liquidity risks. Foreseen external factors cover energy production shifts, market dynamics, and growing competition, requiring shorter time-to-market cycles.

As renewable energy grows to supply over half of Germany's power generation and the demand for green Power Purchase Agreements (PPAs) grows, RM must integrate green products into existing systems to manage risks, including weather forecast accuracy. Weather variability affects multiple producers simultaneously, exposing them to more significant price and volume risks compared to conventional sources.

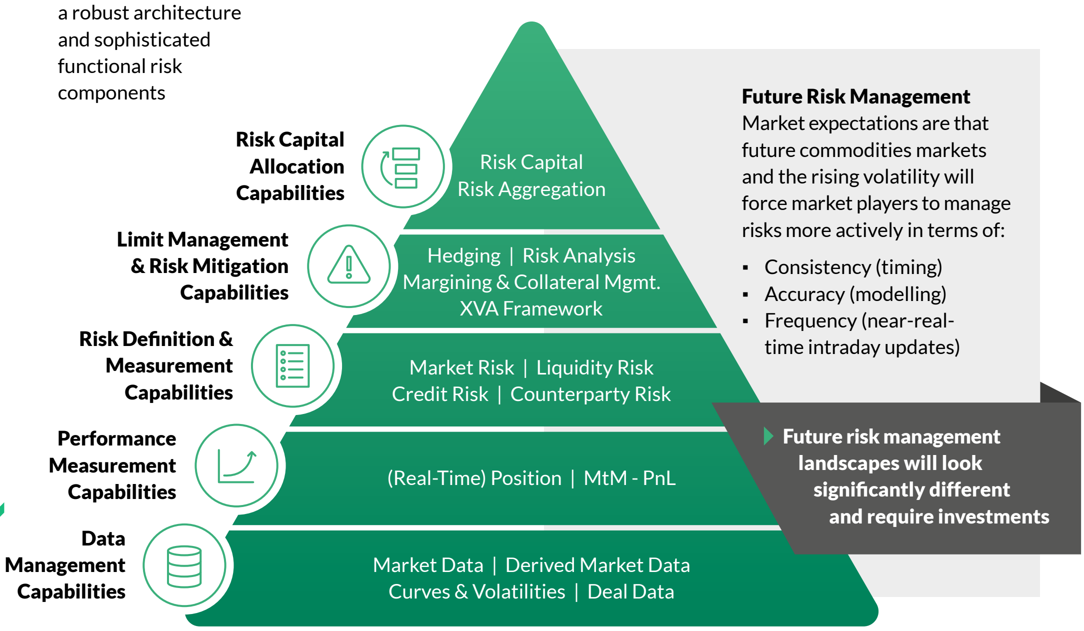


Figure 1: Capability Stack for Future Risk Management: Building a cross-commodity and cross-currency risk management framework requires a robust architecture and sophisticated functional risk components

	PRICE TAKER			RISK TAKER	
	Static Risk Management	**Advanced Static Risk Management**	**Reactive Risk Management**	**MaRisk Compliant Risk Management**	**Risk Management like a Bank**
Frame-work/ Processes				▪ Independent report on risk management to risk organization board	▪ MaRisk compliant by default ▪ Risk management embedded into all aspects of value chain and business processes ▪ Introduction of risk capital and risk adjusted returns as a management device ▪ Group-wide risk management approach
Governance				▪ Clear separation of Front Office, Risk, and Back Office ▪ Mandatory documentation of processes and guidelines ▪ Mandatory 4-eyes principle and other control structures ▪ Incident management database ▪ Internal revisions	▪ Clear separation of Front Office, Risk, and Back Office ▪ Mandatory documentation of processes and guidelines ▪ Mandatory 4-eyes principle and other control structures ▪ Incident management database ▪ Internal revisions
Risk Metrics	▪ Simple parametric or historical VaR	▪ Historical reports ▪ Simple parametric or historical VaR	▪ Sensitivity and scenario analysis ▪ Monte Carlo simulations ▪ Parametric or historical VaR	▪ Operational risk ▪ Sensitivity and scenario analysis ▪ Monte Carlo simulations ▪ Parametric or historical VaR	▪ Measuring all relevant and corresponding metrices
Tools	▪ Excel	▪ Database ▪ Excel	▪ Risk management system ▪ Database ▪ Python	▪ Risk management system ▪ Database ▪ Python	▪ Dedicated risk management tools and services
Reporting Time	▪ More than a day	▪ Daily	▪ Intraday	▪ Near-real-time	▪ Near-real-time
	Level 1	Level 2	Level 3	Level 4	Level 5

Portfolio Complexity

Risk Management Maturity Level

Figure 2: Risk Management Maturity Model for Energy Trading Organizations: Building a comprehensive RM framework requires trading organizations to know their starting point and to define their target risk capabilities

Effective short-term renewable trading requires rapid reactions achievable only through timely data input, analysis, and monitoring. This drives companies to adopt advanced tools that offer advantages in terms of time and flexibility.

Open markets attract diverse participants, from renewable producers to financial institutions seeking risk premiums via sophisticated RM systems. At the market level, the increasing number of participants and the quality of their frameworks decrease profits for inefficient traders. At the organizational level, expanding business strategy significantly contributes to risks. Trading organizations frequently aim to broaden their strategies, market reach, and portfolios to boost profits. However, this growth introduces greater risks if RM infrastructure and policies are inadequate.

Finding the Right Maturity Level

Considering the fast-paced business climate described above, understanding your organization's RM maturity is crucial for success. FORRS provides a framework with five maturity levels progressively increasing in sophistication and effectiveness.

- Level 1: **Static Risk Management** is basic and reactive, addressing risks as they arise without proactive mitigation.
- Level 2: **Advanced Static Risk Management** offers a more structured approach but remains responsive.
- Level 3: **Reactive Risk Management**, organizations actively deal with risks when they occur, moving towards a dynamic response system.
- Level 4: **MaRisk Compliant Risk Management** aligns with established standards, promoting a comprehensive approach that preempts risks before they affect the business.
- Level 5: **Risk Management like a Bank** embodies proactive practices, similar to those of a bank, embedding RM into culture and strategy, optimizing processes to preemptively tackle risks.

Assessing your RM maturity level is the first step towards improvement. By knowing your starting point, you can target your efforts to reach a higher level, enhancing decision-making, resilience, and competitive edge. Advancing RM maturity transforms it from an obligation to a strategic advantage, allowing organizations to anticipate and mitigate potential threats. Let us help you understand your current status and craft a path to improved security and opportunity.

Voices from the Market: Shaping Future Risk Management Together

Energy markets get together, right here. Industry professionals share their insights on the biggest challenges and opportunities in tomorrow's energy markets. These experts emphasize the impact of volatile markets, regulatory changes such as REMIT, and uncertain geopolitical developments.

AVIV HANDLER
Managing Director | ETR Advisory

The year 2026 will see yet another year of regulatory changes. For example, in REMIT reporting, significant changes will be finalized. Additionally, we see an increase in regulatory interventions and investigations. Therefore, it is important to ensure compliance and to be ready to easily respond to inquiries from regulators without delays in information retrieval. Being prepared before each event is therefore fundamental.

MARIA DE KLEIJN
Partner | Kearney B.V.

More volatile term markets and liquidity pressures mean that the premium to manage market risk is going up. Single-technology independent power producers (IPPs) and retailers are exposed, as they have historically outsourced managing market risk with limited visibility into their own operations. Now, they see their competitiveness under threat, as the costs are becoming apparent.

Beyond balancing their portfolios, these players should consider managing selected risks in-house. This requires the ability to calculate risk levels, assess hedging strategies, and execute trades. Those capabilities used to be something only the major trading houses could do. However, advances in data and analytics solutions put this within reach for all. In-house risk management is certainly a trend to watch in 2026.

OLA LOME
Independent Energy Market Consultant
Enervea

Most asset-backed traders have automated trade execution and can focus on what truly creates value: building multi-market strategies across day-ahead, intraday, and ancillary services markets. Yet, short-term risk management lags behind. Too many traders act as if intraday risks that do not show up in their books overnight simply do not exist.

As short-term trading volumes continue to grow, I hope to see the adoption of more sophisticated risk management approaches that go beyond basic limit checks.

TROND STRAUME
Managing Director | Partners Group

Whether the priority is decarbonization, energy sovereignty, or geopolitical stability, the conclusion is the same: Europe needs more power, not less. Wind, solar, and batteries are no longer niche solutions or moral statements. They are industrial-scale technologies that must be deployed faster and at greater volumes.

Electrification is accelerating across industries, transportation, data centers, and households, and demand will not wait for political consensus. Without a decisive increase in power production, Europe risks bottlenecks that erode competitiveness and shift value creation elsewhere.

Abundant, reliable electricity underpins industrial resilience, strategic autonomy, and long-term peace. The next decade will reward regions that build capacity early.

ANDREAS SCHWENZER
Partner Energy & Climate Change
Argon & Co

Energy markets and the business models of energy companies are ever changing. Due to uncertain geopolitical and regulatory developments, as well as the dynamics in customer requirements, energy companies are facing significant strategic and operational uncertainty.

To cope with these challenges, proper enterprise risk management systems are needed. Considerable transformational effort is required to prepare for changing requirements, so leading energy companies must improve their integrated corporate planning and make enterprise risk management a priority.

JOSH GRAY,
Chief Scientist | ION Group

Driven by renewable growth, volatility, and accelerating client demand, Battery Energy Storage Systems (BESS) are fast becoming central to Europe's evolving power markets. Effective risk management is essential to unlocking the full commercial value of BESS.

With revenues shifting from contracted ancillary services to merchant arbitrage opportunities, operators face complex price, congestion, operational, and regulatory risks across day-ahead, intraday, and balancing markets. BESS participants must manage these exposures through integrated trading, operations, and risk solutions that combine co-optimized dispatch, stress scenarios, and cash-flow-at-risk metrics. This will support confident decision-making and ensure sustainable profitability.

DR. MARTIN FENGLER
CEO and Founder | Meteomatics

Volatility has become the operating condition of energy markets. We see more and more stakeholders come to us in search of ever more accurate and faster weather data. Without that level of data quality, strategic decisions are based on assumptions, rather than facts, and energy companies cannot afford that any longer.

University of
Duisburg-Essen

PROF. DR. RÜDIGER KIESEL
Professor for Energy Trading and Financial Services

A Methodological Risk Management Blueprint for Energy Markets in a VUCA World

Contemporary global energy markets are undergoing an unprecedented transformation. This massive change is driven by geopolitical tensions, disruptive technologies, climate change policies, and shifting consumer preferences. No wonder energy markets are more volatile in price behaviour, uncertain in policy frameworks, ambiguous in interpretation of events, and complex in structure than ever.

Today's energy markets are characterized by rapid price swings in oil, gas, and electricity, dramatically affected by supply shocks such as the war in Ukraine, extreme weather events, or sudden shifts in demand. For example, the 2022 energy crisis saw European gas prices spike over ten times their pre-war levels.

Unpredictable policy shifts, such as introduction and abolishment of subsidies, phase-outs of fossil fuels, postponement of carbon trading schemes, and carbon taxes make reliable forecasting of regulatory frameworks impossible and create uncertainty for market participants.

Moreover, modern energy systems involve complex, interconnected structures, such as grids, storages, digital platforms, carbon markets, supply chains, and global financial flows. The rise (and fall) of elements, including new structures such as Power Purchase Agreements (PPAs) or Battery Energy Storage Systems (BESS), can ripple across markets, regulations, and infrastructures. Moreover, market, political, or regulatory events may allow for different interpretations, leading to ambiguity in each component of the energy system. For instance, a surge in renewable energy may reduce fossil fuel demand, as well as increase grid instability. Thus, the same data can be interpreted in multiple ways, depending on context and perspective.

With so much Volatility, Uncertainty, Complexity, and Ambiguity (VUCA) in the world energy markets, a risk framework is needed. This will enable organizations to move beyond reactive risk control and act on a proactive, adaptive mindset to increase resilience.

The following four-level approach (adapted from [KR], see also [KS]) shows which risk management strategy should be chosen, depending on the dominating VUCA component.

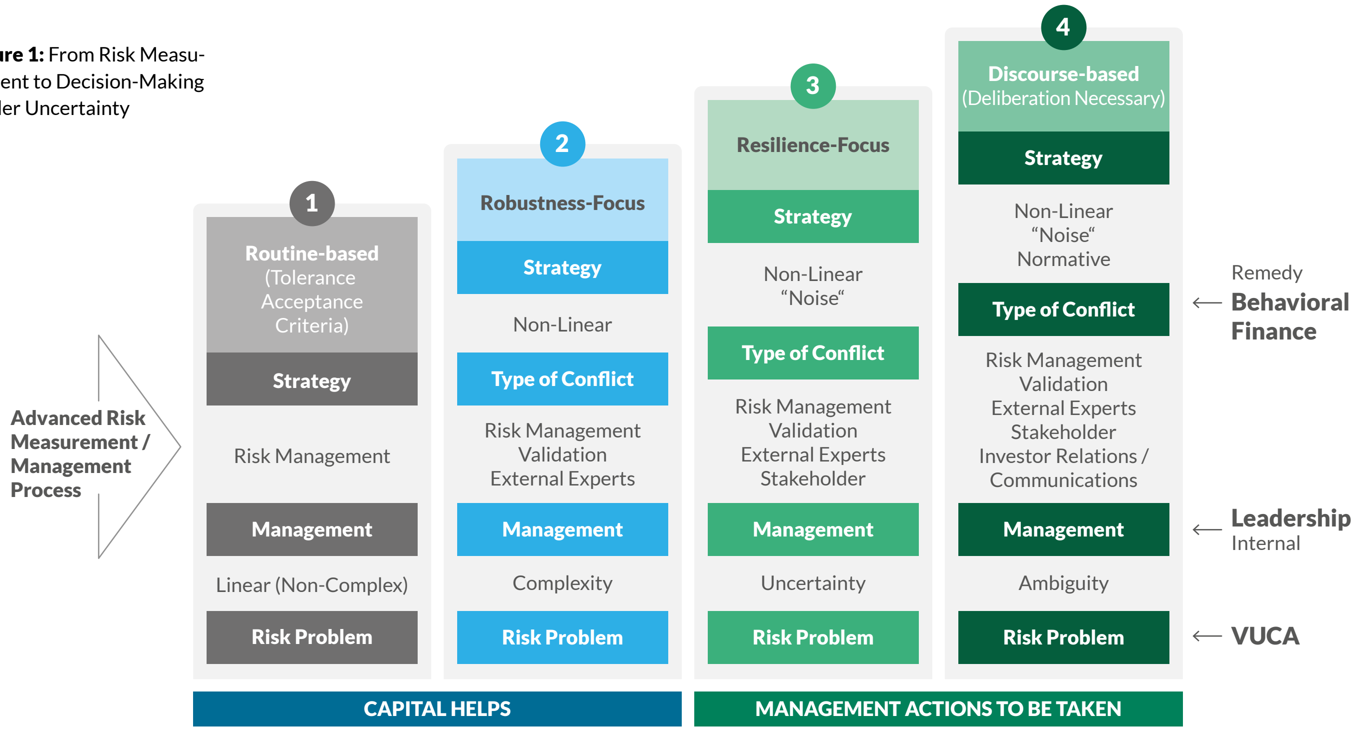
The first level (linear, routine-based approach) is applied to well-understood risk management tasks (such as selling power plant output on the futures markets) under normal circumstances. Here, traditional approaches work perfectly. Model uncertainty is limited, and decisions are typically easy to make.

For more complex situations with extreme events, such as sudden price spikes in highly volatile market circumstances which may lead to massive losses in long-term fixed contracts, the second level is needed. Typically, at this level dynamic hedging with options and flexible contracts is applied by experienced risk managers to take complexities adequately into account. Related risks are still considered acceptable, as they are in line with the strategy, limit, and threshold system.

The remaining two levels are characterized by significant epistemic uncertainties and high non-linearity. Typically, the process of risk measurements is unstable (caused by ambiguities) and accompanied by various uncertainties.

For example, a utility's renewable integration relies on proper forecasting, grid management, and independent storage systems. Risk management must use structured decision-making tools (such as scenario planning with multiple futures, including

Figure 1: From Risk Measurement to Decision-Making Under Uncertainty



rapid decarbonization vs. gradual transition) and factor in diverse perspectives, that may challenge standard assumptions. Decisions must be made by cross-functional teams with appropriate regulatory intelligence and knowledge of (global) market trends.

More importantly, senior management needs to be a catalyst for implementing a VUCA-ready risk management culture. The strategic tone of the organization must align with VUCA principles, which need to be included in mission statements, performance metrics, and board level reporting. Teams within the organization must feel empowered to challenge assumptions, report risks early, and think in innovative ways.

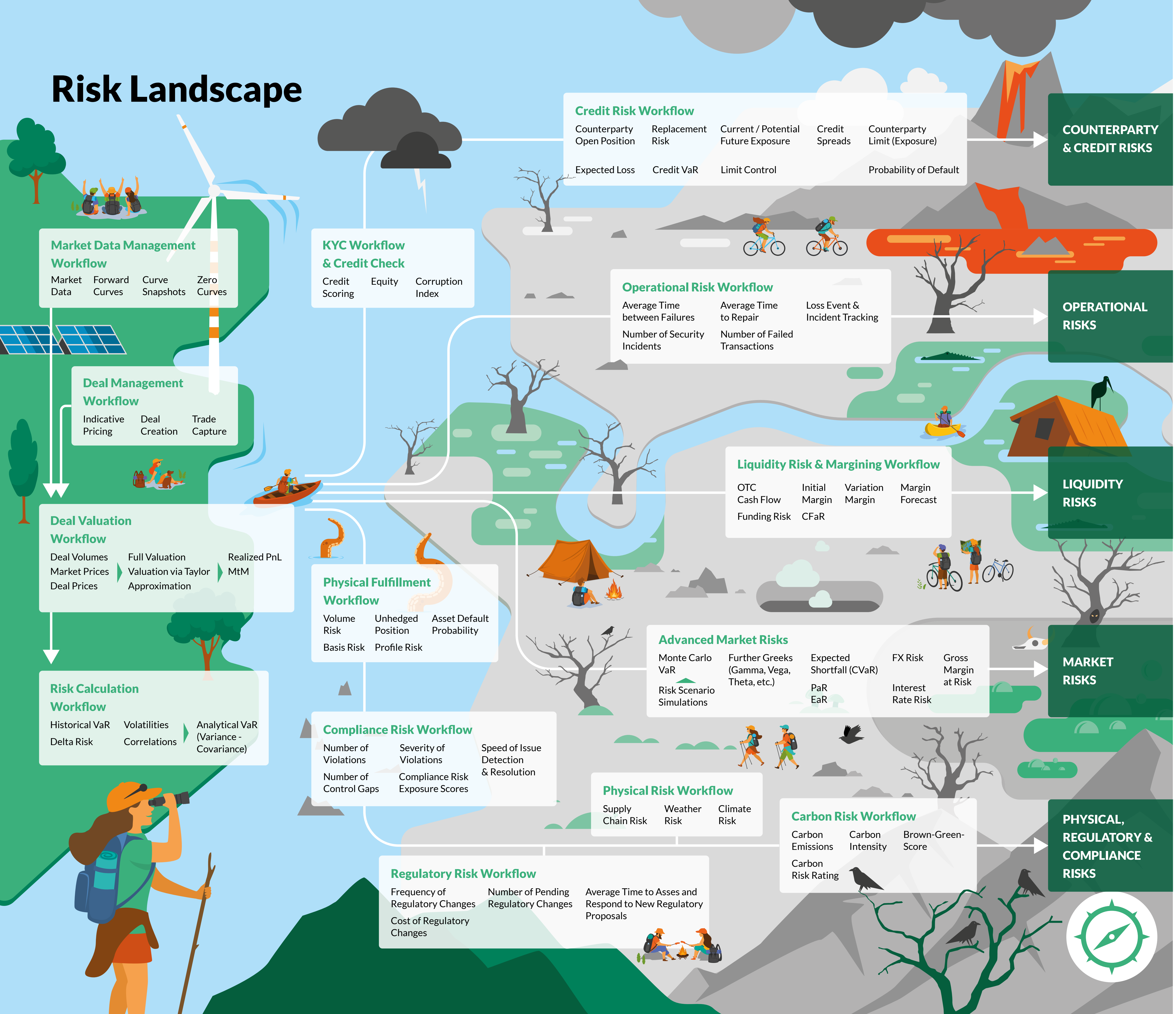
As teams need to be able to manage complexity and ambiguity, necessary tools — such as AI agents, data in high-quality, scenario planning, and personal skills training — must be available. Executives must demonstrate agility by revising strategies based on new data, reacting transparently to uncertainties, and encouraging a positive failure culture that learns from mistakes. Senior management must break down silos by requiring collaboration between risk, finance, and engineering teams to ensure holistic problem assessment.

By identifying and addressing the specific risk management problems tied to each VUCA component, organizations can build resilience. But ultimate success relies on senior leadership to drive cultural change, allocate resources, and model adaptive decision-making.

Literature

[KR] Klinke, A. and Renn, O. (2015) Risk governance and resilience: New approaches to cope with uncertainty and ambiguity, Springer 2015.

[KS] Kiesel, R. and Stahl, G., (2023) An uncertainty-based framework for managing climate risk, Annals of Actuarial Science, 1-18.



The New Era of Enterprise Risk Management (ERM)

Recent geopolitical shifts, rapid technological advances, and development away from fossil-based power generation are fundamentally transforming how energy market participants manage their portfolios.

Traditionally, risk management identified and managed market risk as its core discipline. It relied on backward-looking approaches for controlling financial exposures in portfolios. Recent developments have upended this paradigm. Managing renewables now demands significantly improved forecasting capabilities. "Seeing tomorrow" has become essential for risk managers, who must oversee a much larger spectrum of enterprise risks.

Wherever risks exist, business opportunities emerge. To seize them, many market participants are shifting from pure price-taking towards more deliberate risk-taking. This requires a holistic, coherent risk framework that makes business risks explicit, understood, and deliberately warehoused.

In this environment, accurate pricing and valuation are even more critical. They form the backbone of consistent, reliable risk metrics. A robust risk framework rests on a large array of consistently calculated, tightly interlinked measures. It makes consistency the defining foundation of modern enterprise risk management.

Experience from mature sectors, such as the financial market, shows that a far larger set of metrics must be calculated at high frequency to gain a clear view of current risks and exposures. Therefore, technology takes a central role, requiring enterprises to build scalable, adaptable platforms that support this analytical depth and efficiently meet future demands.

C:WAN

New Dynamics are Redefining Energy Trading

KIRAT SINGH
President of Risk and Alternative Assets
Clearwater Analytics

Dynamic pricing and real-time valuations are transforming energy markets. As volatility and exotic instruments rise, traders need transparent risk management and cloud-native platforms to deliver speed, scalability, and precision in today's high-stakes environment.

Variable pricing and dynamic valuations are currently being used in an increasing range of industries. Sophisticated dynamic algorithms enable firms to update prices, ranging from gasoline to data processing capacity, multiple times a day, based on a wide assortment of input factors.

This is certainly not news to energy traders, who have dealt with multi-factor pricing models for decades. But growing model complexity and a flood of new, exotic instrument types are raising the stakes.

Price per barrel, type, and destination? Not anymore. Now, it is one of several descriptions of energy grade or content whether spot or long-term, with multiple exercise dates and payoff structures that account for the needs of each producer, shipper, trader, and consumer, linked to other oil or gas prices, with additional conditions layered on top.

Combine all this with the volatility of energy markets, accelerate it to the speed and volume of modern energy trading, and then multiply it by the unpredictability of geopolitical and climate issues. The result? You have a market that needs faster and more accurate valuations.

The Rise of Exotic Instruments

The advent of new and improved types of energy generation, transportation, and storage is fueling a shift in trading patterns and a wealth of new financial instruments. To remain competitive, energy traders and analysts need to add or modify any instrument in their risk management platform, regardless of type or complexity. Opaque valuations and black-box models have no place in this market.

Along with energy instruments, new and improved portfolio and risk management platforms have been introduced to the market. Advanced energy trading, valuation, and risk tools bring down the barriers to transparent portfolio and risk management. With open-code licenses and customizable instrument definitions, analysts can clearly see the calculations behind any valuation, modify the terms or parameters, and build completely new ones. Once tested and approved, new or updated models and instruments are instantly distributed to appropriate portfolios throughout the firm. Any questions or unexpected changes can be quickly answered, and appropriate adjustments can be made.

Accelerating the Valuation Process

In addition, the increasing volatility and uncertainty of energy markets are demanding faster responses. Accurate, on-demand valuations are crucial for assessing risk exposure and making strategic decisions. End-of-day valuations without intraday or real-time risk, cross-asset and portfolio aggregations, or updated Value at Risk (VaR) and Profit and Loss (PnL) analytics, are simple not enough.

Modern, cloud-based infrastructures are powering the response to these needs. When markets move faster or macro uncertainties increase, cloud-native platforms scale as needed. High-performance computing and data fabrics deliver the complex inputs and compute resources necessary for calculating valuations and related analytics, revealing important risk factors when they are needed.

The Taming of the Wildcat

It sounds simple – markets are growing more complex and moving faster, so energy trading firms need to ingest more, calculate more rapidly, and respond with precision. But legacy systems have become dry holes, no longer able to meet these growing demands.

Beacon by CWAN is taming this wildcat technology through a legacy of building advanced models for investment banking around a core of modern infra-structure and best practices. From innovative partnerships and renewable energy sources to midstream assets and carbon credits, energy firms can now own the model development and lifecycle, delivering confidence in valuations, accelerated responses, and better performance.

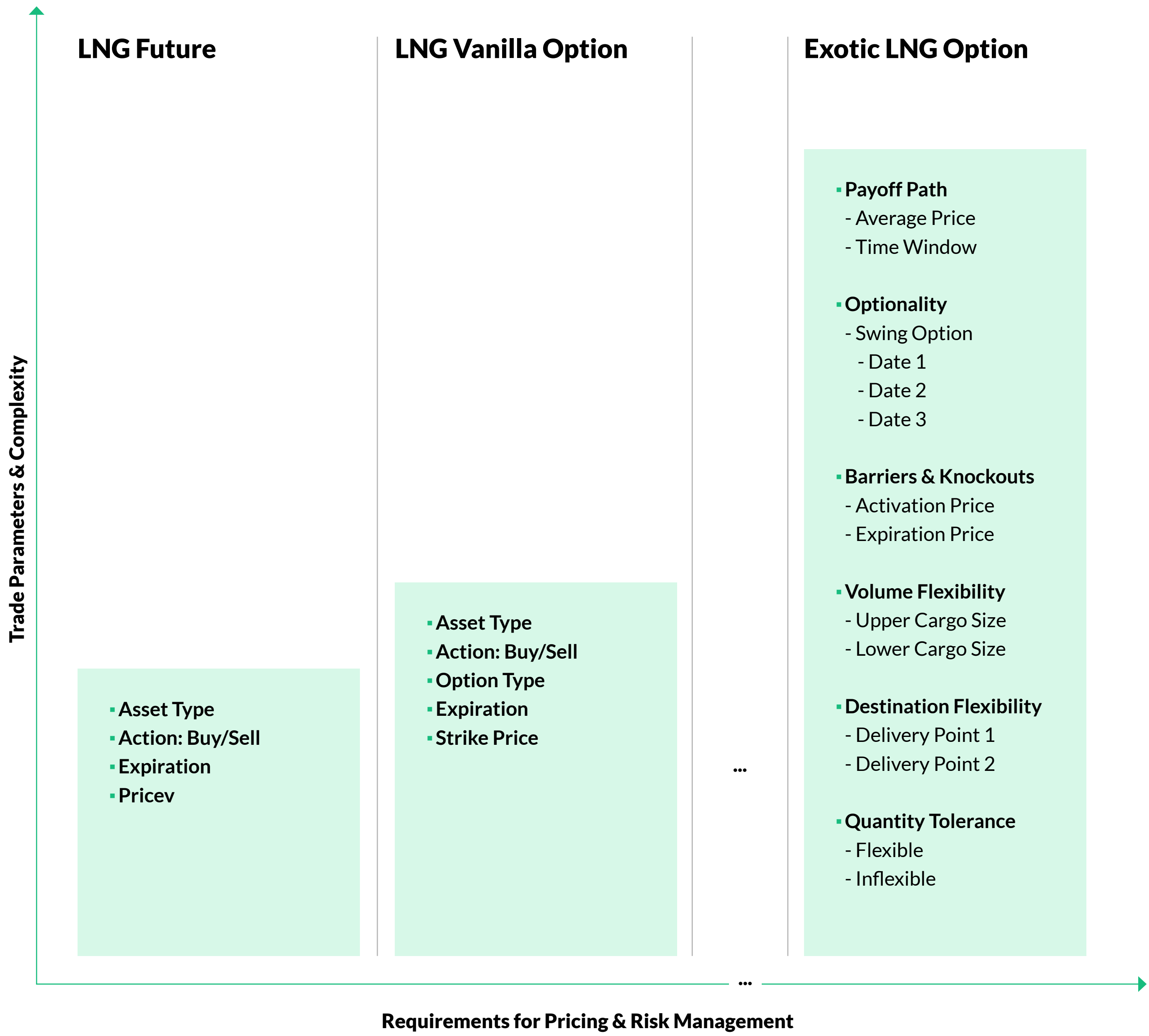


Figure 1: Increasing Complexity of LNG Derivatives and Risk Management Requirements

kinetic mind

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FORRS

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The Unknown Pitfalls of Taylor Approximation in Energy Trading Valuation

From quick estimates to costly errors: Understanding the pitfalls of Taylor approximations in energy risk management.

Taylor approximations are widely used in energy trading for their speed and simplicity. They enable near-real-time risk reporting and sensitivities, which is crucial for operational decision-making. However, when used as a substitute for full valuation, they can distort risk metrics, misprice convexity, and fail under stress – leading to implausible Value at Risk (VaR), misaligned hedges, and poor capital allocation.

Using the example of a gas swing contract, this article explains why the approximation fails for common energy structures, where the largest errors arise, and proposes full valuation as basis for more robust valuation and risk frameworks.

Nonexistent in the Banking Sector – Common in the Energy Sector

Taylor approximation can be a handy tool for risk management when it comes to the valuation of complex derivatives or products. Compared to a full revaluation, there is no need for expensive and time-consuming Monte Carlo simulations, as an approximation is usually 'close enough'. By contrast, the front office in energy trading typically uses full valuation for pricing and PnL, as accuracy is critical for trading decisions.

In the banking sector, both front office and risk management usually employ full valuation for pricing and risk measurement. This is driven not only by the complexity of banking portfolios – often containing exotic derivatives and nonlinear payoffs – but also by regulatory requirements under Basel frameworks, which mandate accurate risk modeling for capital calculations, backtesting, and stress testing.

How Taylor Approximation Works

Taylor approximation is a mathematical technique used to approximate a complex function by a simpler polynomial, based on its derivatives at a specific point. It is widely used in energy trading to estimate changes in product values and risk metrics without performing full revaluation.

If you have a function $V(x, \sigma)$ that is difficult to compute for every possible input, you can approximate it near a point (x_0, σ_0) using its derivatives at that point. For a product value V depending on prices x and volatility σ, the Taylor approximation is given by:

$$V(x,\sigma) \approx V(x_0,\sigma_0) + \sum_i \Delta_i (x_i - x_{i,0}) + \frac{1}{2} \sum_{i,j} \Gamma_{ij} (x_i - x_{i,0})(x_j - x_{j,0}) + \nu (\sigma - \sigma_0)$$

Where:

- $\Delta_i = \frac{\partial V}{\partial x_i}$: Delta – sensitivity to price changes
- $\Gamma_{ij} = \frac{\partial^2 V}{\partial x_i \partial x_j}$: Gamma – curvature with respect to prices
- $\nu = \frac{\partial V}{\partial \sigma}$: Vega – sensitivity to volatility changes

The Taylor approximation is used because of its speed compared to full valuation. It also provides quick estimates of portfolio sensitivities and is easier to aggregate across positions. But it assumes small changes around the expansion point, and works best for smooth, linear functions. The approximation usually breaks down for non-linear, path-dependent, or discontinuous payoffs.

The calculation of Greeks, such as Delta, Gamma, and Vega, requires access to a full valuation model, because these sensitivities are derived from changes in the instrument's value under small variations in market parameters. This full valuation model is typically developed and maintained for front office purposes to ensure accurate pricing and trading decisions.

Risk management leverages the same model to compute Greeks but does not use full revaluation for every risk metric. Instead, once the Greeks are calculated, risk teams apply Taylor approximations based on these sensitivities to estimate portfolio changes with reduced computational effort. Note that this approach also makes risk management dependent on front office models.

Risk Management is More than a VaR on Market Prices

While Taylor approximations can provide sufficiently accurate results for short-horizon risk metrics, such as VaR based on minor changes in market prices, they have significant limitations for other types of risk.

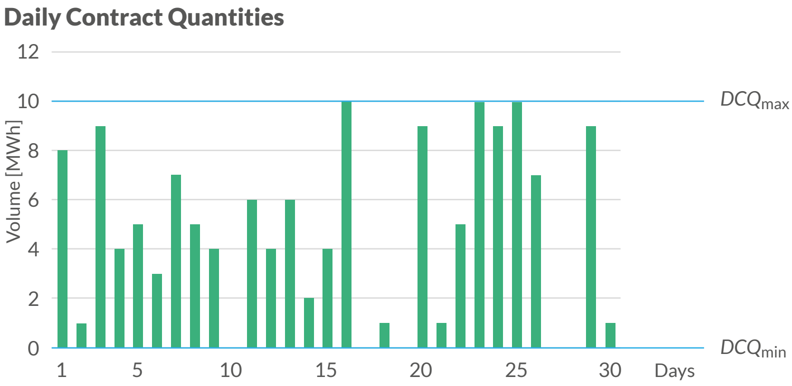
For example, in credit risk calculations, where exposures can change abruptly due to defaults, rating migrations, or counterparty events, the linear and quadratic assumptions underlying Taylor expansions often break down. This can lead to unstable and unreliable results, as approximations fail to capture discontinuities and nonlinear effects inherent in credit-sensitive instruments.

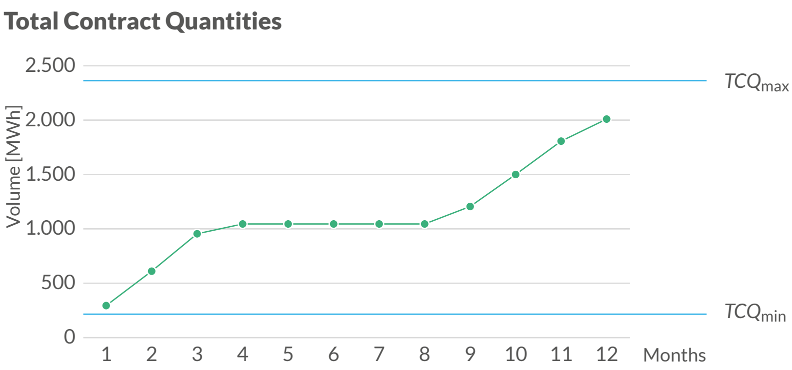
Therefore, while approximations are useful for speed in certain market risk contexts, they are generally unsuitable for metrics that involve structural changes or jump risks.

Example: Gas Swing Contract

The limitations of Taylor approximations become evident when applied to complex, highly nonlinear contracts such as a gas swing contract. These contracts allow the holder to vary daily or monthly gas offtake within predefined limits, creating significant optionality.

Figure 1: Illustrated Daily and Total Contract Quantities of the Gas Swing Contract, Including their Respective Boundaries.





While a Taylor expansion based on Greeks may approximate small price movements reasonably well for short-term market risk metrics, it fails to capture the path dependency and embedded optionality inherent in swing contracts.

For example, changes in volatility or forward curve shape can drastically alter the optimal exercise strategy, leading to large valuation shifts that a Delta-Gamma approximation cannot predict. As a result, relying on approximations for such instruments can produce unstable and misleading risk figures, especially for metrics beyond short-horizon VaR, such as credit exposure or stress scenarios. This illustrates why full valuation is essential for complex energy derivatives.

1. Contract Specifications

A long gas swing contract provides the option to buy gas daily for a fixed price, with some quantitative restrictions specified for the days, months, quarters, or the total contract period.

In the study below, the following gas swing specifications offer the daily option to buy a maximum of 10 MWh of gas. Furthermore, one needs to buy at least 240 MWh, and can, at most, buy 2,400 MWh per year. This results in a so-called daily contract quantity (DCQ) between DCQ_{min}=0 and DCQ_{max}=10, and a yearly or total contract quantity between TCQ TCQ_{min}=240 and TCQ_{max}=2,400.

2. Gas Spot Price Simulation via BM

In the following example, a spot model that is tied to a deterministic forward curve is used for the full valuation approach,

$$\mathrm{Spot}(t) = \mathrm{Forward}(t) + X(t),$$

where $X(t)$ is an Ornstein-Uhlenbeck process (OU) of the form

$$dX(t) = \; -\kappa(X(t) - \theta)dt + \sigma dW(t).$$

This OU process makes the spot process move randomly around the forward level in time. The volatility σ determines the size of the shocks generated by the random increments dW, whereas the mean reversion speed κ controls how fast the spot process moves back into the direction of the forward after a shock. The mean reversion level θ is typically set to 0 in the additive model, as defined above.

The described model is a common approach to spot modelling, also applicable in a logarithmic form, and can be easily extended with stochastic forward dynamics.

Figure 2 shows an example of a daily gas forward curve and its monthly average prices, together with simulations using the model described.

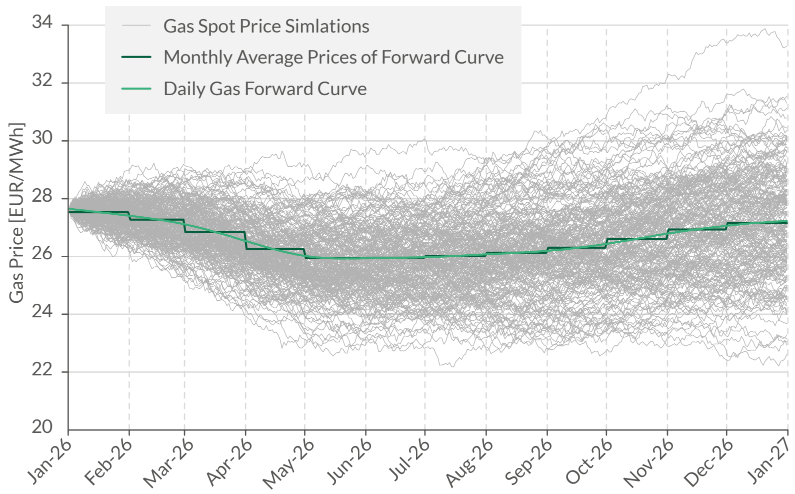


Figure 2: Gas Forward Curve and Simulated Spot Prices Based on the Forwards and the Described Model

3. Model for Full Valuation

Like other structured energy products, gas swings can be priced in different ways. The most common approaches – each offering greater flexibility but also requiring more computational effort – are analytical methods, numerical solutions of partial differential equations (PDEs), and Monte Carlo simulation techniques.

In this study, the PDE approach is used, since the gas swing option that is analyzed is of moderate complexity. A rough description of how the premium price is computed is given by the following steps:

1. The lifetime of the gas swing is discretized into days, as nominations are made on a daily basis as well.
2. The admissible volume levels and nomination volumes are determined and discretized in accordance with the imposed restrictions.
3. For each time and volume action, an expected value for the next time step can be formulated and calculated by solving a PDE. The model parameters described above are part of the matrices that define the PDE problem.

For the base scenario forward curve and valuation date 31st of December 2025, **the full valuation price is 583.75 EUR.** The Deltas and Gammas are computed using finite differences, first for a shift in the yearly price, then separately for each month within the swing period. The Vega is calculated only on a yearly basis, as it is less sensitive to temporal granularity. The exact numbers are displayed below in Table 1.

The monthly and daily Deltas in relation to the cumulated minimum and maximum volumes given by the restriction are shown in the upper part of Figure 4. Only the days from January to March and from November to December are in-the-money, relative to the contract price of 27 EUR.

Consequently, the maximum admissible daily gas volume is nominated at the beginning and end of the swing period. The daily Deltas flatten during days when the forward price is at-the-money and approach zero in summer, when market prices are low.

4. Pricing under Market Shock Scenarios

Two plausible market shock scenarios are considered:

1. The first reflects an increase in the forward prices at the short end (Winter 2026) with a smaller price increase in later maturities. A rationale for this scenario could be an unusually cold winter, or lower-than-expected gas storage levels.
2. The second scenario builds on the first, but includes an upward shift of the entire forward curve by several euros. Such price changes could stem from geopolitical tensions or military conflicts. In the last years, the continental gas markets have been exposed several times to daily jumps of at least that size.

In both scenarios, the volatility is assumed to have doubled. Both market shock scenarios are shown in Figure 3.

Table 2 shows for scenario 1 the Taylor approximated gas swing prices, using the yearly spot Greeks as well as the monthly ones (the yearly Vega is used in both cases). Comparing those to the full valuation price, the relative error is 13% for using monthly spot Greeks and -11% for yearly ones, respectively.

Table 1: Monthly Aggregated Spot Greeks for the Gas Swing Contract

	2026	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Delta	1146.0	307.2	225.3	108.8	8.8	0.0	0.1	3.7	26.9	51.3	95.7	140.5	177.5
Gamma	1077.4	26.6	218.0	267.0	64.6	0.0	0.4	17.5	81.5	116.1	134.5	148.4	108.2
Vega	497.6												

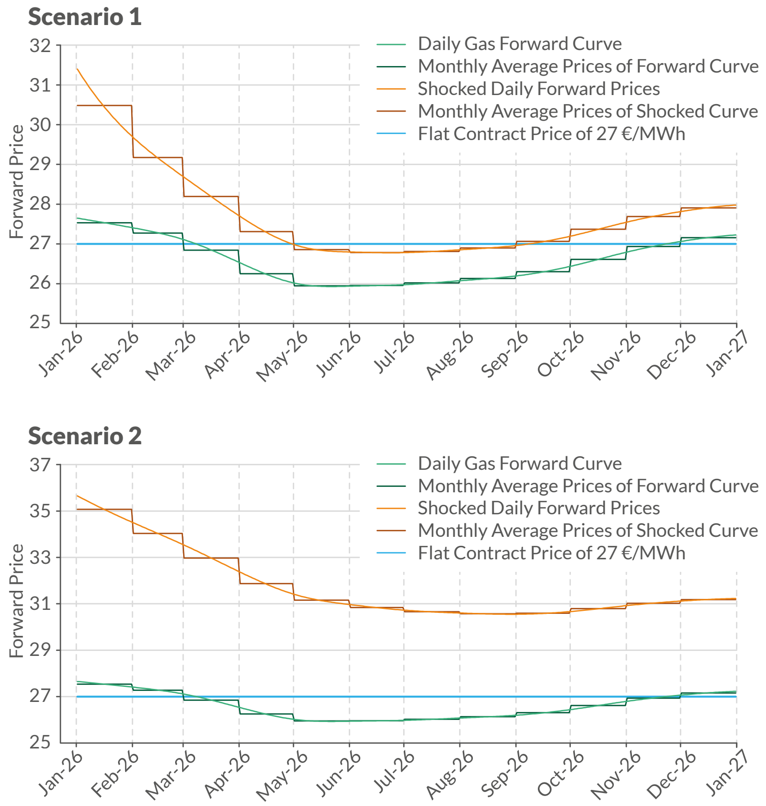


Figure 3: Shocked Forward Curve Scenarios

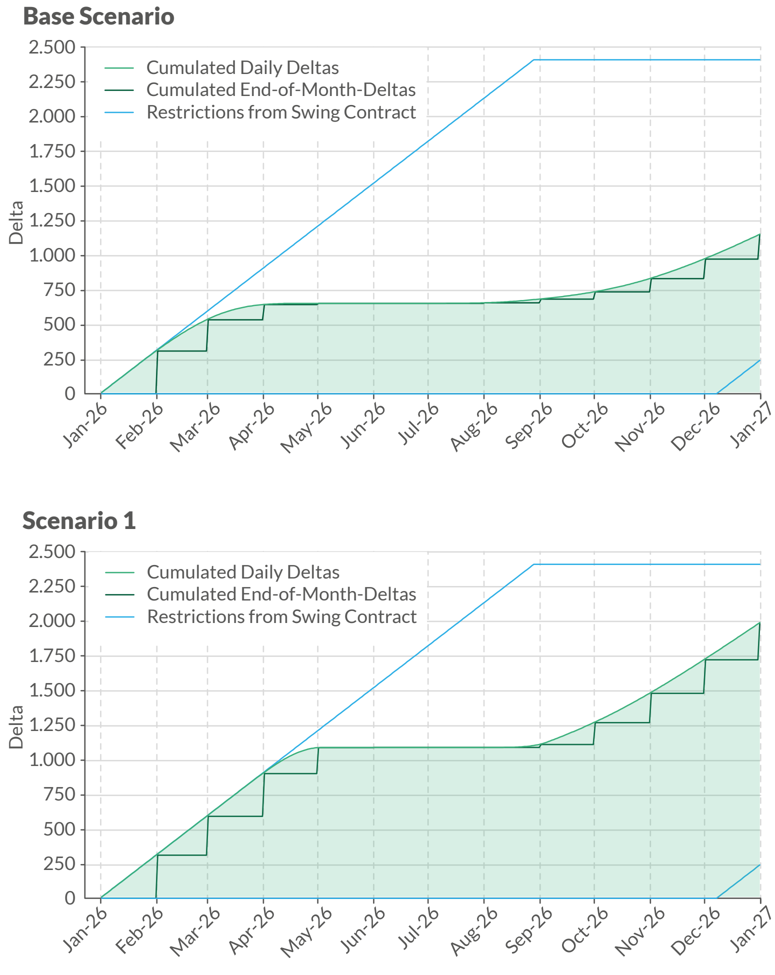


Figure 4: Delta and Volume Restrictions

Method	Gas Swing Price	Relative Error to Full Valuation
Full Valuation	3,432	
Taylor Approximation Monthly	3,887	13 %
Taylor Approximation Yearly	3,061	-11 %

Table 2: The Taylor Approximated Gas Swing Prices for Scenario 1

As can be seen in the lower part of Figure 4, the daily and monthly Deltas derived from the full valuation approach using PDEs now extend into the summer. However, since the forward prices from May to August remain out-of-the-money, the cumulated Delta increase during these months is smaller.

For scenario 2, the Delta-Gamma-Vega approximation no longer works. The Deltas in the base case are too low, as a sizable portion of the forward prices in spring, summer, and autumn were out-of-the-money at that time. For those months in spring and autumn that were near the contract price, the Gamma was particularly high, causing the approximation to get too high as well. Table 3 displays the comparison of Taylor approximation against the full valuation price in scenario 2.

Method	Gas Swing Price	Relative Error to Full Valuation
Full Valuation	12,670	
Taylor Approximation Monthly	24,712	95 %
Taylor Approximation Yearly	21,210	67 %

Table 3: The Taylor Approximated Gas Swing Prices for Scenario 2

Taylor Comes with Unmanaged Risk

As one can clearly see in our model results, a valuation with Taylor approximation can significantly differ from full valuation. This means companies that are using Taylor approximations are not accurately measuring their risk, and may make wrong decisions based on those results.

To overcome this, we strongly recommend changing risk valuation of all products and derivatives to a full valuation approach. The energy market is growing rapidly, with special emphasis on quick decision-making. Those decisions need to be based on reliable and stable risk metrics.

Taylor approximation is a powerful analytic lens, but a fragile proxy when used as a wholesale replacement for valuation in energy trading. The technique's local, smooth, small-move assumptions clash with the industry's reality: nonlinear payoffs, regime changes, path dependence, and correlation dynamics. The results are implausible risk metrics when you need reliability most.

Voices from the Market: Insights from IT Leaders Driving Tomorrow's Markets

At the heart of the energy transition, technology experts share their views on the biggest challenges and opportunities in tomorrow's energy markets. These thought leaders elaborate on the need to adapt effectively to changes by using powerful technologies, while simultaneously meeting the needs of energy traders and risk managers.

MICHAEL RIEDER
Head IT Cloud Consulting | e3 AG

In energy trading, powerful end-user computing is essential for speed, insight, and competitive advantage. However, when spreadsheets, scripts, and cloud tools evolve into unmanaged shadow IT, risks around data leakage, model integrity, compliance, and operational resilience grow rapidly. The challenge is not to restrict traders, but to foster innovation within clear guardrails.

By combining secure cloud platforms, governed analytics, and transparent controls, energy trading firms can preserve flexibility while regaining oversight. This is where a structured, exploratory dialog creates value.

As part of an explorer workshop, e3 works with trading, IT, and security stakeholders to identify concrete value potential, reveal hidden risks and dependencies, and define pragmatic control mechanisms. e3 turns end-user power computing from a liability into a strategic asset.

KEN TWOMEY
Global Advisory Practice Lead | capSpire

Electrification and the rapid growth of AI are fundamentally reshaping global power demand. However, the more profound shift lies in the complexity that comes with it. Utilities are increasingly operating like trading organizations, and large technology players such as Meta and Amazon are actively exploring how to participate more directly in energy markets.

In this environment, no single platform or monolithic system can keep pace on its own. The winners are those adopting best-of-breed technology stacks across trading, analytics, forecasting, risk, and data platforms to stay agile as market rules, products, and behaviors evolve. Success now depends on how effectively an organization connects insight, execution, and risk at speed, while staying flexible enough to evolve as markets change.

HELMUT SPINDLER
General Manager of Energy Software | Volue

Many companies are upgrading their ETRM systems to keep pace with the rising volume of short-term power market activity, as older systems often struggle to handle the growth of intraday trades. Within trading, automating processes across different markets remains a challenge, so we are investing in trading process orchestration across auction, intraday, and ancillary markets to overcome this issue.

Of course, this investment, in turn, provides multi-market PnL views and supports risk management. We also see players adopting new software to maintain REMIT compliance. As organizations increasingly develop custom algorithms in-house, our solutions enable compliance with internal guidelines.

SAMI MADANI
Business Partner Trading IT Risk & Strategic Implementation | EnBW Trading

The importance of energy and enterprise risk is growing with market volatility, legacy complexity, and rising regulatory pressure. Modern platforms cut through this chaos by unifying data, automation, and controls. Yet, they succeed only when cost efficiency, governance, interoperability, disciplined execution, and measurable value realization are built into the operating model.

HARSHAD KOLPYAKWAR
Head of Solution Management Energy and Commodities | FIS Global

Energy and commodities markets are more volatile, regulated, and data-driven than ever. Firms are moving away from fragmented multi-vendor ETRM, market data, and logistics systems to investing in enterprise platforms that provide real-time , cross-commodity risk visibility. The focus is on outcomes for faster decisions, operational resilience, and strong IT partners that provide it all and are dependable global partners.

A holistic enterprise view is now essential because trading, risk, logistics, and market data are tightly interconnected. Winning platforms are those that turn integrated data and analytics into actionable insights at scale - cloud-based, secure by design, elastic, and managed as a service by solution and platform providers.

ASBJØRN HANSEN
CEO | Previse Systems

We see continued investment in enterprise systems, as data quality and control become more critical than ever. Risks are often interconnected, and building a holistic view requires sophisticated models and AI. However, these tools are only as effective as the data they rely on. Without consistent, high-quality data that can be clearly interpreted, their value is limited.

As a result, companies are investing in systems that act as a single source of truth for specific markets, supported by reporting and data-collection layers that feed AI tools and advanced risk solutions. In our view, the rapidly growing volume of data means that ensuring data quality, and the ability to process data in real-time using streaming technologies, will be essential for all energy trading companies going forward.

CHRIS REGAN | Managing Director Brady Technologies

Short-term risk management activities in energy markets are becoming faster-paced, with frequent refore-casting, rapid price movements, rising trade volumes, and constant order updates. Portfolios are increasingly virtualized and flexibility is aggregated, forcing firms to rethink how they operate. Effective risk management now depends on solid foundations, including clean, real-time data, clear visualization across time horizons, and automated, accurate position reporting. Jumping straight to trade automation without these fundamentals in place risks acting on noise rather than on insight. As markets continue to speed up, ensuring the right direction matters more than moving faster.

PROF. DR. H.C. GERHARD STAHL
Retired Chief Risk Officer of HDI Group, currently Non-Executive Director of HDI Reinsurance Ireland SE

Interview with Gerhard Stahl

Entrepreneurs, Leadership, and Risk Management – Think About Risks, Not Rules

Risk management has become a strategic cornerstone for the energy sector amid regulatory shifts and structural transformation. Few experts understand this better than Gerhard Stahl, who shares his perspectives on the role of regulation, emergent risks, and the vital interplay of CFOs and CROs in balancing resilience, agility, and value creation.

FORRS: Which social and regulatory developments that affect risk management should currently be on the energy sector's radar?

Gerhard Stahl: Almost four decades ago, Lyotard's and Beck's prophetic societal analyses of postmodern societies captured the ciphers of our present-day world conceptually as a risk society. In Europe, risks are preferably addressed through avoidance strategies (the current mantra is resilience), which, in their formal implementation, incline towards bureaucracy.

The updated requirements of the auditors' examination standard (IDW PS 340) specify requirements for risk early-warning systems that are relevant for the energy sector. This is true both from endogenous perspectives (proprietary trading and energy producers) and exogenous ones (the decisive role in transforming climate risks).

FORRS: What organizational and strategic challenges do you see in implementing these new auditing standards under IDW PS 340 for energy companies?

Gerhard Stahl: In energy trading and generation, optimized business models of energy companies create requirements for risk systems that make fruitful communication necessary. For example, communication between the CFO of a holding company and the risk manager (CRO) of a trading subsidiary is imperative.

For small and medium-sized companies, this raises the question of efficient and effective implementation. In this context, the CFO materially assumes the role of a "primus inter pares".

From an economic perspective, developing enterprise value, understood as the sum of the balance sheet surplus and the present value of future cash flows, is the focus of both internal and external stakeholders. The many successes and disappointments of countless M&A projects reveal the opportunities and uncertainties inherent in these ventures.

The graphic below brings together many components of modern corporate management. Harmony and consistency between the planning process (CFOs) and

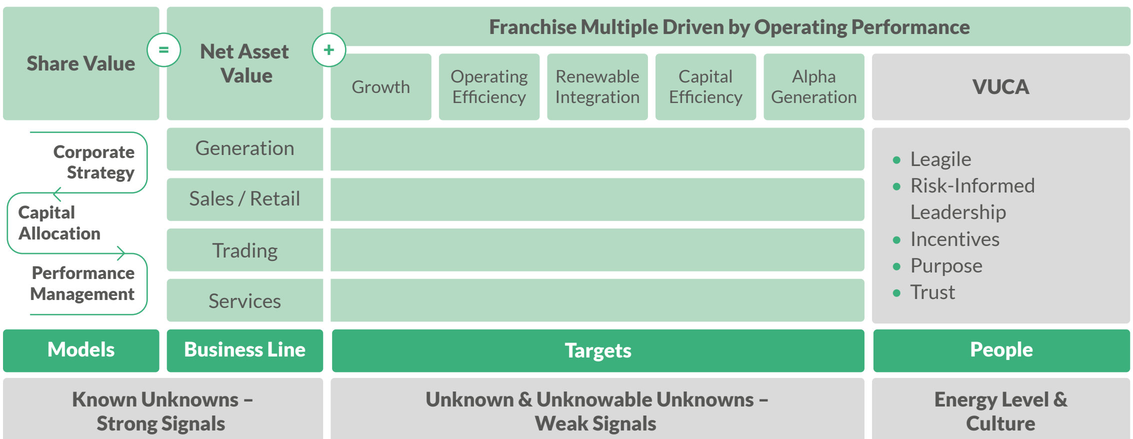


Figure 1: Value Creation Framework - Risk Projection from Known Risks to Emergent Uncertainties

the perception and quantification of uncertainties at the holding level (CFO) and in subsidiaries (CRO) play a key role.

The balance sheet (or values derived from it) serves as a success criterion for many decisions and strategies. The projection of a balance sheet maps risks that are known today over a period. However, this approach can only, to a limited extent, be transferred to the value of future cash flows, as emergent uncertainties (in extreme cases, "black swans") come into play.

Frank Knight already recognized this basic structure of categorizing non-knowledge in 1921 in his groundbreaking work Risk, Uncertainty, and Profit. He understood entrepreneurs as takers of emergent risks or uncertainties.

This marks the essential distinction between a CFO of a holding company and the CRO of a trading subsidiary. CROs use key techniques of derivatives pricing in determining risk and understanding risk as the price change of their investment portfolio. In other words, they act from the perspective of a technical expert.

FORRS: How can companies methodically capture and assess emergent risks of future cash flows?

Gerhard Stahl: In principle, pricing-based, bottom-up approaches would be suitable here. However, their technical requirements (stochastic single-period models) prevent the desired strategic business application.

With top-down approaches, which are comparable to methods such as Earnings at Risk (EaR), a consistent modeling framework has the advantage of actively involving decision-makers. They can incorporate their view of emergent risks into the models, transforming each model from a pure forecasting tool into an instrument of learning (adaptation to the environment). The importance of this in a dynamic, and indeed disruptive, economic environment hardly needs to be emphasized.

FORRS: What role can regulation play in the quantification of emergent risks, and where are its limits?

Gerhard Stahl: This approach, guided by necessity, common sense, and the responsibility that comes with it, shows how the question of dealing with bureaucracy can be answered. Communication grounded in trust and responsibility prevents bureaucracy from arising in the first place.

Industry practices in the financial sector show that overregulation is not only a significant cost factor but also slows down processes in a dynamic environment. Moreover, it lulls users into a deceptive sense of security and overconfidence through compliance with regulations that appear to be all-encompassing.

In summary, the noble task of the executive board is to create a balance between risk and freedom. The entrepreneur is deemed ideal.

FORRS: We have talked a great deal about the quantification of known and emergent risks and their importance for future decisions and strategies of an energy company. What does this mean for the planning process and financial plan of a CFO, which largely determine a company's investments?

Gerhard Stahl: This question strikes at the very core of the matter. A CFO conducts earnings (risk) management based on the planning process. Often, there is no ideal linkage between the target-driven perception of risk and bottom-up models.

Experiences with supply chain risks, particularly during and after the COVID pandemic, led to discrete dynamic models aimed at causalities and the development of alternative courses of action. If one takes a CFO's risks as the starting point, scenario techniques enable them to decide between probability-weighted alternatives of action. The focus is on value-creating courses of action rather than distributing value changes.

FORRS: In the future, will the energy sector and energy trading in particular be more heavily regulated, similar to developments in the financial sector over recent decades?

Gerhard Stahl: Regulatory systems tend to underestimate the learning capability of systems, which can often lead to bureaucracy. Bureaucratic rulebooks are often accompanied by overconfidence, as regulations, perceived as absolute, convey the impression that they are exhaustive.

However, complex times require high degrees of freedom (Ashby's Law) to implement potential adaptations in an agile manner. These requirements argue against regulation.

From a legal perspective, proprietary trading of energy instruments (such as commodities) constitutes trading activities. These are subject to regulation by the Federal Financial Supervisory Authority (BaFin). There are also many substantive reasons in favor of this, including the prevention of (regulatory) arbitrage, systemic risks, and the "golden supervisory rule": same risk, same rule.

Clearing: Take Control of Unexpected Events

CMeXs

MARIO CLAEYS
Founder | CMeXs
Clearing Management

Clearing is a very efficient tool to help protect your business and avoid potential negative market events impacting your targeted profits. At the start, but also later on, a structured approach to optimizing the clearing setup is key for avoiding unnecessary costs and keeping you in control, even when market turbulence is causing serious margin calls.

Markets Evolve, Clearing Follows

In today's energy markets, the number of trading participants has grown very fast. These new players represent new segments of the total energy space: next to utilities and traditional trading houses, also Stadtwerke, local battery operators, startups, and spinoffs from large trading houses have entered, and many more are on their way in. Many of them start trading energy commodities via exchanges and clearing their positions through a central counterparty (CCP). Their intentions might differ just like their backgrounds, levels of professionalism, and knowledge. Nevertheless, they all have one thing in common: the desire to be successful and generate profit.

This increased competition raises the pressure on companies to position themselves well. Having access to the full range of opportunities for their traders, while ensuring protection against downside effects and risks, becomes essential.

One of the important pillars is the financial coverage of the trading activities. Clearing has become a key topic, with a proven importance and an impressive reliability over many years, as it has existed for several centuries.

During the energy crisis of 2022, as volatility peaked, margin requirements reached extreme levels and put significant liquidity pressure on many firms. These events remain present in the minds of many market participants and are often cited as arguments against clearing – particularly by those who observed only the outcomes rather than fully understanding the mechanisms and underlying reason.

Such extreme situations undoubtedly create stress, and at the same time, they emphasize the need to be prepared for such events. Clearing is in fact one of the strongest protections for market stability, but it requires thoughtful preparation. When designed correctly, a clearing setup enables companies to benefit from the various advantages while protecting from sudden market shocks.

Human nature often leads us to forget difficult experiences once the pressure has eased. Some firms might be tempted to lower the interest in sophisticated clearing arrangements or switch to less rigid and complicated solutions. Often without realizing that those alternatives, like OTC trading, come with higher overall risk, including counterparty exposure.

Preparation for a Solid Base

One of the most crucial steps for companies being active in a cleared environment is to have a well-structured clearing strategy. Understanding the setup, clearing arrangements, account setup, risk protections, and financial instruments makes a significant difference to the efficiency and resilience of your trading operations.

This part is often neglected by trading companies because clearing is seen first as a necessity to access the exchange rather than a strategic component full of optimization potential.

However, optimization is not only about avoiding large margin calls and cash constraints. The optimal setup balances multiple factors: risk, financial structure, sustainability, and flexibility. Avoiding cash constraints also means the intelligent use of available financial instruments like guarantees, margin waivers, and eligible assets.

Attention to the clearing setup is a continuous process, even for established and experienced companies. There are many variables with a certain impact: portfolios grow (in size and diversification), markets and trading evolve, regulations change, geopolitical developments reshape risk dynamics, etc. Internal

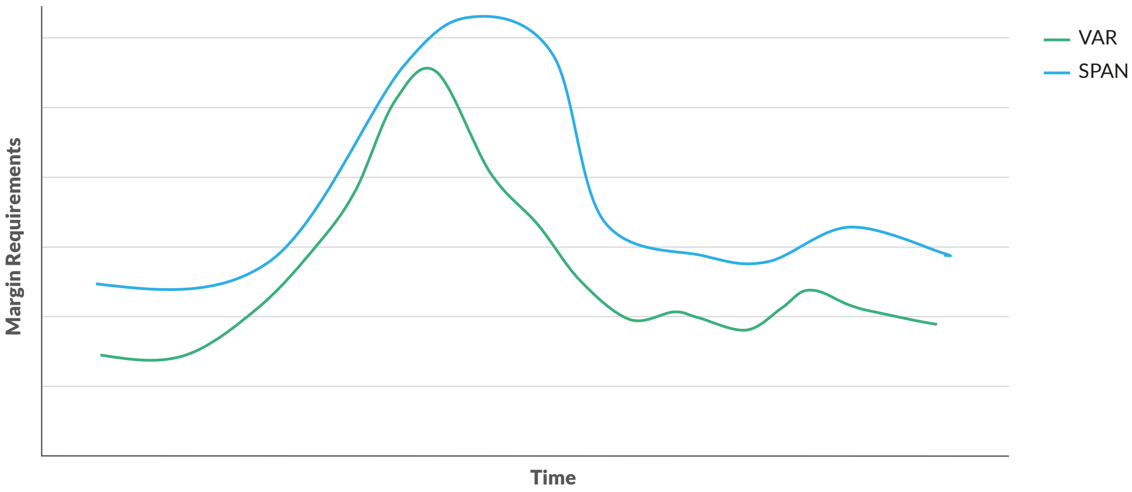


Figure 1: Comparison of Margin Requirements Under VaR and SPAN: VaR typically lowers margins overall but reacts faster to volatility

needs and goals might change over time as well. Even changes in the clearing methodologies will have side effects that demand renewed attention.

Continuous Attention: Migration from SPAN to VaR-Based Clearing Models

Clearing in itself went through massive changes initiated by the various clearing houses, market developments, and impactful events. One of the most significant transitions is the current shift from SPAN-based margin models to Value at Risk (VaR) -based methodologies. These VaR margin models capture portfolio correlations more accurately, include broader offsetting across positions and, not to forget, lead to (significantly) lower margins, essentially bringing a positive effect for the end-user. The recent move by ICE Clear to their VaR-based model IRM 2.0 in early November is a good example: initial margin reductions of up to 25-30% have been observed.

However, VaR models also respond much faster to price volatility and rely less on slowly adjusting parameters. Margins can change more dynamically from one day to the other. On top, each CCP is developing its own version, making it more difficult for trading firms to replicate the margin calls or even forecast the expected amounts for the next day with the same precision as before.

Besides this obvious impact, these developments can affect the entire value chain, including the way clearing banks structure their services and manage client risk. This triggers the need to give clearing the strategic attention it deserves: choosing the right clearing partner but also the right account type, understanding the level of protection, assessing residual risks, reviewing the clearing agreements and conditions, etc. Only after all that is the final step to define a full response plan for unexpected and extreme events.

Clearing: a Strategic Element of Your Trading Business

With the right level of preparation, clearing is not a threat but a solid advantage. It enables firms to operate with confidence, reducing key risk elements to a bare minimum while maintaining access to the transparent, secure, and well-regulated environment that exchanges offer. A well-designed clearing setup acts as both a professional framework for daily trading and as a strong protection shield against exceptional market turbulence.

For new startups, clearing is not something to be afraid of, and for established market players, the current changes are a strong signal to review and strengthen the arrangements. Companies that invest in this preparation will be well-positioned to benefit from the opportunities in today's dynamic energy markets.

Figure 2: Future-Proof Clearing

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The Mechanics of Settlement Risk in OTC Energy Trading Markets

Settlement is the critical final stage of the trade lifecycle, where notional P&L becomes actual cash flow and physical title transfer. It is also the point at which traders face the greatest risk: the potential loss of the full value of a delivered commodity if settlement fails.

In today's market, shaped by volatility, broader participation, and the aftershocks of the 2022 liquidity crisis, settlement is no longer a back-office checkbox. Instead, it is a trader's imperative, requiring an understanding of settlement risk. This includes settlement timing risk (Herstatt Risk[1]) embedded in M+20 cycles, along with the automation tools needed as markets accelerate toward T+1 settlement.

To understand this pressure point, its necessary to distinguish between the key categories of risk embedded in OTC energy settlement:

1. A Taxonomy of Settlement Risks

In OTC energy trading, risk is a triad of distinct exposures: Counterparty default risk, settlement timing risk, and operational failure risk (see Figure 1). Counterparty default risk encompasses both replacement cost and principal risk, with principal risk exposure typically far larger.

Settlement timing risk is a systemic exposure codified in the EFET Agreement. According to EFET, European power and gas contracts typically settle on the 20th of each month following delivery (M+20). The seller delivers continuously, while the buyer pays with a delay, creating a unidirectional credit extension. This asynchronous structure embeds Herstatt risk over weeks, rather than days, exposing market participants to full principal loss if a counterparty defaults between delivery and payment.

Operational failure risk arises from system failures, human error, or process inefficiencies that can translate directly into financial loss under strict grid-balancing rules.

2. Settlement Risk Mitigation

Effective mitigation relies on legal structures (contract text) and active credit management, through:

- **Close-Out Netting:** This is the most critical mitigation tool. It is the legal right to offset mutual obligations upon default. However, enforceability varies by jurisdiction, as some bankruptcy laws prioritize gross asset recovery. Risk managers rely on legal opinions to determine whether credit limits can be set on a net basis, thus enabling liquidity, or must remain gross, restricting trading.

Table 1: Summary of Settlement Risk Mitigation Techniques

Technique	Risk Targeted	Mechanism	Key Limitation
Close-Out Netting	Counterparty Default	Offsetting mutual obligations upon default	Requires legal enforceability in the relevant insolvency jurisdiction
Credit Support Annex	Replacement Cost	Daily exchange of variation margin.	Creates liquidity risk (cash drag) and requires daily operational processes
Central Clearing	Counterparty Default	Novation to central entity; default waterfall	Concentrates systemic risk; rigid margin calls cause liquidity crises
Payment Netting	Settlement Timing Risk (Herstatt Risk)	Netting monthly invoices (cash flow reduction)	Only reduces settlement risk, not replacement risk; valid only if solvent
Confirmation Matching	Operational	Pre-verification of trade terms	Does not prevent physical nomination errors downstream
Settlement Matching	Operational / Timing	Automated invoice matching (T+n)	Adoption rate; requires IT integration

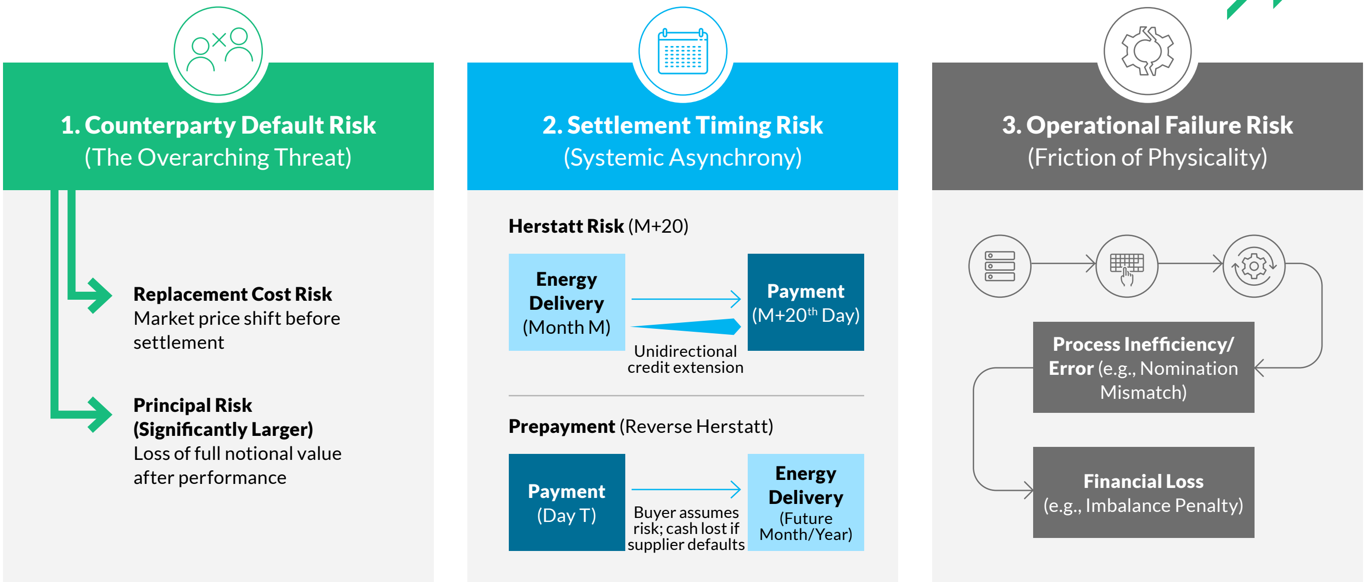

Figure 1: OTC Energy Trading Settlement Risks

- **Collateral Management:** The Credit Support Annex (CSA) governs collateral posting to mitigate risk. Variation margin is the daily re-valuation of portfolios (mark-to-market). If values shift, the losing party posts cash/securities to cover replacement cost risk. Independent amount (initial margin) covers gap risk, the potential volatility between the last margin call, and the time of close-out. Lastly, Material Adverse Change (MAC) clauses may trigger additional collateral following credit deterioration (for example, below BBB-).
- **Migrating to Central Clearing Counterparties (CCPs):** This mitigates risk via novation. The CCP becomes the buyer to every seller and the seller to every buyer, extinguishing the original bilateral contract. CCPs are bankruptcy remote, utilizing a default waterfall to cover losses.
- **Liquidity Trade-Off:** The 2022 energy crisis exposed the liquidity trade-off inherent in clearing. Margin calls shifted risk from counterparty insolvency to funding liquidity, pushing otherwise solvent firms into technical default.

While legal structures handle insolvency, day-to-day risk often is operational. Traders must aggregate large transaction volumes, adjust forecasts, and net them to 15-minute grid intervals.

To combat operational failures, the industry is increasingly adopting EFET's electronic Settlement Matching (eSM) standard, enabling automated T+n settlement matching that flags discrepancies early and reduces disputes.

Earlier matching also shifts dispute resolution upstream, reducing manual intervention at month-end and improving cash-flow predictability. However, achieving accelerated settlement will require new approaches to liquidity management, intraday funding, and closer alignment between wholesale settlement cycles and retail cash collection, particularly for utilities with monthly retail billing cycles.

3. The Future: Accelerated Settlement

The pressure to modernize is mounting. While USA financial markets have moved to T+1 settlement, OTC energy trading continues to operate on M+20 settlement cycles, allowing credit exposure to compound to ~50 days.

Moving energy to daily/weekly settlement would drastically reduce capital requirements and systemic risk. However, a structural gap remains. Utilities collect revenue from retail customers on a monthly basis, while paying wholesale costs daily (T+1), creating a significant one-sided working capital deficit.

[1] "Herstatt Risk" derives from the 1974 collapse of Bankhaus Herstatt (FX markets). Regulators closed the bank after it received DM payments but before releasing USD payments, causing 100% principal loss for counterparties.

Conclusion:

Settlement risk in European OTC energy markets represents a hybrid exposure where the slow, monthly rhythms of physical billing collide with the instant volatility of modern power grids. Mitigation has evolved from bilateral trust to a sophisticated architecture of master agreements, CSAs, central clearing, and automated matching. The trajectory is clear: the market is converging toward accelerated settlement. The capital cost of the traditional M+20 payment cycle is becoming unsustainable in a digitized sector that is shaped by renewables. While the shift to T+1 cycles appears inevitable, it demands a fundamental re-engineering of utility cash flow strategies. Market participants must now trade liquidity risk for credit risk. This high-stakes structural shift will define the next decade of energy trading.

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Renewable Energy for Tomorrow – Some Thoughts on Quantifying Uncertainty in Prediction

The rapid and sustained expansion of renewable energy, particularly wind and solar power, presents substantial challenges for the integration into electricity systems. Because wind and solar generation depend on weather conditions, they cannot be easily dispatched on demand. This intermittency introduces uncertainty into the energy system, requiring continuous balancing of supply and demand. Unexpected production deficits lead to higher-cost compensation from flexible conventional generators, while excess renewable supply results in curtailment and negative prices.

Short-term renewable generation forecasts, over intraday to multiday-ahead horizons, help reduce uncertainty about future renewable production. These forecasts enable more efficient reserve allocation, reduce reliance on conventional plants held in standby, improve unit commitment and economic dispatch decisions, and support grid stability by allowing operators to better plan for fluctuations in net load. They also help energy market participants to pursue more optimal trading strategies.

In recent years, numerous data-driven techniques, including machine learning models, have improved the accuracy of renewable energy forecasts. However, due to the inherently unpredictable nature of weather, forecasts are never exact. Point forecasts, as single-valued estimates of future outcomes, fail to capture the range of plausible realizations. In contrast, probabilistic forecasts deliver a predictive distribution, quantifying both expected outcomes and their associated uncertainty, thereby supporting risk-aware decision-making in power system operations.

In renewable energy, uncertainty emerges from multiple sources and layers, which can be captured through probabilistic forecasts in several ways.

One approach is to introduce uncertainty through the inputs, for example, by generating multiple meteorological scenarios, assigning each a probability, and feeding them into a point forecasting model. The resulting ensemble of forecasts forms a distribution that reflects uncertainty in the inputs.

Alternative approaches capture model-based uncertainty, which is uncertainty in the relationship learned from the data, either through probabilistic model construction or through post-processing of point forecasts. Common examples of the former include Bayesian models and quantile regression methods, which directly issue distributional outputs. We provide an example of this approach by probabilistically forecasting wind and solar power production using Bayesian inference (The basis of our example is data from the Atacama Region in Chile, with the location of renewable power plants shown in Figure 2).

A core characteristic of renewable energy data is its diurnal and seasonal pattern. To capture this structure, each day's 24-hourly power measurements are treated as a single unit of observation. Rather than modeling the full 24-dimensional vector directly, each trajectory is represented through a small set of latent factors extracted through principal component analysis.

In other words, the 24-hourly measurements are embedded into a lower-dimensional space. The latent factors in the embedding space summarize the dominant patterns that govern both the shape and

[1] Mestekemper, Thomas, Göran Kauermann, and Michael S. Smith. "A comparison of periodic autoregressive and dynamic factor models in intraday energy demand forecasting." International Journal of Forecasting 29.1 (2013): 1-12.

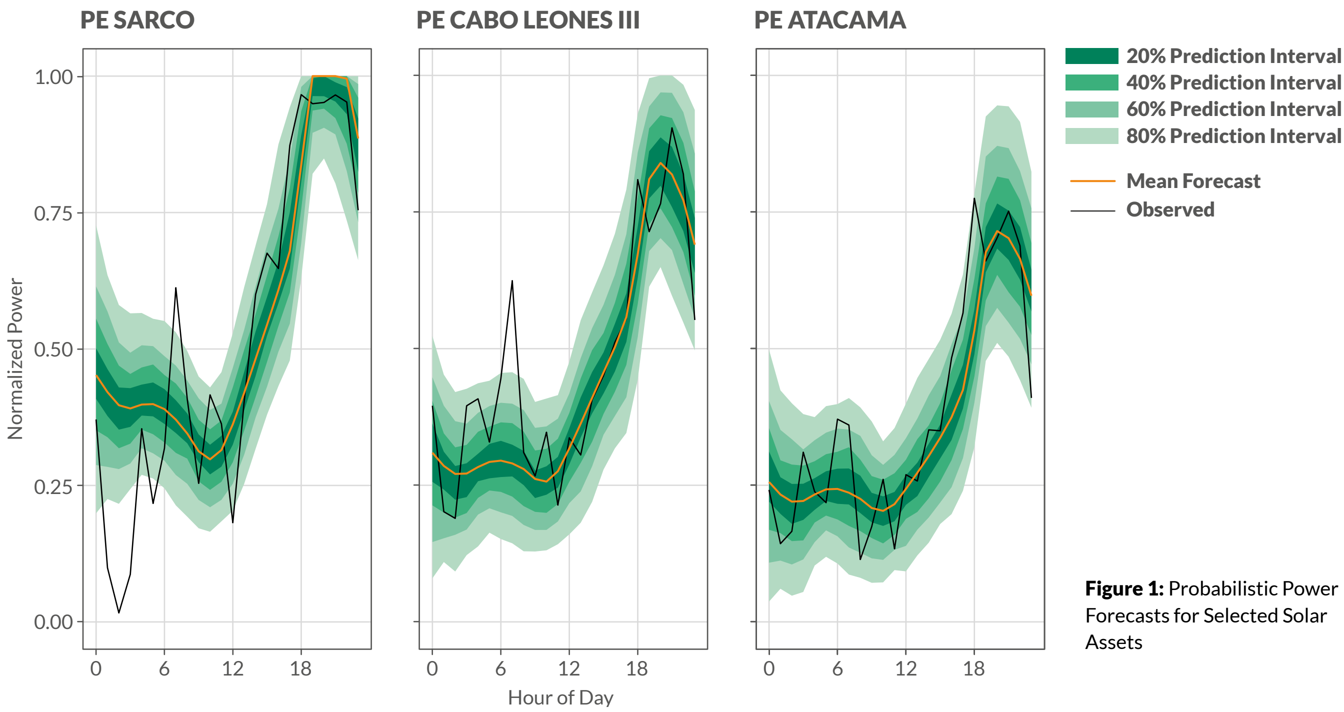

Figure 1: Probabilistic Power Forecasts for Selected Solar Assets

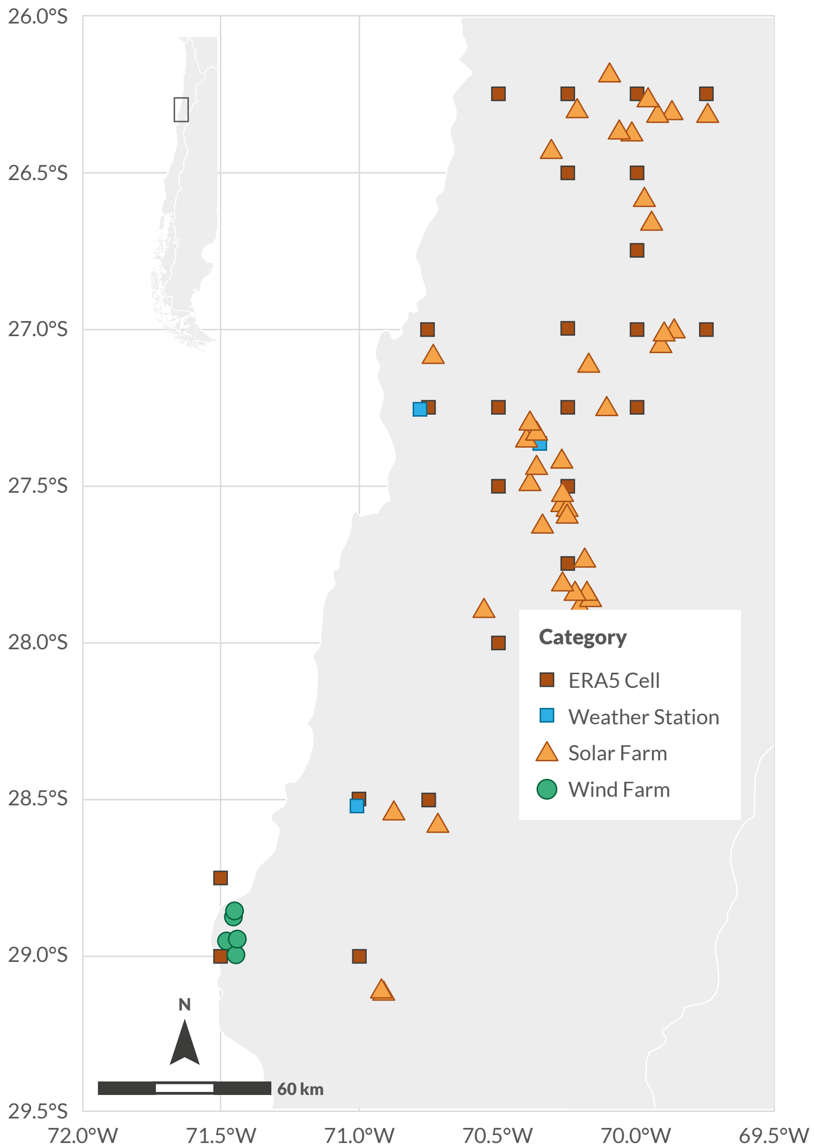

Figure 2: Spatial Distribution of Renewable Assets and Weather Data in Northern Chile

the variability of the daily power curves, providing a compact yet highly interpretable basis for forecasting. The same technique is applied to weather forecasts. Formally, the model corresponds to a dynamic factor model. In simple terms, the complex diurnal and seasonal dependencies of wind, solar, and weather are modelled in low-dimensional latent spaces, and Bayesian estimation allows to extract probabilistic forecasts (details are provided in the recent master's thesis of the first author[1]).

An exemplary distributional forecast for multiple wind power plants in Chile is given in Figure 1. The solid black line is the observed power generation. The green ribbons represent the prediction intervals constructed using the empirical quantiles from the posterior draws. Prediction intervals are reported at nominal levels of 20%, 40%, 60%, and 80%, corresponding to the expected coverage probability, which is the probability with which the observed value is expected to lie within the interval.

Ideally, probabilistic forecasts achieve this coverage in practice, while adjusting interval width to reflect the uncertainty of individual predictions, widening under volatile conditions and narrowing when forecasts are more certain. For wind and solar power generation, this reflects weather-driven variability across the diurnal cycle.

Ten Steps for Dealing with Cyber Risks

Cyber risks are among the greatest threats today, yet they are also the least covered. Few decision makers understand cyber security issues. Measures are not always implemented consistently enough.

THOMAS FÜRLING
CEO | e3 AG

Cyber security issues include defending against threats such as malware and ransomware, securing networks, access, and data, as well as strengthening risk management, contingency planning, and employee training.

Most companies must also deal with security for AI, the cloud, and the supply chain. In addition, security systems must be checked regularly. Bringing in an organization that specializes in cyber defense ensures Confidentiality, Integrity, and Availability (CIA).

The CIA Triad

To maintain business operations without disruption, the CIA triad is critical.

Integrity is best covered by the triad, which happens primarily in applications. Digitalization and automation ensure more consistent application coverage of processes. This leads to increased integrity as a by-product, through better auditability via logs and fewer process interruptions.

Availability is threatened by ransomware encryption of systems and distributed denial-of-service (DDoS) attacks. While these can usually be resolved by a specialized network provider, the ransomware problem runs deeper. Confidentiality is under attack on several fronts. Ransomware attacks are increasingly focused on stealing data, rather than just encrypting systems. To prevent disclosure, money is extorted and data is offered for sale.

Another potential threat is employees stealing data for later use. The risk of illegal access by governments has also increased. More must be done to protect data in connection with AI.

Step 1: Develop ISMS

An information security management system (ISMS) creates clarity, prevents important risks from being overlooked, and protects against unnecessary investments.

Availability
Protect your resources from external manipulation, manage necessary capacities and ensure that errors are detected preventively or as quickly as possible.

Step 2: Protect Systems

Antivirus software, firewalls, and strong authentication are essential to prevent attackers from taking over systems. "Living off the land" attacks exploit existing resources. Access to these resources should be prevented wherever possible.

Step 3: Prevent DDoS

Engage your network operator to prevent denial-of-service attacks. This must be done by a specialist with sufficient resources.

Step 4: No Reaction without Detection

Good monitoring of all resources is important, as attacks cannot be prevented 100% of the time.

Step 5: Deploy Rapidly

Deploying new resources must happen quickly on clean sources, so a secure environment can be swiftly restored. Kubernetes is one of the most common methods. "Infrastructure as code", in conjunction with hyperscalers, also offers a good measure of high availability.

Confidentiality
Confidentiality is based on two principles: data can be locked or encrypted, while all other measures essentially relay in trusting the providers. However, in a zero-trust approach, that implicit trust in data storage and management is deliberately removed.

Step 6: Use IAM

Authorization of access (IAM) is a mandatory requirement for people, machines, services, and AI agents.

Step 7: Draw a Perimeter with DLP

Data should be where it is needed. Everywhere else, it is unnecessary. If the environment is under full control, establishing a perimeter, through data loss prevention (DLP) or resource separation, is sufficient. Since DLP is required, it is advisable to start with it first. However, segregation impacts the entire architecture, which makes it costly to install.

Step 8: Encrypt

If a system cannot be fully controlled, it poses a challenge to sovereignty. This can be addressed by using more local resources, through greater trust in contracts, or with encryption.

More local resources require established tools, capacities, and functionalities. Europe has lagged behind in this area. There is even a risk that AI increases dependencies.

Trust through better contracts might be difficult in the current geopolitical situations. Hence, encryption remains the only feasible and sustainable solution to address the sovereignty.

Step 9: RMS and CDPG

Data encryption depends on representation of the data. Files are encrypted using rights management solutions (RMS). Data in structured form requires field-level encryption of tokenization, usually provided by cloud data protection gateways (CDPG).

Cyber Security in Municipal Utilities
The resources available to municipal utilities are limited. Most expenditure is therefore absorbed by day-to-day operations. Cyber security should be integrated into day-to-day operations on a risk-based basis. For the measures to be effective, they must not be treated as a minor issue.

Step 10: Keep It Simple

An integrated risk management system is necessary to identify critical aspects and address them directly. Avoiding unnecessary actions is as important as taking the appropriate measures. This is the only way to make optimal use of available resources.

Cyber Security in Energy
Energy must flow. Availability is therefore the most critical factor. As a highly attractive target, defense against external attacks is of primary importance. Therefore, no compromises should be made on steps 1 to 5.

A network of suppliers makes integrity a significant issue. The chain breaks at its weakest link. For integrity, this means that no link can be weaker than the entire chain. This requires standards, regulations, and a mutual understanding.

AI
The data hunger of AI is insatiable. Without data for training, the models will not improve. Exposing data only where necessary is an important factor.

It will be difficult to operate without AI in the future. That is why two other aspects are currently becoming more important:

1. Prompt management prevents sensitive information from reaching AI via queries (prompting).

2. Agentic AI is the new hot topic. Countless agents with specialized tasks collaborate to achieve an overall result. For this to work, these agents often have extensive permissions. To ensure they do not undermine the "least privilege" effort, every action taken by these agents should be analyzed on a case-by-case basis.

Next Steps

This article has outlined the overarching direction and key considerations for addressing these challenges. It is not intended to define a fully integrated risk management framework or a comprehensive ISMS. Where these structures are not yet in place, establishing them should be the immediate next step and the foundation for future progress.

Ransomware Considerations

Preventive measures include backups, awareness training for employees, and keeping a watchful eye. With AI-supported attacks, their quality typically increases faster than employee awareness.

To avoid blackmail over content, and to prevent it from being sold to third parties, encryption is recommended. This removes a significant part of the attackers' business case, causing them to focus on easier targets.

Risk Thinking.ai

DR. RON DEMBO
Founder & CEO
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RiskThinking.ai produces solutions for measuring and managing climate financial risks.

Its ClimateEarth DigitalTwin™ and forward-looking stochastic methodology uniquely position the company to assess the effects of climate risk on banks, insurance, infrastructure, and asset management.

www.riskthinking.ai

The Evolution of Data for Enterprise Risk Management in an Energy Company

For decades, Enterprise Risk Management (ERM) in the energy sector has concentrated on market volatility, credit risk, and operational safety. However, a new systemic factor has appeared that is fundamentally different: climate-driven physical risk. Unlike traditional financial risks, climate risk is non-stationary.

As regulators – particularly in the UK – move to treat climate risk equally with market and credit risk, the energy sector must shift from relying on historical data to incorporating forward-looking stochastic data and analytics.

The Direct Link: Climate Variability and Energy Performance

The shift to a renewable-dominated grid has established a direct, heightened sensitivity connection between climate patterns and asset-level performance. In the traditional energy sector, a power plant's fuel was a commodity with a market price. In the renewable sector, the "fuel" is the climate itself.

Solar generation: Variations in cloud cover patterns and local ambient temperatures directly influence photovoltaic output. A 2-degree Celsius rise in local temperature can reduce solar cell efficiency, thereby affecting the asset's Internal Rate of Return (IRR) during the mid-lifecycle.

Wind generation: Like solar panels, wind turbines tend to perform better in colder conditions. However, for wind turbines, this is because denser air carries higher kinetic energy, a different mechanism from that affecting solar panel performance. Variations in local wind shear and the frequency of "wind droughts" can cause substantial revenue shortfalls. If climatological drift at a specific site is not accounted for in the asset's financial model, it can lead to overestimation or underestimation of the asset's value. Both excessive and insufficient wind levels can pose challenges.

Transmission lines are considered "linear assets" that are exposed to climate-related physical risks at multiple sites, potentially under different hazard conditions.

The Adaptation-Efficiency Nexus

An often neglected, yet key aspect of climate ERM is the connection between infrastructure adaptation and energy efficiency. In the energy sector, adaptation is usually seen as a "cost" of strengthening assets against extreme weather. However, a detailed risk analysis uncovers a dual benefit:

1. Structural Resilience as an efficiency enhancer: Strengthening a structure to endure extreme heat or storms typically involves upgrading materials and building envelopes. These modifications often lead to significantly reduced energy costs and lower operational baselines.

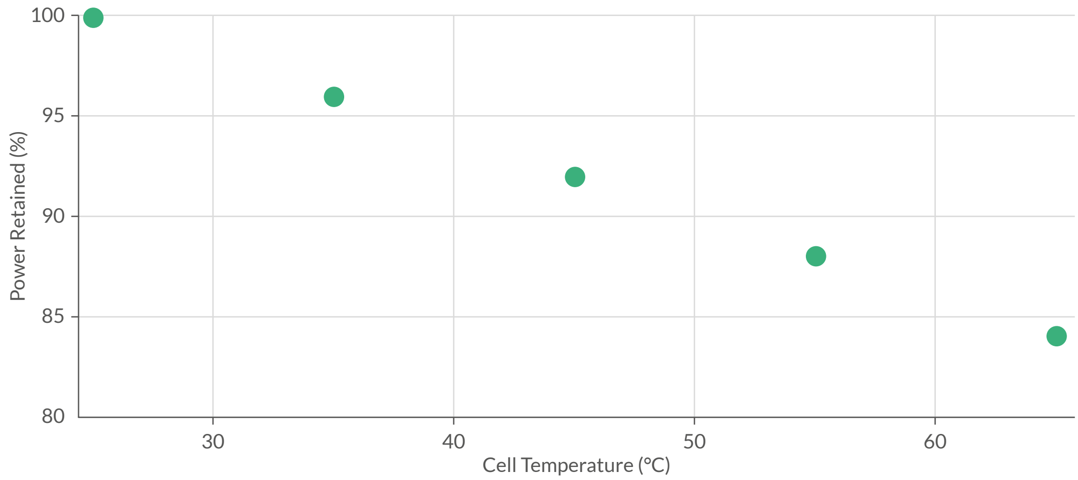
2. Optimizing the Balance Sheet: By viewing adaptation through the lens of efficiency, risk managers can shift from "disaster mitigation" to "performance optimization". An adapted asset is not just safer but also more cost-effective over its lifecycle.

Geographic Non-Equivalence in Enterprise Risk

Traditional energy ERM often considers identical assets, such as two substations or two LEED-certified office buildings, as having similar risk profiles within the same asset class. Climate analysis shows that this is a misconception.

The Coordinate-Specific Risk: Two identical buildings in different locations face markedly different systemic risks. One may be threatened by subsidence from

Power Retained vs. Cell Temperature



Source: IEC 61215 standard, Note: Y-axis starts at 80%

Figure 1: Power Retained vs. Cell Temperature

drying clay soils, while the other, just a few kilometres away, faces hazards like flash flooding or equipment failure caused by extreme heat.

The Granular Gap: Without a climate-first approach, an enterprise risk report may misclassify these assets, thereby obscuring the "geographic tail risk". Real estate and energy portfolios require analysis at the coordinate level to identify where 'standardized' infrastructure fails due to local climate variations.

Technicalities of Geospatial Granularity

Energy assets, such as a single wind turbine, a substation, or a section of the transmission grid, are "small" data points in a geospatial sense, but they carry significant financial weight.

Spatial Resolution vs. Relevance: Standard climate models operate on grids of 100km or more. For an energy asset, we must use downscaled data that considers local topography and microclimates. A wind turbine on a ridge faces a different risk profile than one in a valley a kilometer away.

Geospatial Data Governance: Unlike financial trades, geospatial climate data requires a strict governance framework to ensure that the "lineage" of the data point is clear. The provenance of the geospatial coordinate is as important as its value.

The Burden of Forward-Looking Derived Data

Regulators now require forward-looking data, but this data is mostly "derived" – it results from complex models rather than direct observation. This also involves managing significant uncertainty.

The Validity of Derivation: When we derive a 2040 wind-speed projection, we combine model assumptions with uncertainties in the carbon pathway.

The Governance of Uncertainty: It is no longer enough to report just a single number. We need to show the range of outcomes and how sensitive the data is. If a risk manager cannot explain the "why" behind a derived climate metric, that data becomes a liability rather than an asset.

From Deterministic to Stochastic

To align climate risk with market and credit risk under UK regulations, we need to treat climate data as stochastic. However, this affects the analytics used.

The ClimateEarthDigitalTwin™: At RiskThinking.ai, we utilize a "digital twin" approach to run thousands of potential future scenarios for a specific asset location.

Multifactor stress testing is essential because many factors can influence an asset over time. This enables us to identify the "tail risks" that deterministic models often overlook.

These stress tests must be generated algorithmically, as it is impossible for humans to consider all possibilities. From a governance perspective, we need to assess the accuracy of these simulations.

Multivariate Analysis: We must integrate physical climate variables with financial variables. A physical risk event often coincides with a market risk event but also managing them separately is no longer practical.

Protecting the Balance Sheet

Integrating climate data into ERM is more than just a compliance task. It is a fiduciary duty. By using a science-based stochastic approach that considers geographic non-equivalence and the connection between adaptation and efficiency, energy companies can identify which assets are genuinely resilient and which are "financially stranded".

Naturally, in this article, we have only just touched on the applications to the energy sector. There are clearly more areas affected by climate.

Glossary

Asset Default Probability
The probability that an asset has a longer outage or defaults completely.

Basis Risk
A difference that occurs because the price of the hedging instrument and the price of the underlying asset do not change identically, even though they are correlated.

Brown-Green-Score
A classification index that measures how "brown" (carbon-intensive, fossil-fuel dependent) or "green" (low-carbon, sustainable) a company or portfolio is.

Carbon Risk
The financial and operational risk a company faces due to its carbon footprint and exposure to carbon-related regulations, taxes, or market changes.

Carbon Risk Rating
A metric or score that evaluates a company's exposure to carbon-related risks and its ability to manage them.

Cash Flow at Risk (CFaR)
The difference between expected cash flow and cash flow at a given confidence level (the $(1 - \alpha)$ quantile). CFaR indicates if a company has sufficient cash reserves and supports assessment of capital structure and creditworthiness.

Central Clearing Counterparties (CCPs)
Clearing institutions that mitigate counterparty credit risk by interposing themselves between buyers and sellers, enforcing margin requirements, netting positions, and maintaining default funds.

Clearing
The process in which a CCP interposes itself between trade counterparties to manage credit risk and ensure settlement.

Climate Risk
The broader, long-term risk associated with climate change and its consequences.

Compliance Risk
The risk of legal or regulatory sanctions, financial loss, or reputational damage that an organization faces when it fails to comply with laws, regulations, internal policies, or industry standards.

Correlations
Reflections of how strong two curves (such as price time series) are positively or negatively related.

Corruption Index
An indication of the role corruption plays in the country of the counterparty.

Counterparty Limit (Exposure)
A defined exposure limit for a counterparty. If this limit is reached, mitigating measures need to be conducted.

Counterparty Open Position
The total Mark-to-Market (MtM) value of all trades with a counterparty.

Counterparty Risk
The risk that the other party in a deal will default before the final settlement.

Credit Risk
The risk of financial loss arising from a counterparty failing to meet its contractual obligations (such as not paying on time or at all).

Credit Scoring / Credit Rating
The external or own calculated scoring of a counterparty's creditworthiness.

Credit Spreads
The extra compensation (in basis points) that investors demand for taking on the credit risk of the issuer, compared to a risk-free investment.

Earnings at Risk (EaR)
The difference between expected earnings and earnings corresponding to a given confidence level.

Electronic Settlement Matching (eSM)
An automated reconciliation process that matches settlement and invoicing data between trading counterparties, reducing operational risk.

Energy Trading and Risk Management (ETRM)
Integrated systems and processes supporting trade capture, valuation, risk measurement, settlement, and compliance across energy portfolios.

Enterprise Risk Management (ERM)
A holistic, organization-wide framework for identifying, assessing, and managing market, credit, operational, and strategic risks within a unified governance structure.

Equity
A reflection of the net worth of a company.

European Federation of Energy Traders (EFET)
A European industry body developing standard energy trading agreements and promoting liquid, harmonized wholesale markets.

Expected Loss
The expectation of loss due to counterparty default, considering probability of default, loss given default, and exposure at default.

Expected Shortfall or Conditional Value at Risk (CVaR)
An estimate of the average loss in worst-case scenarios beyond a given confidence level.

Exposure
The amount of money that one party stands to lose if the counterparty defaults, given the current or future values of the transactions between them.

Exposure at Default
The amount of exposure a bank or trading firm expects to have at the moment that a counterparty defaults.

Full Valuation
The calculation of the financial value of a trade or contract across its entire lifecycle, considering all relevant factors.

Funding Risk
The risk that an institution will be unable to obtain the necessary funding to meet its obligations as they come due, or that the cost of funding will rise significantly.

FX Risk
The risk due to trading with foreign currencies or trading commodities in other currencies.

Greeks
The sensitivities of a derivative's payoff function, compared to market prices (Delta, Gamma), volatility (Vega), and other factors.

Gross Margin at Risk
A risk metric that estimates the potential reduction in gross margin (revenues minus variable costs), due to adverse market movements over a specified time horizon and confidence level.

Initial Margin
The margin that needs to be posted at the exchange when entering into an exchange-traded derivative.

Interest Rate Risk
The risk of loss due to changes in interest rates that can affect the value of fixed-income instruments, derivatives, and funding costs.

Know Your Customer (KYC) Workflow and Credit Check
A process where different aspects of the counterparty are checked to understand if it is safe enough to engage in trades with the counterparty.

Liquidity Risk
The risk that a company does not have enough liquid assets (cash) to cover liabilities or unexpected cash outflows.

Margining Workflow
The end-to-end process of calculating, calling, posting, and reconciling collateral (margin) between two parties, to cover potential losses from market movements or counterparty default.

Mark-to-Market (MtM)
The not-yet-realized profits and losses (PnL) of each deal, which estimates how the PnL will evolve.

Monte Carlo Simulation
A stochastic simulation method that models the distribution of portfolio outcomes by repeatedly sampling from underlying risk factors.

Operational Risk
The risk of loss resulting from inadequate or failed internal processes, people, systems, or external events.

OTC Cash Flow
The margin cash flow between two counterparties on an OTC deal.

Profit and Loss (PnL)
A financial metric summarizing trading performance, combining realized gains or losses from closed transactions with unrealized mark-to-market valuation changes on open positions.

Profit at Risk (PaR)
A risk measure that estimates the maximum potential decline in profit over a specified time horizon and confidence level, given normal market conditions.

Potential Future Exposure (PFE)
A risk metric used in counterparty credit risk management to estimate the maximum expected credit exposure a firm might face at a future point in time, under normal market conditions, and with a given confidence level.

Physical Risk
The potential financial, operational, and strategic impacts that arise from physical hazards that are linked to climate change or environmental events.

Price Forward Curves
(Self) calculated curves that are in line with observed market prices, representing the expected future prices of a commodity, asset, or financial instrument for different delivery dates.

Probability of Default
The probability that a counterparty is unable to meet its obligations.

Profile Risk
The risk of renewable assets' production profile being different than expected.

Realized Profit and Loss (PnL)
Refers to the actual gains or losses that have been locked in after closing a position or completing a transaction.

Regulatory Risk
The risk due to changing regulations.

Replacement Risk
The risk that a counterparty defaults on a contract, where the original party must replace the transaction at a less-favorable market price.

Supply Chain Risk
The potential for disruptions or failures within a company's supply chain that can impact production, delivery, or profitability.

Taylor Approximation
A polynomial-based method commonly used in energy trading for estimating changes in product values and risk metrics without full revaluation.

Unhedged Position
The open position between asset production and associated hedges.

Value at Risk (VaR)
An estimate of the potential loss of a portfolio over a given time horizon at a specified confidence level. Analytical VaR: Calculates analytically using observed volatilities and correlations. Historical VaR: Based on actual historical market data. Monte Carlo VaR: Based on simulated market scenarios; more computationally intensive.

Variation Margin
The daily margin changes on the exchange due to fluctuating market prices.

Volatilities
These reflect how much and how quickly prices or volumes move, and is used as an indicator of risk or uncertainty.

Volume Risk
The risk of assets (especially renewables) producing different volumes than expected (for example, because of different weather patterns or outages).

VUCA (Volatility, Uncertainty, Complexity, Ambiguity)
A framework describing market environments with high price variability, limited predictability, interdependent drivers, and unclear causal relationships.

Weather Risk
The financial or operational risk arising from short-term weather variability (such as daily or seasonal changes).

Dear Readers,

Digitalization. New, exotic products. Artificial Intelligence (AI). Increased volatility. Accelerated pace. These are just a few of the challenges that risk managers in the energy industry must deal with today. In an environment that is changing so fast, it is difficult to keep up-to-date with all these topics simultaneously.

This 4th Edition of FORRSight Magazine tackles important questions in these areas.

Only through close collaboration and exchange among diverse stakeholders, current and future challenges can be successfully addressed. With the insights and experience of the long-established, innovative professionals or leaders and companies featured in this edition, we aim to contribute to a holistic perspective on the future of the energy industry.

The mission of FORRS has always been to strengthen connections and foster new partnerships, whether with utilities, consumers, service providers, technology companies, universities, or other key market participants. We are convinced that dialog and collaboration will lead to innovative solutions that will sustainably shape our industry.

We would like to thank all those who contributed to this issue with their knowledge and perspectives. Without their valuable support and expertise, this collection of inspiring content would not have been possible.

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