

Original Research Article

Research on optimizing sulfur production and sales strategies based on supply and demand trend analysis

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Abstract: Against the backdrop of global energy transition and restructuring of the chemical industry chain, sulfur—A critical industrial byproduct and chemical feedstock—Is undergoing profound shifts in its market supply-demand dynamics. China's sulfur market currently exhibits high external dependency and severe regional supply-demand mismatches. This paper analyzes the structural contradiction of "excess liquid, insufficient solid" in product composition and logistics bottlenecks faced by enterprises, based on the "tight balance" status of the domestic sulfur market and using the practical case of a natural gas purification plant in northeastern Sichuan. It applies supply-demand equilibrium theory and the 4Ps marketing theory. The study proposes implementing a capacity optimization strategy of "solid-liquid adjustment and solid-based flow maintenance." This involves expanding into high-value-added niche markets like new energy materials and establishing a digital-intelligent production-sales coordination system. These measures aim to maximize sulfur resource value and enhance the enterprise's risk resilience.

Keywords: sulfur market; supply and demand trends; production and sales strategies; new energy demand; structural optimization

1. Introduction

As a key byproduct of petroleum refining and natural gas purification, sulfur has long been regarded as an environmentally friendly co-product for treating acid gases, with its economic value remaining largely untapped. However, with the acceleration of global energy transition and the "carbon neutrality" process, sulfur's resource attributes are undergoing a transformation. Particularly against the backdrop of explosive growth in the new energy industry, the reliance on sulfur resources for new materials such as lithium iron phosphate batteries has significantly increased. By 2030, global sulfur demand is projected to shift from traditional "agriculture-dominated" drivers to a "dual-engine" model propelled by both industrial and new energy sectors. This trend necessitates upstream producers to reevaluate their production and sales models to adapt to the evolving market landscape.

In the Chinese market, supply-demand mismatches and structural imbalances remain pronounced. As the world's largest sulfur consumer, China faces relatively scarce domestic resources. Its 2025 consumption reached approximately 18 million tons. Domestic production capacity is primarily controlled by leading state-owned enterprises like Sinopec and PetroChina, exhibiting significant regional imbalances: major production zones are concentrated in Southwest China (e.g., Puguang and Yuanba gas fields), The primary consumer markets are concentrated in the southwest, north, and east regions., widening the spatial gap between production and consumption.

For natural gas purification enterprises in Southwest China, this spatial mismatch compounded by product structure imbalances has created severe operational challenges. Take a purification plant in northeastern Sichuan as an example: liquid sulfur sales account for 80% of its output. Constrained by hazardous chemical transport radii (typically under 500 kilometers) and downstream plant maintenance schedules, its sales channels lack flexibility. Any disruption in liquid sulfur shipments directly triggers inventory shortages, forcing upstream

gas fields to reduce production—Creating severe production safety hazards and operational risks. Therefore, amid intensifying market volatility (such as the price hitting a record high of 2,465 yuan/ton in Q1 2025 before retreating), grounded in new shifts in supply-demand trends, in-depth research into optimizing sulfur production and sales strategies is not only an urgent necessity to alleviate the current structural imbalance of "excess liquid, insufficient solid" but also crucial for ensuring upstream energy supply security and maximizing resource value.

2. Analysis of sulfur market supply-demand dynamics and marketing trends

2.1. Global supply landscape: Middle east's core position and low-cost impact

Global sulfur supply exhibits pronounced "geopolitical concentration," with the Middle East serving as the "ballast" of worldwide supply. The region accounts for over 40% of global production and dominates half of the trade volume. Saudi Arabia, the United Arab Emirates, and Qatar collectively contribute 85% of the region's capacity, forming a supply system with substantial economies of scale. Notably, new projects in the region widely adopt advanced recovery technologies like GD50, achieving recovery rates exceeding 99.9%. Leveraging abundant associated gas resources, their production costs are 15%-20% lower than those of by-product sulfur from Chinese refineries^[2]. As Middle Eastern and Central Asian capacities continue to expand, China's sulfur import market is undergoing profound restructuring. While diversifying import sources helps mitigate geopolitical risks, the persistent availability of low-cost imports exerts sustained downward pressure on pricing power for domestically produced, higher-cost by-product sulfur. This forces domestic enterprises to shift from pure "price competition" toward "service and differentiated competition."

2.2. Domestic market dynamics: Structural differentiation amid tight supply-demand balance

As the world's largest sulfur consumer, China's market is accelerating its shift from a "relatively loose" state to a "tight balance," with pronounced structural divergence emerging on both the supply and demand sides. On the supply side, domestic capacity growth has entered a plateau phase. Constrained by the refining industry's transition toward lighter feedstocks, China's domestic capacity growth rate is projected to slow to around 3% over the next five years. More critically, capacity distribution exhibits extreme imbalance—Southwest China, as the core resource export region, must annually transport approximately 1.4 million tons of sulfur to consumption hubs in East and South China. This "West-to-East sulfur transfer" pattern heavily relies on Yangtze River shipping and rail transport capacity, making logistics channel stability a key variable constraining marketing efficiency.

On the demand side, consumption patterns are undergoing qualitative changes. While phosphate fertilizers maintain their foundational role with a 52.75% share, "new energy" applications have emerged as the largest marginal growth driver. In 2024, sulfur demand from the lithium iron phosphate material sector surged by 38.34% year-on-year. Unlike traditional fertilizer clients, new energy customers impose stringent requirements on sulfur purity (low carbon, low ash) and product form, generally preferring solid granular sulfur for precise dosing and long-term storage. This signals a market shift from "homogeneous bulk commodities" to "high-end differentiated specialty products."

2.3. Diagnosing marketing pain points of case companies

Focusing on a natural gas purification plant in northeastern Sichuan, its existing production and sales model has struggled to adapt to rapid market changes, specifically manifested in severe production-sales mismatches. First, there is a mismatch between product structure and market demand. The plant has a designed daily capacity of 1,200 tons, but due to outdated equipment, its daily solid sulfur production is only 240 tons—Less than 20% of capacity—With the remaining 80% being liquid sulfur. Given that new energy clients predominantly demand solid sulfur and distant customers cannot accept liquid sulfur, this production structure causes the enterprise to miss opportunities in both high-end and remote markets.

Second, there is a mismatch between sales rhythm and production safety. Since liquid sulfur relies on hazardous chemical tankers for short-distance transport and has limited storage time, the enterprise is forced to heavily depend on a few nearby phosphate fertilizer plants as its primary customers. However, when downstream customers enter maintenance periods or off-seasons, liquid sulfur sales suffer, leading to inventory buildup and even forcing upstream gas fields to reduce production—Creating production safety hazards. Furthermore, the existing 2,000-meter liquid sulfur pipeline faces leakage risks due to thermal stress issues. These hardware limitations severely constrain the company's ability to achieve "full production and full sales" profitability during peak seasons, preventing maximum capacity utilization.

3. Design of optimization strategy for sulfur production and sales

Based on the preceding in-depth analysis of global supply-demand dynamics and the inherent contradictions within the case enterprise, this study concludes that mere adjustments to sales tactics cannot resolve the fundamental issues. The enterprise must adopt a holistic supply chain perspective to establish a three-dimensional optimization strategy system comprising "capacity structure alignment + market segmentation precision + logistics channel restructuring." This approach facilitates a strategic shift from "passive route maintenance" to "proactive value creation."

3.1. Product structure optimization: Establishing a "solid-liquid dynamic adjustment" production mechanism

Addressing the long-standing structural bottleneck of "excess liquid and insufficient solid" in purification plants and the resulting safety and environmental risks, the primary task is to reconfigure production capacity allocation. This entails establishing a production strategy driven by both solid and liquid components, with solid production ensuring operational stability.

On one hand, implement a dual upgrade of production capacity scale and configuration. It is recommended to abandon the traditional piecemeal approach to technical upgrades and instead adopt a replacement solution that maximizes lifetime benefits. Construct a new modern sulfur-based molding facility to replace the existing outdated production line. Upon commissioning, the new facility will boost daily solid sulfur production from 240 tons to 600 tons, optimizing the plant's solid-liquid capacity ratio from 2:8 to 1:1. This ratio adjustment will grant the enterprise significant operational flexibility: during peak agricultural seasons and surrounding liquid sulfur demand surges, it can operate at full capacity for liquid sulfur production to reduce packaging and labor costs; during off-peak seasons or downstream maintenance periods, it can swiftly switch to high-load solid sulfur production mode. By converting liquid hazardous chemicals into ordinary solid goods, it effectively avoids liquid sulfur storage risks and completely breaks free from the passive "production-based-on-sales" model.

Concurrently, the company will pursue a "quality differentiation" strategy targeting premium applications. Recognizing the extreme sensitivity of new energy battery materials (such as lithium iron phosphate precursors) to raw material impurities, the new production line will abandon traditional drum granulation in favor of advanced wet granulation technology. This technology not only significantly reduces on-site dust but also controls product moisture to extremely low levels, producing sulfur that meets new energy industry standards—characterized by "high purity, low moisture, and regular spherical shape." This enables the creation of a high-premium blue ocean market within the homogeneous red ocean competition. Although the initial investment for the new construction plan is significantly higher than retrofitting existing lines, calculations indicate that its full lifecycle return on investment (ROI) will substantially outperform the retrofit option. This advantage stems from reduced unplanned downtime losses, decreased maintenance frequency, and premium pricing for high-end products.

3.2. Market segmentation strategy: Building a "volume-profit balanced" customer pyramid

To mitigate cyclical risks from sole reliance on the fertilizer market, the company should employ customer value matrix analysis to construct a tiered, differentiated "customer pyramid" system. The base consists of "stable-type" customers, primarily large nearby phosphate fertilizer enterprises. These customers represent substantial and consistent demand, serving as the "ballast" for the company's liquid sulfur sales. Strategically, deepen partnerships through long-term supply agreements guaranteeing both volume and pricing. Locking in baseline sales ensures production capacity utilization, enabling basic operations to persist even during market downturns by sacrificing margins to maintain volume. The middle tier comprises "growth-oriented" clients, prioritizing development of fine chemical and caprolactam enterprises. Leveraging the enhanced sulfur transportation capacity post-upgrade, break through the 500-kilometer hazardous chemical logistics radius constraint and actively expand into high-price consumption regions like East and South China. Utilize regional price differentials for arbitrage to mitigate the price depression effect caused by the narrow local market.

The top tier comprises "high-margin" clients, focusing on new energy battery material suppliers. These clients exhibit relatively low price sensitivity but demand extremely high supply stability and consistent quality. Strategically, leverage high-quality products from new facilities to offer customized services (e.g., specific particle sizes, ultra-low ash content). Build high barriers through technical marketing to capture premium value-added profits, positioning this segment as the core profit growth engine. Complementing this, the existing static pricing model must be reformed into a dynamic pricing mechanism based on "benchmark price + quality premium + regional linkage." This involves using spot prices at major Yangtze River ports (e.g., Zhenjiang Port)

and electronic futures prices as benchmarks, combined with product quality tiers (industrial-grade/new energy-grade) and regional logistics cost differentials, to enable agile price adjustments and maximize capture of market premiums.

3.3. Channel layout optimization: Spatio-temporal substitution and digital intelligence empowerment

To address the inherent disadvantage of inland resource-based enterprises being distant from consumer markets, "spatio-temporal substitution" must be achieved through logistics model innovation. Physically, implement a "forward warehouse" strategy. Utilize dry seasons or periods of abundant social transport capacity to pre-transport solid sulfur produced at factory sites to locations near consumption hubs (e.g., ports along the Yangtze River or leased warehouses near key customers). This initiative transforms "passive inventory" stagnating at the factory into "active inventory" near markets. It alleviates factory storage pressure while shortening delivery cycles from weeks to days, enabling rapid response to market fluctuations and achieving the regulatory function of "stockpiling during off-peak seasons and shipping during peak seasons."

In digital and intelligent infrastructure development, focus on resolving logistics efficiency bottlenecks. The introduction of an automated liquid sulfur loading system, utilizing visual recognition and automatic alignment technology, significantly reduces the dwell time of hazardous chemical vehicles at the factory, enhancing turnover efficiency. Simultaneously, data interfaces between the ERP system and logistics carriers have been established, enabling end-to-end visibility tracking from factory weighbridge records and in-transit routes to customer delivery confirmation. This not only lowers logistics loss risks but also provides decision-making support for subsequent big data-driven, precise production and sales scheduling.

4. Implementation safeguards for production and sales strategies

Optimizing production and sales strategies involves more than merely adjusting marketing tactics; it is a systematic endeavor encompassing production technology, digital intelligence infrastructure, and organizational management. To ensure effective execution of the aforementioned "structural adjustment" and "market segmentation" strategies, enterprises must establish a comprehensive safeguarding system across three dimensions: hardware support, data empowerment, and institutional standardization.

4.1. Technical and hardware assurance: Strengthening production foundations and establishing intrinsic safety

Strategy implementation fundamentally relies on the hard capabilities of production facilities. Addressing the case company's longstanding "liquid-heavy, solid-light" capacity bottleneck and safety hazards in aging equipment necessitates prioritizing modern capacity construction. On one hand, the company should expedite the implementation of the new 600 tons/day sulfur shaping facility project at Xuanhan Purification Plant. This project is not only the key vehicle for achieving the "1:1 solid-liquid capacity ratio" structural adjustment but also the fundamental solution to completely eliminate the risks of thermal stress leakage in existing long-distance pipelines and the spontaneous combustion hazards of ferrous sulfide in storage tanks. By adopting advanced processes like wet granulation, we can address quality pain points such as high moisture content and excessive dust at the source, providing a standardized material foundation for entering the high-end new energy market. Concurrently, a long-term production and maintenance mechanism centered on "Safety, Stability, Longevity, Full Capacity, and Excellence" must be established. This involves strengthening preventive maintenance and full lifecycle management of equipment to ensure continuous full-load operation during peak market seasons or high-price periods. This prevents missed market opportunities due to unplanned shutdowns, achieving a fundamental shift from "reactive supply assurance" to "proactive stable production."

4.2. Digital intelligence platform development: Breaking data silos to drive scientific decision-making

Amid the digital transformation wave, experience-driven marketing models struggle to adapt to rapidly changing market conditions. Aligned with the company's digital transformation strategy, building an integrated sulfur marketing big data platform encompassing "data collection, trend analysis, and strategy generation" is imperative. First, at the data integration level, barriers between internal ERP systems, production DCS systems, and external market data must be dismantled. This involves horizontally connecting multi-dimensional data streams such as global customs import/export data, real-time inventory at major ports, and operating rates of downstream phosphate fertilizer and new energy enterprises to form a panoramic market situation awareness map. Second, at the decision-making support level, artificial intelligence and machine learning algorithms should be introduced to build price trend prediction models. Through deep learning of historical price cycles, crude oil

correlation, and supply-demand gaps, these models assist management in forward-looking analysis. This enables scientifically informed sales decisions—Such as "sell on dips, not rallies" (dumping at highs) or "lock-in forward pricing" (hedging risks)—Minimizing emotional interference in transactions while enhancing marketing decision accuracy and responsiveness.

4.3. Organizational and compliance management: Reshaping business processes to build risk defenses

As the sales radius expands and customer groups diversify, the supporting organizational management and compliance systems must upgrade accordingly. First, revise and improve the "Detailed Rules for Sulfur Sales Management" to establish a dynamic customer onboarding and credit evaluation system. For newly developed clients in sectors like new energy and fine chemicals, implement rigorous credit background checks. Differentiate credit limits and payment terms based on clients' procurement scale, payment history, and industry standing to mitigate funding risks at the source. Second, strengthen legal compliance reviews for emerging business scenarios such as import substitution in foreign trade and long-distance cross-regional sales. Form cross-departmental risk control teams comprising legal, finance, and marketing personnel to focus on reviewing fulfillment clauses, force majeure definitions, and price adjustment mechanisms in long-term contracts, thereby preventing contract performance risks. Simultaneously, establish a production-sales-R&D coordination mechanism by regularly convening joint production-sales meetings. This ensures front-end market demand signals are promptly and accurately transmitted to back-end production and logistics operations, fostering an organizational ecosystem characterized by "market orientation, compliant operations, and efficient collaboration."

5. Conclusion

Faced with the dual challenges of low-cost imports from the Middle East and the rising domestic demand for new energy, natural gas purification enterprises in northeastern Sichuan must shift from a "production-oriented" to a "market-oriented" approach. By optimizing the solid-liquid production ratio to 1:1 through newly constructed facilities and integrating wet granulation technology, these enterprises can not only mitigate inventory expansion risks but also enter high-value-added markets like new energy battery materials with premium-grade solid sulfur. Establishing an agile production-sales coordination mechanism is essential to gain the upper hand in market competition.

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