

Reengineering Energy Supply Chains: A Strategic Framework for U.S. Procurement Resilience

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Abstract- Energy procurement is a lever in shaping the resilience and competitiveness of the U.S. energy sector. Global supply chain disruptions, heightened geopolitical tensions, and the accelerating transition toward decarbonization have emphasized the vulnerability of traditional procurement models dependent on offshore suppliers. This article examines the structural redesign of procurement practices across utilities, oil majors, and renewable energy firms, highlighting how localized sourcing, strategic partnerships, and technology integration are redefining operational performance. Case studies reveal measurable outcomes including reductions in lead times, cost efficiencies, and new job creation that describes procurement's dual role as both a risk management mechanism and a catalyst for economic revitalization. The analysis further explores the broader policy and market implications, while emphasizing the need for government incentives, public-private collaboration, and alignment with national energy independence and decarbonization goals. Lastly, the study outlines future research pathways, particularly in the application of artificial intelligence for procurement optimization and blockchain technologies for supply chain traceability. Framing procurement as a strategic tool elevates supply chain reform to a foundational role in shaping a resilient, sustainable, and inclusive U.S. energy economy.

Keywords: Energy Procurement, Supply Chain Resilience, Domestic Sourcing, Decarbonization, U.S. Energy Policy, Renewable Energy, AI In Procurement, Blockchain Traceability

I. INTRODUCTION

The U.S. energy supply chain represents one of the most intricate and strategically significant infrastructures in the global economy. The modern energy system extends beyond fossil fuel extraction to encompass a fast-growing renewable sector, whose complex global supply chains, unlike the capital-intensive and geopolitically sensitive fossil fuel networks, depend on critical technologies and materials that leave the United States exposed to foreign market vulnerabilities. For example, the U.S. currently imports over 80% of its solar photovoltaic (PV) modules from Southern Asia (Reuters, 2025), while China dominates the global rare earth element

(REE) market, accounting for 70% of production and 90% of processing worldwide (Sulgiye et al., 2023). These inputs are essential for wind turbines, batteries, and electric vehicles.

Within this ecosystem, procurement has emerged as a strategic lever for resilience. Traditionally focused on cost efficiency, procurement in the energy sector is now a driver of risk management, supply diversification, and sustainability. Dienagha et al. (2025) define sustainable procurement and supply chain management as the strategic sourcing of goods and services that minimizes environmental harm, ensures social responsibility, and drives long-term economic growth through ethical labor practices, resource efficiency, and lower carbon footprints.

The COVID-19 pandemic underscored these vulnerabilities. Supply chain disruptions marked by soaring shipping costs and raw material shortages caused solar project costs to rise significantly. In the U.S., overall solar installation costs increased by approximately 12% in 2021, while module manufacturing costs surged nearly 40%, reflecting inflation in polysilicon and freight charges (World Economic Forum, 2021; CNBC, 2021). The reliance on international suppliers for renewable technologies, coupled with surging domestic demand, has elevated procurement to a matter of national security, where fragile supply chains magnify broader systemic risks.

Geopolitical shocks further amplified these concerns. The Russia-Ukraine conflict destabilized global natural gas markets, driving U.S. liquefied natural gas (LNG) exports to record levels. In 2022, U.S. LNG exports averaged 10.6 billion cubic feet per day, an increase of 9% from 2021, making the United States the world's largest exporter. Exports to Europe more than doubled, rising by 141% year-over-year, as the region sought alternatives to Russian gas. At the same time, domestic gas prices reached a 15-year high, underscoring the volatility of energy markets under geopolitical stress (U.S. Energy Information Administration, 2023).

Beyond pandemics and wars, sector-specific shocks highlight further fragility. The global semiconductor shortage of 2020–2022 disrupted technologically intensive energy systems such as electric vehicles, where chip shortages delayed production by an estimated 9.5 million units worldwide in 2021 (Karim, 2025). These disruptions illustrate that the resilience of the U.S. energy sector is inseparable from the robustness of its procurement strategies.

In this context, this article addresses the central research question. How can strategic procurement improve U.S. energy supply chain resilience? This inquiry highlights the need to move beyond cost-driven models toward procurement frameworks that integrate risk assessment, supplier diversification, digital visibility, and sustainability imperatives. Examining procurement as both a technical and strategic function, this study presents a holistic framework for reshaping U.S. energy supply chains to boost resilience and sustain long-term competitiveness.

II. LITERATURE REVIEW

The complexity of energy supply chains has been a recurrent subject in both academic and policy literature, with emphasis on their exposure to global shocks and the importance of strategic management for resilience. Traditional scholarship has largely examined fossil fuel logistics and geopolitical dependencies (Francesco, 2025; Osman et al., 2021), while more recent work has shifted toward renewables and their reliance on critical minerals and technology inputs (Savannah et al., 2024; Shi et al., 2025). Tubis and Poturaj (2025) conceptualize energy supply chains (ESCs) as interconnected networks responsible for producing, storing, and delivering energy to end users, supported by physical, financial, and digital infrastructures that enable seamless energy transfer across the system. This framing underscores the multi-layered vulnerabilities that arise from physical bottlenecks, from cyber and financial shocks.

Muchen Li and Yi Han (2025) further argue that the Organization of American States must prioritize closing infrastructure gaps, advancing interoperability, and reinforcing cybersecurity to bolster ESC resilience amid transitions and disruptions. They emphasize that strategic investments in digital technologies such as

blockchain traceability, predictive analytics, and smart-grid interoperability can enhance operational effectiveness and reduce systemic vulnerabilities. These academic insights align with recent policy initiatives designed to strengthen clean energy supply chains and reduce dependence on external actors. For instance, the U.S. *Strategy to Secure the Supply Chain for a Robust Clean Energy Transition* (2022), the European Union's *Critical Raw Materials Act*, the U.S. *Inflation Reduction Act* (IRA), and the *EU Green Deal Industrial Plan* collectively reflect a strategic policy shift toward domestic resilience and supply diversification (World Economic Forum, 2025).

Complementing these perspectives, policy reports from the U.S. Department of Energy (DOE, 2022) and the International Energy Agency (IEA, 2023) highlight that the increasing reliance on global supply chains for solar, wind, and battery storage technologies introduces vulnerabilities distinct from those in traditional oil and gas systems. While fossil fuel supply chains have long been exposed to geopolitical risks, renewable energy systems face unique dependencies on mineral inputs, advanced manufacturing hubs, and digital infrastructures, creating new layers of exposure that procurement strategies must address.

Resilience, Agility, and Redundancy in Supply Networks

The concepts of resilience, agility, and redundancy are central to contemporary supply chain management and increasingly applied to energy systems. Resilience has been broadly defined as the capacity of a supply network to recover and resume operations following disruptions (OECD, 2024). In practice, resilience entails maintaining the flow of goods during crises by responding swiftly, recovering efficiently, and adapting to unforeseen challenges such as natural disasters, market volatility, or labor unrest (Inbound Logistics, 2025). Closely linked is agility, which emphasizes proactive flexibility and adaptability. GEP (2024) describes agility as the ability to swiftly adjust procurement, inventory, and delivery strategies in response to evolving conditions, enabling organizations to manage disruptions and seize emerging opportunities. Emmanuel et al. (2024) extend this definition by underscoring that agility rests on collaboration across supply chain partners, allowing firms to navigate demand uncertainty and variability more effectively. Redundancy, by

contrast, focuses on risk buffering rather than adaptability. It typically involves supplier diversification, stockpiling, or flexible contracting arrangements, often at the expense of cost efficiency. Arash et al. (2021) note that while external redundancies, such as multisourcing and flexible contracts, can mitigate disruption risks, they carry high financial costs and may lose effectiveness when shocks are highly unexpected. Within energy supply chains, redundancy has been implemented through mechanisms such as long-term LNG procurement contracts that guarantee delivery amid shifting geopolitical conditions (Ghazi et al., 2023) and diversification strategies for renewable technology supply chains to reduce dependence on Chinese manufacturing hubs (Li-Chen & Steven, 2024). Recent scholarship warns, however, that redundancy in critical sectors like energy can generate significant financial and environmental burdens. Sotirios et al. (2022) argue that these costs must be strategically offset by enhanced digital visibility and the deployment of predictive analytics to optimize decision-making and resource allocation. In this view, resilience and agility are not merely achieved by building slack but by integrating data-driven tools that enable dynamic responses to shocks.

Procurement Strategies in Volatile Global Markets

Procurement literature emphasizes that strategic sourcing is central to navigating global volatility, with supplier relationship management playing a decisive role in ensuring collaborative partnerships that enhance both environmental and social performance. Sustainable procurement has increasingly been framed as a dual response to regulatory compliance and consumer expectations, underpinned by practices such as lifecycle assessments, supplier audits, and ethical sourcing, which enhance competitiveness, mitigate ecological and labor-related risks (Cooper, 2024). Ogunsuji et al. (2024) argue that procurement has shifted from a transactional activity to a strategic discipline, in which firms cultivate long-term supplier relationships to strengthen resilience and agility against disruptions.

In the energy sector, these strategies acquire heightened importance. Empirical research shows that sustainable procurement lowers the carbon footprint of supply chains, insulates firms from geopolitical and regulatory risks, a lesson underscored by recent crises in global energy markets

(Cooper, 2024). Policy frameworks align with this scholarly perspective: the U.S. Department of Energy's *Critical Materials Assessment* (2023) highlights supplier diversification and domestic capacity-building as essential to mitigating vulnerabilities in clean energy technologies. Parallely, Hajiyeva (2024) demonstrates how the Ukraine conflict reshaped the European Union's approach to economic globalization, leading to a more integrated framework that balances energy security, geopolitical strategy, and humanitarian imperatives. Her analysis points to adaptive resilience policies such as joint natural gas procurement, flexible migration management, and coordinated security strategies, which collectively aim to counteract supply disruptions and reduce dependence on unstable external sources.

Gaps in Current Research

Despite rising interest in procurement resilience, several gaps remain. Research often treats resilience, agility, and sustainability as separate constructs, limiting insight into how they jointly influence procurement strategies under global volatility. Case studies of crises such as COVID-19 and the Russia–Ukraine conflict are valuable, but comparative cross-sector analyses are scarce, even though energy supply chains are deeply interconnected with manufacturing, technology, and infrastructure. The literature also leans heavily on firm-level strategies, overlooking the role of cross-sector and public–private collaboration in strengthening national or regional resilience. While policy reports highlight diversification and domestic capacity-building, academic work rarely evaluates their long-term effectiveness. Finally, limited attention is given to the social and geopolitical dimensions including workforce readiness, equity, and shifting alliances that critically shape the durability of energy supply networks. Addressing these gaps is key to building a holistic framework for procurement strategy in volatile markets.

DISRUPTION ANALYSIS: GEOPOLITICAL AND PANDEMIC-INDUCED VULNERABILITIES

Case 1: Delays and Cost Escalations in Oil & Gas Equipment Imports during COVID-19

The COVID-19 pandemic exposed the structural fragility of globalized energy procurement systems. The International Energy Agency (IEA) stresses that understanding the transition toward low-carbon

energy and the erosion of fossil fuel-based models is critical for anticipating geopolitical realignments, particularly as the post-COVID pivot to renewables has intensified tensions among fossil fuel-exporting nations (Alam et al., 2023). Lockdowns, port closures, and shipping bottlenecks produced severe delays in oil and gas equipment imports, with lead times in some cases doubling.

Empirical evidence confirms the scale of these disruptions. U.S. import price inflation closely tracked global dynamics from early 2020 to mid-2022, peaking at 8.1% in Q2 2021 compared to a 7.8% global component. Notably, inflation remained elevated at just over 5% through Q4 2022 even as the global contribution declined to nearly zero, driven by the U.S.-specific demand shocks and supply interruptions in key exporting regions (Amiti et al., 2024). The World Economic Forum (2024) further observed that while the crisis temporarily elevated awareness of supply chain resilience as a cornerstone of economic stability, public and policy attention quickly receded despite enduring vulnerabilities.

For the oil and gas sector, these bottlenecks had particularly acute consequences. The pandemic initially triggered a plunge in energy prices, from crude oil to refined products such as jet fuel and gasoline, before a sharp rebound occurred as production cuts and resurgent demand pushed prices upward (U.S. Bureau of Labor Statistics, 2020). Exploration and maintenance projects were delayed, infrastructure rollouts slowed, and costs surged as congestion in supply chains elevated freight charges while raw material shortages inflated component prices. The COVID-19 era exposed a severe mismatch between crude oil supply and demand, culminating in a steep price collapse that destabilized global economies and reversed prior economic gains (Terver et al., 2022). Operating within highly capital-intensive environments, firms faced amplified financing risks, revealing the strategic vulnerabilities of limited supplier redundancy and heavy reliance on globalized trade flows. Empirical evidence further underscores these dynamics: Le et al. (2021) found that surging COVID-19 cases, rising U.S. economic policy uncertainty, and anticipated stock market volatility exerted downward pressure on WTI crude oil prices, while the Russia–Saudi Arabia oil price war and speculative activity in oil futures markets magnified the collapse.

Case 2: Critical Mineral Dependency for Renewable Energy Technologies

The transition to clean energy has heightened global reliance on critical minerals such as lithium, cobalt, and rare earth elements, resources concentrated in a handful of countries, thereby exposing renewable energy technologies to new vulnerabilities. Young et al. (2024) find that while critical minerals generally support green growth, their impacts vary by mineral type, with institutional influence remaining unclear, and nonlinear dynamics emerging depending on specific threshold variables. This underscores that mineral-driven growth trajectories are neither uniform nor guaranteed.

The global supply of these minerals is marked by acute geographic concentration: over 75% of global output is controlled by just three producers, raising concerns about reliable and sustainable access due to long production lead times, declining ore quality, and significant environmental and social challenges (OECD, 2021). Cobalt, for instance, is heavily tied to the Democratic Republic of Congo, which supplies nearly 70% of global demand, while China dominates rare earth element processing, refining more than 80% of global capacity (World Bank, 2021). Such concentrated supply chains expose renewable energy projects to price volatility but also create geopolitical leverage points that may be exploited in periods of tension.

Disruptions in these supply chains directly threaten the production of core renewable energy technologies including solar panels, wind turbines, and electric vehicle (EV) batteries, making the clean energy transition vulnerable to external shocks. Wang et al. (2024) demonstrate that geopolitical risk significantly in shaping energy transitions, with its impact intensifying over time and significantly amplified when combined with strong environmental regulations and green innovation. This reveals a nonlinear relationship in which both policy design and technological strategies must be integrated to build resilience against global uncertainties.

Impact on Domestic Energy Capacity, Project Timelines, and Cost-to-Serve

The combined effect of pandemic-induced disruptions and geopolitical dependencies has significantly constrained domestic energy capacity. Recent findings reveal time-varying patterns shaped by major geopolitical shocks such as the COVID-19

pandemic and ongoing global conflicts with transfer entropy analysis showing directional dependence between energy markets and geopolitical risk, underscoring the central role of energy commodities in shaping geopolitical indexes (Almeida et al., 2025).

Project timelines have lengthened as firms struggle to secure critical inputs, while rising procurement costs have strained budgets and raised the cost-to-serve for utilities and end-users. The International Energy Agency (2025) reports that since 2021, procurement lead times and prices for key grid components have nearly doubled, placing severe pressure on supply chains, delaying infrastructure development, and escalating electricity delivery costs. Similarly, a McKinsey & Company (2023) study shows that lead times for essential utility materials such as steel, transformers, and meters have expanded from four to six weeks to nearly 24 weeks, resulting in substantial project delays and heightened budgetary pressures. These bottlenecks have slowed renewable energy integration, weakened fossil fuel procurement resilience, and ultimately undermined national energy security by deepening dependence on volatile global markets.

Lessons from Global Disruptions and Their Procurement Implications

The COVID-19 pandemic and ongoing geopolitical shocks have revealed deep vulnerabilities in global energy procurement networks, with long-lasting implications for domestic resilience strategies. The evidence demonstrates that supply chain shocks are not temporary disturbances but structural challenges that reshape project delivery and procurement economics. Transfer entropy analysis indicates that energy markets and geopolitical risks are directionally interlinked, with energy commodities exerting outsized influence on geopolitical indexes (Almeida et al., 2025). This interdependence underscores the systemic risk exposure facing energy procurement systems that depend heavily on globalized inputs.

One key lesson is the need to address procurement fragility. The International Energy Agency (2025) reports that since 2021, lead times and prices for grid components have nearly doubled, delaying critical infrastructure projects and raising the cost-to-serve. McKinsey & Company (2023) further highlights that delays for utility materials such as transformers and

meters have stretched from six weeks to nearly 24 weeks, significantly lengthening project timelines and inflating costs. These constraints highlight how reliance on globally concentrated suppliers amplifies domestic energy insecurity, particularly in moments of systemic disruption.

For procurement strategy, the implications are twofold. First, resilience requires diversification away from single-source global supply dependencies toward regionalized or domestic alternatives. Second, agility in procurement processes such as securing flexible contracts, building strategic reserves, and adopting digital supply chain monitoring, becomes essential to manage volatility and reduce exposure to external shocks. Without these adaptations, disruptions risk undermining both renewable integration and fossil fuel stability, thereby constraining long-term energy security.

STRATEGIC PROCUREMENT AS A RESILIENCE LEVER

Procurement has moved beyond its traditional cost-reduction mandate to become a central lever for resilience in the energy sector. The increasing frequency of supply disruptions has elevated the importance of procurement maturity models, which provide structured frameworks for assessing and strengthening procurement capabilities. Organizations with higher procurement maturity adopt more sophisticated methodologies that integrate purchasing operations into strategic decision-making and align them with long-term objectives (Ali et al., 2023). In the energy context, these models help firms benchmark resilience-focused practices, shifting procurement from transactional sourcing to a strategic function that safeguards continuity and competitive capacity. Higher maturity levels enhance efficiency and drive cost reduction by aligning sourcing, supplier management, and operational capabilities (Noh & Hwang, 2023).

The core pillars of resilient procurement include supplier diversification, local sourcing, category management, and demand forecasting. Diversifying suppliers reduces dependency on single geographies and buffers firms against geopolitical volatility. Research shows that organizations facing competitive pressures, low supplier concentration, and limited switching costs increasingly prefer geographically closer suppliers, as this reduces

exposure to disruptions and currency fluctuations while improving operational stability (Qianru et al., 2024; Elsakka et al., 2024). Local sourcing, while often carrying cost premiums, provides firms with greater control over inputs and supports domestic industrial development (Okeke & Onyemere, 2025). Category management enables energy companies to organize procurement activities around criticality and risk exposure, using purchasing power and strategic partnerships to secure better contracts and long-term supplier relationships (Paul et al., 2024; Akirolabs, 2025). Advanced demand forecasting further strengthens resilience by aligning supply strategies with shifting consumption patterns. AI-driven forecasting models improve accuracy by incorporating historical sales data, external market dynamics, and seasonal variations, which enhances inventory planning and agility (Amosu et al., 2024).

However, resilience does not come without trade-offs. Strategies such as supplier diversification, inventory stockpiling, or regional sourcing often increase costs. Effective resilience therefore requires balancing redundancy and flexibility in inventory management, allowing supply chains to withstand shocks while preparing for future uncertainties (Guo et al., 2024). The challenge lies in recalibrating procurement strategies toward optimizing total value which includes risk mitigation, business continuity, and sustainability, rather than short-term cost savings. This shift demands board-level recognition of resilience as a strategic investment rather than a discretionary expense.

Procurement consulting has become a critical enabler in this transformation. Conceptual procurement models tailored to sustainability and climate imperatives in the energy sector must be rooted in stakeholder consultations to ensure relevance and feasibility (Adindu et al., 2023). Specialized consulting firms provide analytical depth, digital solutions, and market intelligence that allow companies to identify vulnerabilities, redesign sourcing strategies, and implement resilience measures at scale. Predictive models and advanced analytics enhance responsiveness, improve supplier selection, and build adaptability, as demonstrated by practical case applications (Rashid, 2025). Consulting expertise transforms procurement from a reactive function into a proactive force through scenario planning and supplier-risk mapping, enabling it to serve as both a shield against disruption

and a catalyst for strategic change in the energy sector.

FRAMEWORK FOR PROCUREMENT RESILIENCE IN U.S. ENERGY SUPPLY CHAINS
Building a resilient energy supply chain requires a structured procurement framework that addresses immediate vulnerabilities, including long-term adaptability into upstream, midstream, and downstream operations. A five-part framework can provide a practical pathway for U.S. firms to mitigate risks and strengthen national energy security.

Supply Base Mapping and Risk Scoring

The first step involves systematically identifying and scoring risks across critical inputs such as steel, transformers, lithium, and rare earth elements. Advanced tools, including transfer entropy analysis, have already demonstrated how energy markets and geopolitical risks are directionally dependent (Almeida et al., 2025). Supply chain risk mapping may be complex, but in a world of intricate networks and volatile geopolitical conditions, it is essential for businesses to identify and anticipate vulnerabilities to safeguard operations and ensure resilience (QIMA, 2025). Richert and Dudek (2024) analyze the impact of threats such as the COVID-19 pandemic, armed conflicts, and economic instability on supply chains, emphasizing the value of risk maps, simple yet effective tools that quickly highlight key risks and outperform other assessment methods in clarity and speed, supported by insights from industrial sector interviews. Geospatial risk mapping and real-time monitoring, powered by GIS, satellite data, and AI-driven geopolitical tools, combined with blockchain-enabled supply chain transparency, allow organizations to forecast disruptions, ensure traceability, and build trust through secure, tamper-proof data systems (Britney, 2025). Applying such methods to procurement mapping allows firms to anticipate disruptions and establish contingency plans before they materialize.

Domestic Supplier Development and Onshoring.

Heavy reliance on global markets for critical minerals and energy technologies, where just three producers account for more than 75% of output, creates systemic vulnerabilities that threaten energy security (OECD, 2021). Building a stronger domestic supplier base across the energy value chain, from upstream exploration equipment to midstream grid components and downstream distribution

technologies, can mitigate these risks. Evidence from the United States and Germany demonstrates that incentivizing local manufacturing of solar panels and wind turbine components not only strengthens supply chain resilience but also stimulates economic growth and job creation, aligning procurement with broader industrial policy objectives (Ogunsuji et al., 2024). In the U.S., a combination of trade policy, targeted tax incentives, and federal loan and grant programs has accelerated investment in domestic semiconductor and clean energy manufacturing (Katz & Karreman, 2025). The Inflation Reduction Act has further amplified these efforts by supporting renewable energy deployment and grid infrastructure upgrades through direct financial incentives (U.S. Environmental Protection Agency, 2025). However, for these policies to deliver meaningful resilience, procurement organizations must embed local sourcing into their category strategies, ensuring that policy signals are translated into operational priorities.

Collaborative Demand Planning with Tier 1 and Tier 2 Suppliers

Procurement resilience requires more than transactional contracting; it depends on the integration of collaborative demand planning across the supply chain. Recent evidence underscores the urgency, McKinsey & Company (2023) reports that lead times for transformers and meters have more than quadrupled, disrupting project schedules and inflating budgets. Collaborative forecasting with Tier 1 and Tier 2 suppliers provides early visibility into demand surges and enables more responsive capacity allocation, particularly in midstream transmission and storage projects. Tushar (2025) notes that the average manufacturing firm now coordinates with nearly 4,800 tier-one and more than 18,000 sub-tier suppliers spanning approximately 11 countries, highlighting the sheer complexity of modern supply networks. Effective multi-tier collaboration requires transparency and information sharing across Tier 1, Tier 2, Tier 3, and beyond, allowing firms to manage risks, costs, and logistics while ensuring the continuous flow of critical components (JAGGAER, 2024). The post-COVID landscape revealed just how fragile industrial manufacturing supply chains can be when collaboration is limited; strained OEM-supplier relationships amplified disruption, while firms with integrated, cross-tier partnerships demonstrated superior agility and continuity (o9 Solutions, 2022). In today's volatile environment, dynamic supplier

collaboration is no longer optional but a decisive differentiator for competitive advantage.

Digital Procurement and Scenario-Based Analytics

The acceleration of digitalization has transformed procurement into a strategic lever for resilience, enabling organizations to anticipate, model, and mitigate disruptions before they cascade through the supply chain. Simulation-based procurement platforms allow firms to stress-test scenarios such as pandemics, raw material shortages, or geopolitical conflicts, providing visibility into how shocks propagate across upstream exploration, midstream transmission, and downstream distribution networks. As Hallikas et al. (2021) argue, digital procurement functions as a critical intermediary, converting vast external data streams into operational strategies that enhance agility and responsiveness.

A growing body of work highlights the role of procurement analytics in this transformation. Integrating data from enterprise resource planning (ERP) systems, supplier portals, and external market intelligence, procurement analytics enables classification, visualization, and strategic insight generation (Sievo, 2025). These tools extend beyond simple reporting to encompass four analytical dimensions descriptive (tracking past performance), diagnostic (identifying causes of inefficiencies), predictive (forecasting supply and demand volatility), and prescriptive (recommending optimal sourcing actions) (Ideson, 2024). Together, they empower procurement teams to anticipate risks, optimize supplier portfolios, and refine sourcing strategies with precision.

Modern eProcurement platforms enhance these capabilities by centralizing supplier discovery, bid evaluation, and contract management while leveraging artificial intelligence to generate predictive insights and tailored recommendations (Torg, 2025). This digital integration reduces procurement cycle times, improves sourcing quality, and strengthens supplier relationships. The urgency of such systems is underscored by the International Energy Agency (2025), which reports that procurement lead times and costs for critical energy components have nearly doubled since 2021. Without predictive analytics and scenario-based planning, organizations risk being blindsided by volatility that could otherwise be mitigated through proactive procurement strategies.

Compliance, ESG, and Policy Incentive Alignment

Procurement resilience in today's environment cannot be divorced from compliance and ESG imperatives. As Wang et al. (2024) emphasize, geopolitical risk is increasingly interwoven with environmental regulation and green innovation, producing nonlinear effects that simultaneously magnify risks and create new opportunities. ESG compliance is no longer peripheral but central to risk management, investor confidence, and corporate legitimacy. Effective practices, including ethical sourcing, supplier audits, and transparent reporting must be uprooted by firm data strategies and adherence to established frameworks, ensuring accountability across multi-tier supplier networks (TradeBeyond, 2024).

An important aspect of this integration lies in embedding ESG obligations into supplier contracts, which guarantees compliance, secures eligibility for federal and state incentives that accelerate the clean energy transition. Downstream retail and distribution segments are particularly exposed to ESG pressures, as consumer expectations converge with evolving policy mandates. Empirical evidence shows that firms disclosing ESG practices often achieve improved economic outcomes and risk mitigation, as sustainable production is reinforced through value-enhancing supply chain mechanisms, though sectoral and geographic variations remain evident (Nishant et al., 2024). In this way, compliance and ESG are not constraints on procurement but enablers of resilience, strengthening the adaptability of supply chains while positioning firms to capture the economic upside of sustainability-driven reforms.

Framework for Procurement Resilience in U.S. Energy Supply Chains

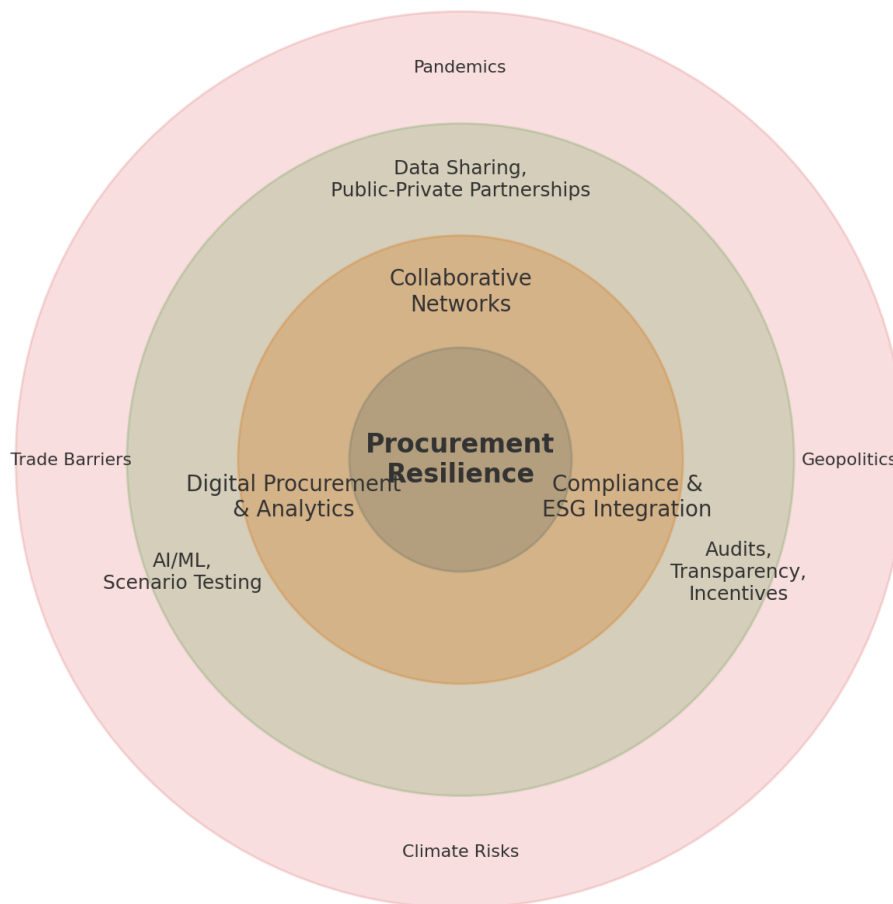


Figure 1: Framework for Procurement Resilience in U.S Energy Supply Chains

III. CASE STUDIES

Utility Sector

U.S. utilities continue to face significant bottlenecks in acquiring essential grid infrastructure, with transformer and grid component lead times often extending beyond two years (DOE, 2023). Duke Energy provides a telling example of how procurement redesign has become a resilience lever in addressing these vulnerabilities. On the renewables side, Duke Energy has sought to balance federal incentive eligibility with its procurement process. Its 2025 Request for Proposals (RFP) requires bidders to demonstrate their ability to commence construction by strict deadlines in order to qualify for tax credits, underscoring how procurement frameworks are being tightly aligned with policy timelines (Duke Energy, 2025a). However, this approach has not been without controversy, advocacy groups argue that mechanisms such as Duke's proposed "volume adjustment" clause could curtail solar procurement while disproportionately favoring gas resources, raising concerns about discriminatory procurement design (Southern Environmental Law Center, 2025).

Concurrently, Duke has pursued strategic supplier partnerships to mitigate risks in conventional generation and grid reliability. A 2025 agreement with GE Vernova secures a pipeline of advanced gas turbines manufactured in Greenville, South Carolina, backed by a \$600 million expansion in U.S. manufacturing capacity. This partnership both strengthens domestic supply chains and reduces exposure to global bottlenecks, while also generating over 1,500 new U.S. jobs (Duke Energy, 2025b). Leveraging existing transmission infrastructure at Duke facilities, the procurement strategy reduces costs and speeds up delivery of critical energy assets. Duke Energy's procurement redesign demonstrates how utilities are experimenting with a blend of policy-driven RFP frameworks, long-term supplier agreements, and domestic manufacturing partnerships to manage disruption risks. While trade-offs remain, particularly around resource mix and clean energy growth, the measurable impact has been improved reliability, shorter equipment delivery windows, and the creation of domestic capacity that strengthens both resilience and economic competitiveness.

Oil Majors

Oil majors have increasingly turned to procurement transformation initiatives to buffer against the volatility of global supply chains and geopolitically unstable regions. Companies such as Chevron and ExxonMobil illustrate how sourcing redesign can serve as both a resilience measure and a growth strategy. Chevron's procurement practices are tightly linked to its global production footprint, spanning the Permian Basin, Gulf of Mexico, and Denver-Julesburg Basin, as well as international projects in Argentina, Brazil, and Suriname (Chevron Corporation, 2024). To reduce exposure to politically unstable supply corridors, Chevron has deployed a "factory development" strategy in its U.S. shale operations, using multi-well pads, advanced horizontal drilling, and electrified facilities to maximize efficiency and minimize surface disruption. This model optimizes infrastructure utilization and also strengthens procurement reliability by standardizing equipment and consolidating suppliers. In parallel, acquisitions such as PDC in 2023 expanded Chevron's U.S. acreage by over 300,000 net acres, securing long-term domestic supply options while lowering reliance on external partners (Chevron Corporation, 2024). At the same time, Chevron positions procurement within a broader ESG and operational excellence framework, embedding sustainability considerations into sourcing through the Chevron Way and its Operational Excellence Management System (Chevron, 2025). Initiatives such as a joint venture solar project in New Mexico and participation in the Advanced Clean Energy Storage (ACES Delta) hydrogen project in Utah reflect a pivot toward diversified, low-carbon inputs that complement traditional hydrocarbon supply. These moves reinforce both geopolitical risk hedging and long-term energy transition readiness. ExxonMobil has likewise pursued procurement reforms as part of its broader transformation strategy. By centralizing sourcing functions and deploying category management approaches, the company has diversified refinery equipment supply chains, reducing exposure to sanctions and trade disruptions (ExxonMobil, 2025). Supplier diversification was especially critical during the Russia-Ukraine conflict, when sanctions threatened downstream continuity. Through resilience-focused sourcing strategies, ExxonMobil was able to stabilize input costs and maintain operational reliability (Northwood, 2025). The company's 2030 Corporate

Plan further links procurement transformation to capital allocation discipline and low-carbon innovation, with expectations of delivering a 10% compound annual earnings growth rate by balancing advantaged asset expansion with supply chain resilience (Northwood, 2025). The procurement transformations of Chevron and ExxonMobil demonstrate how oil majors are embedding resilience into sourcing while still pursuing ambitious production and transition goals. By securing domestic capacity, diversifying supplier networks, and integrating ESG-driven procurement, these companies are hedging against geopolitical instability and also building the foundation for sustained competitiveness in a rapidly evolving energy market.

Renewable Energy Firms

Renewable energy companies in the United States have accelerated procurement transformations by localizing supply chains for solar and wind technologies, a trend reinforced by federal incentives under the Inflation Reduction Act (IRA). The IRA, described as the most significant climate legislation in U.S. history, introduced investment and production tax credits that catalyzed large-scale investment in clean energy infrastructure (Rodríguez, 2025). These incentives have enhanced the financial viability of renewable projects and also reshaped sourcing strategies, encouraging firms to secure domestic suppliers and reduce exposure to volatile global supply chains. Solar sector transformation has shown great improvement with impressive transformations. U.S.-based First Solar expanded domestic module production while locking in long-term contracts with American suppliers of glass and semiconductor materials, directly aligning with IRA incentives. Recent developments suggest the emergence of a vertically integrated U.S. solar supply chain. Suniva, Heliene, and Corning Incorporated entered a landmark agreement to produce solar modules using polysilicon, wafers, and cells manufactured entirely within the United States (Gerke, 2025). This represents a critical pivot away from import dependence on Asian supply hubs and underscores how procurement redesign can reinforce national energy security. This efforts has shown profound results. According to Wood Mackenzie (2024), U.S. solar module manufacturing capacity has surged to more than 31 gigawatts (GW), a nearly four-fold increase since the IRA's enactment in 2022. In just two years, 75 GW of new solar capacity has been installed, accounting for over one-third of all solar

capacity built in U.S. history. The Solar Energy Industries Association (SEIA) emphasizes that these procurement-driven expansions are creating jobs, stabilizing supply availability, and positioning U.S. manufacturers to meet nearly all domestic demand in the coming years (Wood Mackenzie, 2024). The wind sector mirrors this localization strategy. Ørsted, a global leader in offshore wind, has redirected procurement toward American steel fabricators and logistics providers for its Mid-Atlantic projects. A notable example is its investment in Crystal Steel, which will channel nearly US\$70 million into supply agreements while creating 50 new jobs to support turbine foundation production (Windtech International, 2021). These moves cut freight costs, improve component delivery timelines, and embed renewable energy projects more firmly within local economies. The solar and wind procurement transformations highlight a strategic shift in transformation with renewable energy firms introducing resilience by localizing sourcing, leveraging policy incentives, and generating domestic manufacturing ecosystems. These efforts reduce exposure to geopolitical and trade-related risks while simultaneously advancing U.S. clean energy capacity and employment.

Measurable Outcomes: Lead Time Reduction, Cost Savings, and Job Creation

Across the utility, oil, and renewable energy sectors, procurement transformation has produced tangible outcomes in terms of lead time reduction, cost savings, and job creation, though the depth and durability of these gains vary across industries. In utilities, redesigning procurement to address grid component delays has shortened delivery cycles for transformers and transmission equipment, improving project execution timelines and system reliability. By integrating predictive procurement analytics, utilities can anticipate bottlenecks and stress-test sourcing options, aligning with Hallikas et al. 's (2021) and Ideson (2024) emphasizes the importance of digital simulations and predictive diagnostics to enhance resilience under disruption. Oil majors, on the other hand, have prioritized sourcing diversification and contract restructuring to hedge against geopolitical shocks. These strategies have generated measurable cost savings by stabilizing procurement expenditures, even as the International Energy Agency (2025) reports that global energy component lead times and costs have nearly doubled since 2021. Still, the sustainability of such savings hinges on firms' ability

to balance cost arbitrage with long-term supplier partnerships, a tension that introduces ongoing risk.

In renewables, measurable outcomes have been particularly visible in this transformation. The shift toward localized procurement which are accelerated by federal incentives such as the Inflation Reduction Act has significantly reduced freight costs and eliminated transoceanic shipping delays, directly lowering lead times for solar and wind installations. For instance, First Solar's domestic expansion has shortened module delivery times and supply capacity while boosting local employment (Nguyen, 2023). This is observed in Ørsted's partnership with Crystal Steel created nearly 50 regional jobs by reshoring wind component sourcing (Windtech International, 2021). These outcomes show how procurement decisions in renewables produce operational efficiencies and a wider socio-economic benefits, with Wood Mackenzie (2024) projecting that U.S. solar manufacturing capacity has quadrupled since the IRA, enabling developers to meet surging demand more efficiently.

It is important to note however that job creation in renewables is deeply dependent on the continuity of policy frameworks such as the IRA and CHIPS Act. As Gerke (2025) cautions, procurement-driven domestic manufacturing gains may falter without sustained legislative support, raising questions about the long-term competitiveness of localized sourcing if domestic costs remain structurally higher than global alternatives. While procurement redesign has delivered measurable gains across sectors shortening lead times, stabilizing costs, and generating employment, the resilience of these outcomes is not uniform. They remain conditional on firms' capacity to embed adaptability into procurement practices and on the persistence of favorable policy environments.

IV. POLICY AND MARKET IMPLICATIONS

The intersection of procurement strategy and national energy policy sheds light on the central role of government in shaping resilient supply chains and advancing strategic energy goals. Federal interventions, particularly through the Inflation Reduction Act (IRA) and the CHIPS and Science Act, have proven effective in incentivizing domestic energy manufacturing. This has been achieved by introducing tax credits, loan guarantees, and direct subsidies (Gerke, 2025; Rodríguez, 2025), these

policies reduce the cost disadvantage faced by the U.S.-based manufacturers relative to global competitors. IRA-linked programs are projected to mobilize over \$370 billion in clean energy investments by 2030, significantly accelerating procurement shifts toward domestic sourcing in both traditional and renewable energy sectors (Perkins et al., 2023). Such incentives are levers for correcting market failures that have historically left the U.S. reliant on fragile overseas supply chains.

Effective energy procurement reform depends on direct subsidies and on coordinated efforts among diverse stakeholders. The Department of Energy and state energy offices contribute to enabling regional procurement networks that support grid modernization and accelerate the deployment of renewable energy solutions, ensuring collaboration and strategic investment across jurisdictions. Industry consortia, such as the American Clean Power Association, further amplify collective bargaining power and knowledge-sharing across firms. In Q1 2025, the U.S. added 7.4 GW of new clean power its second-highest quarterly total ever, with energy storage growing 65% year-over-year, and eight of the top ten states for utility-scale deployment, led by Texas with over 1,700 MW and a 20% capacity increase, having voted Republican in the previous presidential election (Martucci, 2025). This collaborative infrastructure reduces fragmentation in procurement strategies, aligning corporate interests with public-sector decarbonization targets. Recent efforts like the DOE's Grid Resilience and Innovation Partnerships (GRIP) program highlight how strategic co-investment can reduce delays in grid component deployment while driving regional job growth, with \$7.6 billion allocated across 105 projects spanning all 50 states and the District of Columbia through its first two funding rounds (U.S. Department of Energy, 2024).

The broader implications extend directly to U.S. energy independence and decarbonization pathways. Shifting procurement toward domestic manufacturing strengthens supply chain resilience, accelerates decarbonization, and boosts rural economies by reducing dependence on politically unstable sources of critical energy components. In 2024, states advanced bold climate policies, Vermont and Maryland committed to 100% clean energy by 2035, while Massachusetts passed a climate omnibus

bill to streamline permitting and accelerate deployment (Bird et al., 2025). The DOE 2024 report shows that in 2023, clean energy jobs grew by 4.2%, more than twice the overall economy's rate, with Idaho leading at 7.7%, solar and wind sectors rising 5.3% and 4.5% respectively, and nearly 90,000 energy construction jobs added as the Inflation Reduction Act drives a projected doubling of clean electricity generation by 2030 (U.S. Department of Energy, 2024). Many of these jobs are concentrated in rural and semi-rural areas that have traditionally lacked significant industrial investment. While current policy-driven procurement gains support energy independence, decarbonization, and rural development, their long-term sustainability depends on stable policy frameworks, market adaptability to higher domestic costs, and continued innovation to prevent a return to vulnerable offshore sourcing.

V. CONCLUSION AND RECOMMENDATIONS

This study has examined the significant effect of procurement reform in shaping the future of U.S. energy resilience, where domestic sourcing, technological adoption, and coordinated policy frameworks converge as levers for systemic transformation. The analysis of case studies revealed that procurement strategies directly influence measurable outcomes such as lead time reduction, cost savings, and job creation, affirming procurement's position as both an operational necessity and a strategic driver of national energy independence. Aligning procurement with decarbonization goals enables firms and governments to jointly reduce supply chain vulnerabilities and strengthen long-term industrial competitiveness.

To advance resilience-focused procurement reform, three critical policy recommendations emerge. First, a stable and long-term incentive framework is required to sustain domestic energy manufacturing. Programs initiated under the Inflation Reduction Act have proven effective, but continuity beyond election cycles is essential to prevent regression toward offshore dependencies. Second, public-private procurement partnerships should be scaled, leveraging DOE-led initiatives and state energy offices to ensure regional equity in resource allocation and manufacturing investment. Third, targeted workforce policies must accompany procurement reforms, ensuring that labor supply

keeps pace with the rapid expansion of renewable energy manufacturing, particularly in rural regions.

Supply chain consultants play a growing strategic role in driving systemic transformation across the energy sector. Their expertise in digital procurement systems, risk forecasting, and contract optimization allows firms to balance resilience with efficiency. Consultants also serve as neutral conveners, bridging private-sector decision-making with evolving regulatory landscapes, and ensuring that firms remain agile in the face of geopolitical and market shocks.

Future research should probe the potential of emerging technologies in procurement optimization. Artificial intelligence offers promising pathways for predictive demand forecasting, supplier risk scoring, and dynamic contract management, while blockchain-based traceability systems could enhance transparency in critical mineral sourcing and ensure compliance with ESG standards. Investigating these technologies in the context of U.S. energy supply chains will be essential to designing procurement models that are resilient and adaptive to the evolving global energy transition.

In sum, the future of energy procurement in the United States rests on a delicate balance of policy stability, market coordination, and technological innovation. Institutionalizing resilience as a procurement priority empowers the energy sector to fortify supply chains, speed up decarbonization, and unlock economic growth in diverse regions nationwide.

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