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POLICY OPTIMIZATION FOR SUSTAINABLE ENERGY SECURITY: DATA-DRIVEN COMPARATIVE ANALYSIS BETWEEN THE U.S. AND SOUTH ASIA

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Abstract

This study investigates how policy optimization shapes sustainable energy security in a comparative context between the United States and South Asia, responding to the problem that many energy security reforms are selected through narrative judgment rather than evidence-backed prioritization. The purpose was to test a quantitative model linking Policy Optimization (PO) to Sustainable Energy Security (SES) and to identify which policy levers most strongly predict energy security outcomes across two real-world cloud and enterprise informed cases (one U.S. case and one South Asia case). Using a quantitative, cross sectional, case-based design, data were collected through structured five-point Likert instruments from 420 stakeholders drawn from energy enterprises, regulators, and institutional policy units (n = 210 per case). Key independent variables were six PO dimensions: regulatory quality and enforcement, renewable integration policy strength, grid modernization policy, energy efficiency and demand side policy, affordability and equity policy, and climate resilience policy. The dependent construct was SES, measured through reliability and resilience, affordability and access, sustainability and acceptability, and supply risk management. The analysis plan applied reliability testing, independent samples t tests for case comparison, Pearson correlation to assess association, and multiple regression to estimate predictive effects with controls. Internal consistency was strong (Cronbach's alpha = .91 for PO and .89 for SES). Case results showed higher PO in the United States than South Asia (M = 3.74, SD = 0.61 vs M = 3.21, SD = 0.67) and higher SES (M = 3.86, SD = 0.58 vs M = 3.12, SD = 0.63). The largest SES gaps were observed in reliability and resilience (4.01 vs 3.05) and supply risk management (4.03 vs 3.13). Overall, PO was positively associated with SES ($r = .62$, $p < .001$). In the pooled regression, policy levers significantly explained SES variance (Adjusted $R^2 = .54$; $F(10, 409) = 50.12$; $p < .001$), with grid modernization emerging as the strongest predictor ($\beta = .31$), followed by regulatory quality ($\beta = .24$) and affordability and equity ($\beta = .21$). Region specific models indicated different leverage points: the United States was most driven by grid modernization ($\beta = .35$) and regulatory quality ($\beta = .22$), while South Asia was most driven by affordability and equity ($\beta = .29$), regulatory quality ($\beta = .26$), and climate resilience ($\beta = .20$). The findings imply that energy security gains can be accelerated by prioritizing enforceable governance and grid modernization in mature systems, while emphasizing affordability, governance capacity, and resilience delivery in constrained systems.

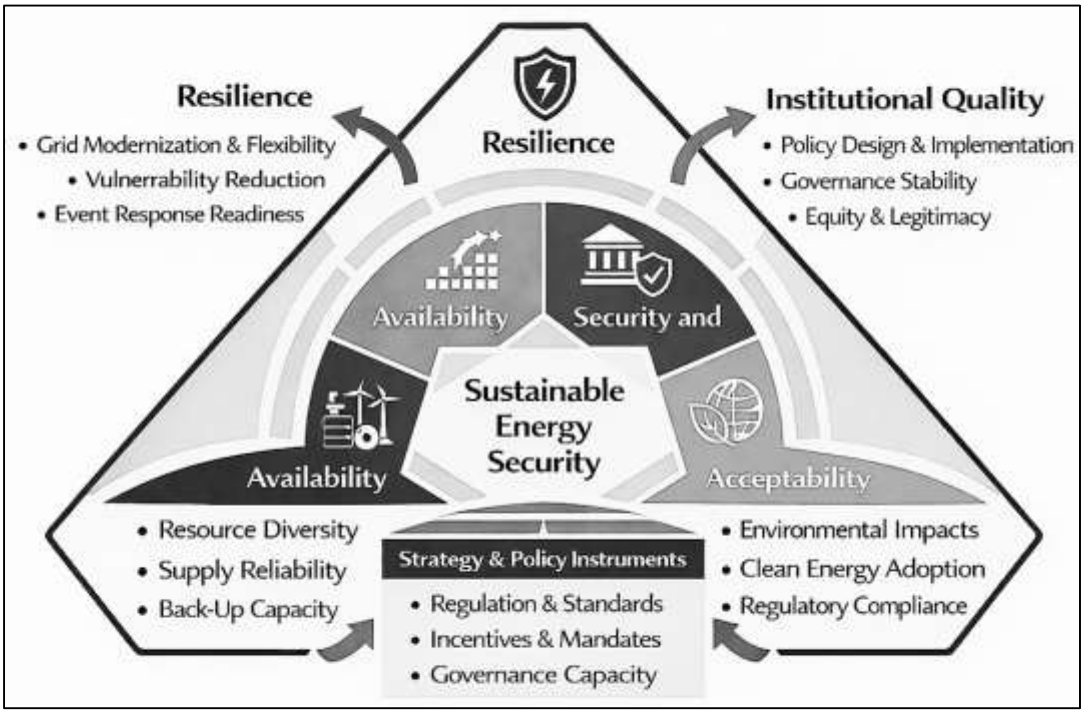
Keywords

Policy Optimization; Sustainable Energy Security; Grid Modernization; Affordability and Equity; Comparative Energy Policy;

INTRODUCTION

Energy security is widely defined as the ability of an economy and society to maintain the continuous provision of energy services at acceptable prices while limiting exposure to disruptions that can originate from technical failures, market volatility, governance weaknesses, or geopolitical pressures (Winzer, 2012). In sustainability-oriented research, energy security is treated as more than fuel availability because it also includes affordability, system reliability, environmental acceptability, and the robustness of institutions that plan, regulate, and finance energy systems (Sovacool et al., 2016). Indicator-based approaches operationalize these ideas by translating energy security into measurable dimensions such as import dependence, diversity of supply, infrastructure adequacy, and exposure to price risks, enabling comparative analyses across countries and time (Kruyt et al., 2009).

Figure 1: Integrated Systems View of Sustainable Energy Security and Policy Drivers



In parallel, systemic approaches emphasize "vulnerability" as a core concept, framing energy security as low susceptibility of vital energy systems to shocks and stressors that undermine energy services (Cherp & Jewell, 2014). These definitions position "policy optimization for sustainable energy security" as a structured decision problem in which governments select and calibrate policy instruments to improve multiple energy security dimensions at once, subject to economic and institutional constraints. The policy optimization idea also aligns with measurement traditions that rely on composite indices and multidimensional dashboards, which help decision-makers identify where policy levers can reduce risk, enhance reliability, and strengthen affordability simultaneously. As empirical work shows, energy security is not a single metric but a bundle of interdependent outcomes, meaning that policy choices often generate trade-offs among cost, reliability, equity, and environmental integrity (Carley, 2009). This framing supports a data-driven comparative approach in which the United States and South Asia can be examined as distinct policy-and-institutional settings that pursue energy security through different mixes of regulation, incentives, and governance mechanisms.

The international significance of sustainable energy security is rooted in the way energy systems underpin industrial productivity, public health, digital infrastructure, and macroeconomic stability, while also shaping national exposure to price volatility and supply interruptions (Costantini et al., 2007). Policy scholarship commonly treats sustainable energy security as a coordination challenge where governments must address multiple failures at once: technology spillovers that suppress private innovation and environmental externalities that shift social costs onto communities and future generations (Jaffe et al., 2005). The economics of energy systems also shows persistent barriers to efficient energy use and clean technology diffusion, reinforcing the need for policies that realign incentives through standards, pricing, and information tools (Gillingham et al., 2009). Empirical policy studies demonstrate that subnational and national interventions can measurably shift technology adoption and generation portfolios, which matters for security outcomes such as diversity and reliability (Bhattacharyya, 2012). Innovation-oriented evidence further indicates that well-designed renewable energy policies correlate with higher levels of clean-energy patenting and technology development, linking policy design to long-run system resilience and competitiveness (Johnstone et al., 2010). Energy security assessments across countries show heterogeneous performance patterns that reflect institutional capacity, market structure, infrastructure investment, and policy consistency, supporting the need for comparative frameworks that do not assume uniform pathways to security (Sovacool & Mukherjee, 2011). Within this international setting, comparative analysis between the U.S. and South Asia becomes important because both regions face high-stakes policy pressures—reliability and affordability expectations, competing fuel pathways, and infrastructure adequacy—yet their governance capacities and socio-economic conditions differ substantially (Ang et al., 2015). As a result, policy optimization research must treat sustainable energy security as an empirically testable outcome shaped by policy design, institutional quality, and socio-technical system conditions, rather than as a purely conceptual aspiration (Allcott & Greenstone, 2012).

A major empirical foundation for policy optimization is the evidence base on how specific policy instruments influence renewable deployment, diversification, and system affordability. In the U.S., research on state-level renewable policies illustrates that Renewable Portfolio Standards and related mandates correlate with measurable differences in renewable penetration, although effects vary across technologies, state contexts, and implementation details (Aized et al., 2017). Broader evaluations of renewable electricity support policies show that tariff design and policy credibility influence investment, project pipelines, and diffusion rates, highlighting the importance of policy structure rather than policy presence alone (Malik et al., 2020). These insights are central to optimization because the "best" policy mix depends on how instruments interact with market conditions, grid constraints, and institutional enforcement capacity (Shrimali & Kniefel, 2011). Evidence from South Asian contexts similarly shows that policy design must be examined alongside energy system realities such as fuel import exposure, generation adequacy, and financing constraints, which shape both feasibility and outcomes of renewable integration and security improvements (Panteli & Mancarella, 2015). Cross-country political economy research also reinforces that institutional quality—regulatory effectiveness, governance stability, and policy consistency—relates to renewable energy consumption patterns, suggesting that institutions moderate the effect of incentives and mandates (Uzar, 2020). When institutional quality is strong, policies are more likely to translate into realized capacity additions and stable operation, whereas weaker institutions can produce implementation gaps and suboptimal outcomes even when policy targets are ambitious (Sovacool et al., 2011). Accordingly, this study treats policy optimization as a measurable alignment between policy instruments and observed energy security outcomes, assessed through quantitative relationships among policy and governance variables and energy security dimensions (Sovacool & Dworkin, 2015). This instrument-focused literature motivates a structured empirical model in which renewable support, regulatory stringency, and institutional quality can be tested as predictors of sustainable energy security outcomes across regions.

A second empirical foundation concerns how energy security is measured through multidimensional constructs that capture availability, affordability, efficiency, and environmental acceptability. Indicator-based energy security studies demonstrate that composite measurement supports policy analysis by revealing where systems are vulnerable to shocks, overdependence, and cost instability (Jenner et al., 2013). In South Asia, sustainable energy security frameworks have been operationalized through subsystem indices that distinguish energy supply dynamics from demand-side efficiency and conversion/distribution performance, enabling targeted diagnosis of policy priorities (Jenkins et al., 2016). These subsystem assessments show that sustainable energy security is shaped not only by generation capacity and fuels but also by demand efficiency, end-use structure, and affordability pressures, which are salient in contexts with energy access deficits and rapid urbanization (Ivanovski & Marinucci, 2021). Energy access scholarship emphasizes that expanding electricity connections alone does not automatically resolve affordability, service quality, and sustainability challenges, supporting the need for multi-dimensional measurement that includes reliability and clean energy attributes (Heffron & McCauley, 2017). In parallel, energy poverty research operationalizes affordability and access as measurable constraints on welfare, showing that household and community vulnerability is a core component of sustainable energy security in developing settings (Islam et al., 2008). Technology-availability reviews in Bangladesh illustrate how renewable resources and deployment constraints intersect with policy and financing structures, reinforcing that measured outcomes reflect both resource potential and policy execution (Gracceva & Zeniewski, 2014). Pakistan-focused research further demonstrates that energy security can be assessed using structured frameworks (such as multi-dimensional "4A" perspectives), providing empirically tractable measures for policy evaluation and cross-regional comparisons (Delmas & Montes-Sancho, 2011). Taken together, these studies justify constructing a survey-based construct set for quantitative analysis—capturing perceptions and measured indicators of affordability, availability, acceptability, and governance effectiveness—so that policy optimization can be linked to sustainable energy security outcomes through correlation and regression models (Bhattacharyya, 2012).

Sustainable energy security is also conditioned by system resilience, which concerns the ability of energy infrastructure and governance processes to withstand and recover from disruptions. Power systems research indicates that resilience is not equivalent to reliability; it emphasizes performance under high-impact disturbances such as extreme weather events, cascading failures, and cross-sector interdependencies, which can amplify security risks (Pachauri & Spreng, 2011). In this view, resilience is shaped by infrastructure redundancy, operational flexibility, grid modernization, and institutional capacity for coordinated response, making it a policy-relevant outcome rather than a purely technical attribute (Narula et al., 2017). Energy security assessment approaches for low-carbon systems likewise emphasize that transitions alter risk profiles, shifting vulnerabilities from fuel supply chains toward infrastructure adequacy, flexibility, and system coordination (Narula et al., 2016). Cross-national energy security benchmarking supports this claim by showing that countries can improve some security dimensions while exposing others, depending on technology pathways and governance quality (Sovacool et al., 2016). Policy stability and economic uncertainty are also empirically linked to renewable energy outcomes, which matters for resilience because investment delays and uneven deployment can preserve structural vulnerabilities in generation mixes and transmission adequacy (Ivanovski & Marinucci, 2021; Mohiul, 2020). Such evidence implies that policy optimization must address not only the selection of instruments but also the consistency and enforceability of those instruments over time, since credibility influences private investment responses and system modernization trajectories (Jinnat & Kamrul, 2021; Malik et al., 2020). The U.S. context highlights these dynamics through extensive state-level policy variation and diverse grid conditions, while South Asia highlights them through capacity adequacy pressures and affordability constraints that influence investment feasibility (Delmas & Montes-Sancho, 2011; Jinnat & Kamrul, 2021). Therefore, a comparative research design that includes resilience-related indicators—reliability perceptions, infrastructure adequacy, and governance responsiveness—strengthens the explanatory power of policy optimization models by connecting policy attributes to observable security performance across different system conditions (Bhattacharyya, 2012; Hasan & Shaikat, 2021).

A theoretically grounded comparison also requires explicit attention to fairness, governance legitimacy, and institutional behavior, because energy policies distribute benefits and burdens across social groups and regions. Energy justice scholarship defines energy systems as ethical and political arrangements that allocate costs, risks, and opportunities, and it provides analytical principles—distributional equity and procedural fairness—that are measurable through perceptions of affordability, participation, transparency, and accountability (Kruyt et al., 2009; Rabiul & Samia, 2021). Complementary conceptual reviews show how energy justice has become a cross-cutting lens connecting energy security, climate governance, and social welfare through consistent evaluative criteria (Mohiul & Rahman, 2021; Rahman & Abdul, 2021; Sovacool et al., 2011). This line of work supports the inclusion of justice-relevant constructs when studying sustainable energy security, because affordability, access, and decision legitimacy can shape compliance, political feasibility, and perceived effectiveness of policy instruments (Jaffe et al., 2005; Haider & Shahrin, 2021; Zulqarnain & Subrato, 2021). A justice-informed approach also aligns with energy poverty measurement research, which empirically links affordability constraints to welfare impacts and policy sensitivity, especially in developing regions (Habibullah & Farabe, 2022; Arman & Kamrul, 2022; Pachauri & Spreng, 2011). At the same time, political economy evidence indicates that institutional quality influences renewable energy consumption and, by extension, energy diversification and exposure to imported fuels, reinforcing the idea that governance capacity is a central explanatory factor in comparative policy analysis (Jenkins et al., 2016; Rashid & Sai Praveen, 2022; Kamrul & Omar, 2022). These theoretical and conceptual foundations motivate a model in which policy optimization is evaluated not only through technical and economic outputs but also through governance and equity constructs that reflect how policies are implemented and experienced (Sovacool & Mukherjee, 2011). Accordingly, the study frames institutional quality and energy justice principles as complementary lenses: institutional quality explains how policies translate into outcomes through enforcement and capacity, and energy justice explains how outcomes are perceived and socially distributed through affordability, access, and procedural legitimacy (Jenkins et al., 2016; Rahman, 2022; Rony & Samia, 2022). This combination strengthens comparative analysis between the U.S. and South Asia because it allows differences in system performance to be interpreted through both policy capacity and social acceptability, which are central dimensions of sustainable energy security (Ang et al., 2015).

The empirical and conceptual literature converges on a gap that motivates this study: many energy security analyses remain region-specific or technology-specific, while policy effectiveness evidence is often separated from multidimensional security measurement, limiting integrated optimization insights that can be tested quantitatively across contrasting contexts (Kruyt et al., 2009). The United States provides a case context characterized by policy heterogeneity across states, mature energy markets, and complex grid governance, where renewable mandates and related incentives demonstrate measurable but varied associations with deployment outcomes (Ang et al., 2015). South Asia provides a contrasting case context where energy access, affordability, import exposure, and governance capacity can constrain or reshape policy performance, and where sustainable energy security indices reveal subsystem-specific weaknesses that policy design must address (Costantini et al., 2007). This study therefore adopts a quantitative, cross-sectional, case-study–based comparative design that uses Likert five-point scale measurements of key constructs (policy effectiveness perceptions, governance/institutional quality perceptions, affordability and access perceptions, and perceived reliability and environmental acceptability) and evaluates relationships through descriptive statistics, correlation analysis, and regression modeling (Ivanovski & Marinucci, 2021). The guiding research questions are: **RQ1**: How do policy instrument strength and perceived implementation quality relate to sustainable energy security outcomes within the U.S. case context? **RQ2**: How do these relationships differ within selected South Asian case contexts where affordability and access constraints are more salient? **RQ3**: To what extent do institutional quality and justice-related constructs mediate or condition the relationship between policy instruments and sustainable energy security across both regions? Building on prior evidence linking policy design, institutional quality, and security outcomes, the study states the following hypotheses: **H1**: Stronger policy instrument design is positively associated with higher perceived sustainable energy security; **H2**: Higher institutional quality is positively associated with sustainable energy security; **H3**: Institutional quality strengthens the positive relationship between policy instruments and sustainable energy security; **H4**: Higher perceived affordability is positively associated with sustainable energy security; **H5**: Justice-related procedural legitimacy is positively associated with sustainable energy security; **H6**: The magnitudes of these associations differ between the U.S. and South Asia due to differences in governance and access conditions (Winzer, 2012). This study is designed to achieve a set of tightly linked objectives that translate the broad idea of "policy optimization for sustainable energy security" into measurable constructs and testable relationships within a comparative, data-driven framework. The first objective is to operationalize sustainable energy security as a multidimensional outcome that reflects reliability and resilience of supply, affordability and accessibility of energy services, and environmental acceptability of the energy system, so that "security" is captured as an integrated performance construct rather than a single indicator. The second objective is to operationalize policy optimization as a structured bundle of policy and governance dimensions that can be assessed consistently across the United States and South Asia, including regulatory quality and enforcement capacity, renewable energy integration policy strength, grid modernization and reliability-focused investment policy, demand-side efficiency and conservation policy, affordability and equity protection measures, and climate-risk and resilience integration into energy planning. The third objective is to quantify the degree to which these policy optimization dimensions are associated with sustainable energy security outcomes in each case setting using a cross-sectional survey instrument measured on a five-point Likert scale, enabling systematic comparison of central tendencies and variation in stakeholder assessments across the two regions. The fourth objective is to evaluate the strength and direction of relationships among constructs through correlation analysis, providing an empirical map of how specific policy levers co-move with sustainable energy security outcomes and revealing which policy dimensions align most closely with reliability, affordability, and sustainability performance. The fifth objective is to test explanatory models using regression analysis to identify the most influential predictors of sustainable energy security, estimate the relative contribution of each policy dimension while controlling for respondent and contextual factors, and determine whether the statistical structure of these relationships differs between the United States and South Asia. The sixth objective is to produce a clear comparative ranking of policy optimization priorities by translating regression coefficients and significance patterns into an ordered set of leverage points for each region, allowing the study to distinguish which policy areas emerge as the strongest drivers of sustainable energy security under differing institutional capacity, infrastructure conditions, and affordability constraints. The final objective is to consolidate these empirical outputs into a coherent analytical narrative that stays consistent with the study's quantitative scope, enabling the research to demonstrate how policy design, implementation capacity, and system-level governance dimensions jointly shape sustainable energy security performance in two contrasting contexts.

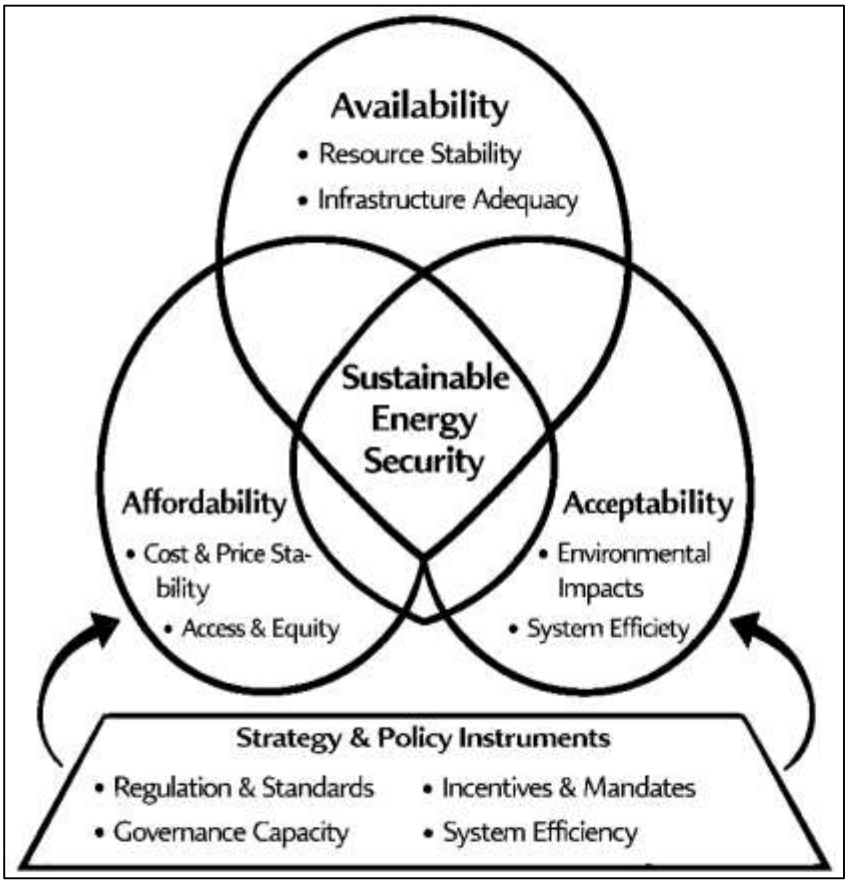
LITERATURE REVIEW

The literature on policy optimization for sustainable energy security brings together three closely connected bodies of scholarship: multidimensional energy security measurement, evidence on policy instrument performance, and comparative governance-informed energy transition studies. In this research area, energy security is treated as a composite concept that extends beyond fuel availability to include reliability of supply, resilience to shocks, affordability for households and industry, accessibility and equity in service provision, environmental acceptability, and the institutional capacity required to plan, finance, regulate, and coordinate complex energy systems. Because these dimensions interact, the literature increasingly emphasizes frameworks that can diagnose vulnerabilities across the full energy value chain—from supply diversity and import exposure to grid adequacy, demand-side efficiency, and price volatility—while also capturing sustainability constraints associated with emissions reduction and environmental risk. Alongside measurement frameworks, a major strand of research evaluates the effectiveness of policy instruments that governments use to shape energy system outcomes, such as renewable energy targets and mandates, feed-in tariffs, auctions, fiscal incentives, carbon pricing, energy efficiency standards, and grid modernization programs. This evidence indicates that policy effects depend not only on the presence of instruments but also on their design features, credibility, stability, enforcement strength, and alignment with market structure and infrastructure readiness. A third body of scholarship focuses on the political economy and governance conditions that enable or weaken policy implementation, recognizing that institutional quality, regulatory transparency, and administrative capability influence investment certainty, technology diffusion, and the delivery of reliable and affordable energy services. These themes become especially salient in comparative research because energy policy outcomes differ across regions where resource endowments, demand growth, financing conditions, and governance capacity vary. The United States represents a context where energy policy is shaped by federal–state interactions, diversified markets, and heterogeneous subnational implementation, while South Asia represents contexts where energy access deficits, affordability constraints, import dependence, and capacity limitations can intensify vulnerability and alter the effectiveness of similar policy tools. For this reason, contemporary literature increasingly calls for comparative, data-driven approaches that integrate policy design and governance factors with multidimensional energy security outcomes, allowing researchers to identify which policy optimization levers most strongly correlate with sustainable energy security performance in different institutional and infrastructural settings. Building on these foundations, the present review synthesizes prior findings to structure a coherent theoretical lens and conceptual framework that support measurable constructs, hypothesis development, and a comparative empirical strategy suited to evaluating policy optimization pathways across the U.S. and South Asia.

Sustainable Energy Security

Energy security has expanded from a narrow concern with physical fuel supply into a policy concept centered on the dependable provision of energy services for economies and societies. In this view, security is expressed through an energy system's capacity to keep electricity and fuels available when needed, keep costs within a socially tolerable range, and limit disruptions that damage welfare, production, and public services. The literature therefore treats energy security as multidimensional, requiring indicators that capture availability of resources, diversity of supply options, exposure to geopolitical and market risks, adequacy of infrastructure, and institutional readiness to anticipate shocks. Conceptual work also distinguishes between short-run supply security, which buffers sudden disruptions, and longer-run system security, which depends on planning and investment that reduce vulnerability over time. Within industrialized contexts, energy security is frequently operationalized through measurable indicators such as import dependence, diversity indices, reserve margins, strategic stocks, and price volatility, combined with governance variables that reflect market regulation and resilience planning (Löschel et al., 2010).

Figure 2: Core Dimensions of Sustainable Energy Security



A sustainability-oriented interpretation adds that secure energy services must be delivered in ways that remain environmentally acceptable and economically efficient, because environmental damage and inefficient allocation can create security liabilities through health burdens, stranded assets, and fiscal stress. From an economics perspective, energy security is tied to welfare maximization under uncertainty, where affordability and environmental compatibility function as core constraints shaping feasible policy choices (Blum & Legey, 2012). This integrated definition is especially relevant for comparative analysis between the United States and South Asia because both regions face reliability and price concerns, yet they differ in demand growth, access gaps, institutional capacity, and the distributional stakes of energy pricing. As a result, the literature motivates research designs that translate this multidimensional concept into surveyable constructs aligned with policy levers and stakeholder experience in contemporary practice.

Moving from concept to measurement, energy security scholarship relies on indicator systems and composite indices that summarize complex risk profiles into interpretable scores. Indicator approaches typically begin by selecting a basket of variables representing supply diversity, import exposure, infrastructure adequacy, price stability, and governance quality, followed by normalization and aggregation to enable comparison across time and jurisdictions. Reviews of national indices show large variation in how studies choose dimensions, apply weights, and treat trade-offs, which can lead the same country to appear secure under one index and insecure under another (Gasser, 2020). This diversity is not merely technical; it shapes what policy makers can optimize, because an index emphasizing fuel diversity may reward actions with different social consequences than an index emphasizing affordability or emissions. To reduce ambiguity, studies emphasize transparency about indicator selection, the logic linking indicators to policy instruments, and the sensitivity of results to weighting choices and missing data. A complementary strand develops decision-support models that connect policy levers to security outcomes, allowing scenario testing rather than static scoring. For example, an approach combining quality function deployment with system dynamics models energy security as an interacting set of policy-relevant components and tests how interventions shift key indicators over time (Shin et al., 2013). This work underscores the need to treat energy security as a system with feedbacks among demand growth, import dependence, technology substitution, and regulatory credibility. For a quantitative, cross-sectional case-study design, these insights justify constructing Likert-based constructs that reflect stakeholder assessments of policy optimization domains, such as regulatory quality, diversification strategy, investment adequacy, price management, and sustainability safeguards, and pairing them with secondary indicators when available. In comparative settings, standardized constructs support correlation screening and multivariate regression, helping isolate which policy dimensions most strongly predict perceived energy security under shared measurement across both cases.

Comparative policy research benefits from evidence on how energy security metrics move over long horizons and how those movements relate to policy choices, structural change, and macroeconomic conditions. Longitudinal assessments of industrialized countries suggest that improvements in certain dimensions, such as reduced oil intensity or diversified generation portfolios, can coexist with persistent vulnerabilities linked to price volatility, infrastructure aging, or uneven progress on decarbonization. A multi-decade comparative assessment of OECD countries illustrates how a small set of standardized metrics can reveal both convergence and divergence in national trajectories, highlighting that policy packages may strengthen some dimensions of security while leaving others relatively unchanged (Brown et al., 2014). Such findings matter for a U.S.–South Asia comparison because the regions are positioned differently along key structural axes: the United States has mature infrastructure and deep capital markets, while South Asian systems often combine rapid demand growth with constrained fiscal space and continuing access and affordability pressures. These structural differences shape what "optimization" can mean in practice, because a policy lever that primarily improves efficiency in a high-income context may function as an access-expansion instrument in a lower-income context, with distinct distributional outcomes. The literature therefore encourages definitions of sustainable energy security that accommodate both reliability and equity, treating affordability and service quality as lived outcomes rather than abstract indicators. It also supports integrating environmental acceptability into security assessments, since climate and local pollution risks translate into health costs, policy instability, and capital reallocation that influence system resilience. For cross-sectional survey research, these insights justify measuring perceived performance and governance quality in parallel with objective context variables, and then using correlation and regression to test whether stronger policy optimization is associated with higher perceived sustainable energy security within each case and across cases using comparable constructs under a common analytical framework.

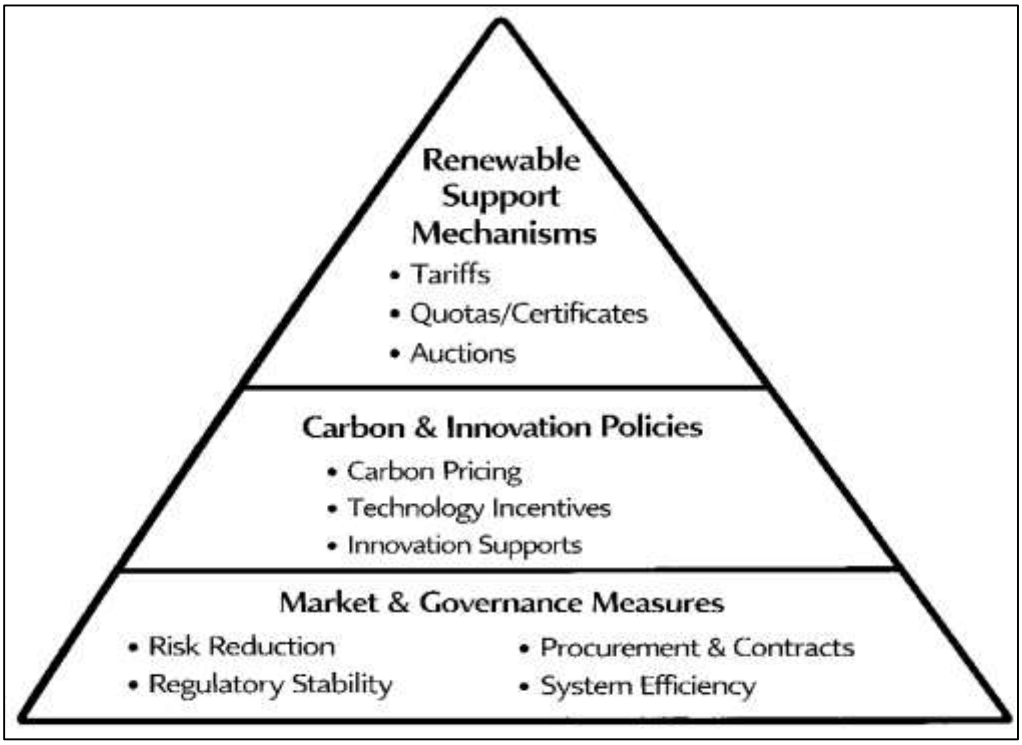
PSustainable Energy Security Optimization

Policy optimization for sustainable energy security is frequently examined through instrument choice, where governments combine measures that influence generation investment, system reliability, consumer prices, and environmental performance. In electricity markets, the most visible supply-side instruments vary in how they allocate risk and create revenue certainty. Price-based approaches such as feed-in tariffs and fixed premiums provide predictable remuneration, lowering financing costs and encouraging entry by smaller developers, while quantity-based approaches such as quotas with tradable certificates expose investors to market prices and compliance uncertainty. A key implication is that policy strength is not only the incentive level but also the stability and bankability of the revenue stream. Comparative evidence on wind policy design shows that different mixes of tariffs, quotas, and auctions can yield distinct deployment patterns and cost outcomes because investors respond to planning risk, grid access constraints, and the credibility of long-term support (Butler & Neuhoff, 2008). These mechanisms matter for energy security because capacity additions and operational reliability hinge on timely project realization and on the ability of the support regime to attract capital through lower risk premia. The literature therefore treats risk reduction as a central pathway linking policy design to security outcomes, emphasizing that predictable prices, clear volume expectations, and manageable balancing responsibilities shape the cost of capital and the likelihood that awarded projects are built. Analysis comparing a renewable obligation to a feed-in system highlights how price, volume, and balancing risks are distributed differently across instruments, with downstream effects on investment behavior and project delivery (Mitchell et al., 2006). For a U.S.–South Asia comparison, this instrument perspective helps structure policy-optimization constructs around credibility, administrative simplicity, and risk allocation, which are expected to translate into higher perceived reliability and affordability where markets and institutions differ. It motivates measuring stakeholder perceptions of tariff stability and delivery risk.

Beyond renewable support, sustainable energy transitions are shaped by policies that internalize environmental externalities and correct innovation-related market failures. A central argument in the policy-mix literature is that no single instrument simultaneously achieves efficient emissions reduction and the socially optimal pace of technological change, because emissions create a negative externality while clean-technology knowledge produces spillovers that private actors cannot fully capture. Carbon pricing improves efficiency by rewarding low-carbon choices across fuels and sectors, yet complementary deployment and innovation policies are often used to overcome nonprice barriers and speed diffusion of cleaner technologies. A stylized electricity-sector assessment shows how different combinations of emissions pricing, performance standards, and technology incentives can shift abatement costs and innovation outcomes, clarifying why policymakers rely on portfolios rather than single levers (Fischer & Newell, 2008). For energy security, the relevance is practical: a policy package that lowers emissions but raises price volatility or undermines investment certainty can weaken affordability and reliability, while a package that cushions prices but delays structural change can amplify exposure to fuel-price shocks and climate risks. Empirical evidence on carbon taxation illustrates the importance of implementation context, showing that a carbon tax can be associated with reductions in per capita emissions in some cases while exhibiting weaker effects in others, reflecting differences in baseline energy mixes and tax design (Lin & Li, 2011). In comparative terms, the same instrument may deliver different energy-security trade-offs across the United States and South Asia, because industrial structure, income constraints, and institutional capacity shape price pass-through and the feasibility of compensating households. For a cross-sectional, survey-based design, these insights support operationalizing policy optimization as perceived coherence of the policy mix, credibility of enforcement, and fairness of burden sharing, and testing whether these perceptions are associated with higher sustainable energy security outcomes in each case in practice.

A growing share of the literature treats competitive procurement as a core instrument for policy optimization because auctions can discover prices, discipline subsidy costs, and align contracted volumes with system needs. Renewable energy auctions are designed around decisions about what is procured, who is eligible to bid, what prequalification rules apply, how bids are ranked, what pricing rule is used, and what obligations and penalties govern delivery. The energy-security implications are twofold. First, well-designed auctions can expand generation capacity at lower support costs, improving affordability and reducing exposure to imported fuels.

Figure 3: Hierarchical Structure of Policy Instruments Supporting Sustainable Energy Security



Second, poorly designed auctions can create a paper pipeline of awarded projects that fail to reach commercial operation, weakening reliability planning and delaying emissions reductions. Empirical evidence using a large multi-country dataset shows that realization rates are strongly associated with enforcement-oriented design elements, particularly prequalification requirements and credible penalties for non-delivery, whereas several debated features have weaker relationships with effectiveness (Matthäus, 2020). This finding motivates treating administrative capability and contract enforcement as essential components of policy optimization, not merely implementation details. In comparative research, the auction lens is useful because it offers a common instrument that can operate in both mature and capacity-constrained settings while still revealing institutional differences. In the United States, auctions interact with organized wholesale markets, interconnection queues, and state procurement mandates; in South Asia, auctions often interact with single-buyer models, sovereign credit risk, land acquisition processes, and grid expansion bottlenecks. A cross-sectional, stakeholder-survey approach can capture how actors perceive auction transparency, contract bankability, and delivery discipline, alongside perceptions of reliability and price outcomes. These measures enable correlation and regression tests that identify whether stronger perceived auction quality is associated with higher sustainable energy security, and whether the magnitude of these associations differs across the two case contexts. This links procurement governance directly to security metrics.

U.S. vs. South Asia

A core theme in comparative energy-security scholarship is that "policy optimization" is shaped by how responsibilities and risks are distributed across institutions, markets, and consumers, and the United States offers a distinctive example of policy delivered through layered governance and heterogeneous implementation. In practice, many U.S. decarbonization and energy-security interventions emerge through subnational policy instruments—especially state-level renewable portfolio standards (RPS), procurement mandates, and complementary financial or regulatory mechanisms—rather than a single centralized policy channel. This structure creates variation in ambition, compliance design, and enforcement capacity across states, while the shared grid and interregional markets transmit spillovers (e.g., renewable certificate trading, congestion, balancing requirements) that influence reliability and costs. Empirical evidence on wind development shows that policy regimes combining mandatory rules, regulatory changes, and financial incentives can generate materially different deployment outcomes across U.S. states because they interact with resource endowments, grid access, and market structure (Menz & Vachon, 2006). A related body of work evaluates RPS performance not only through capacity growth but through the distribution of costs and monetizable benefits, highlighting that compliance costs are typically assessed relative to retail rates, while benefits are often framed around emissions reductions and public-health outcomes and may be estimated with different methods across jurisdictions (Barbose et al., 2015). For a comparative U.S.–South Asia design, these findings are important because they show that the effectiveness of "optimization" depends on measurable design attributes—policy credibility, compliance mechanisms, and administrative capability—rather than the nominal presence of an instrument. They also motivate construct operationalization that distinguishes policy design quality (clarity, stability, enforceability), infrastructure adequacy (transmission expansion, interconnection), and affordability protection (rate impacts and cost containment). By treating the U.S. case as an environment where policy outcomes are mediated by market rules and multi-level governance, the literature supports testing whether perceived instrument quality and governance coherence are statistically associated with perceived sustainable energy security, and whether these relationships differ in regions where institutions and consumer affordability constraints are more binding.

Figure 4: U.S. and South Asia Energy Security Policy and System Comparison

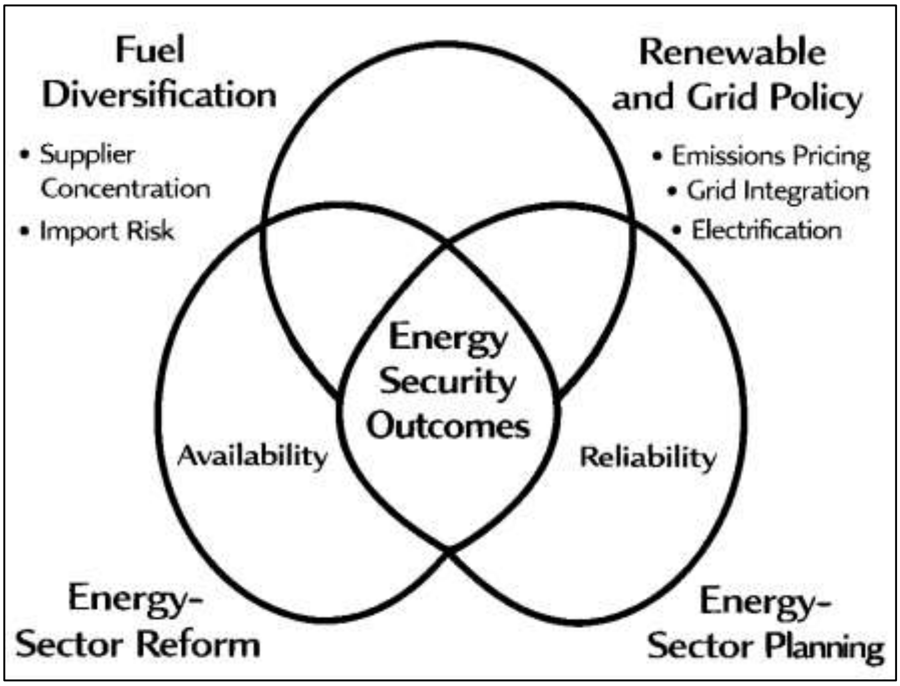
South Asia, by contrast, is frequently characterized in the literature as a region where energy security is inseparable from electricity access, service quality, and affordability, and where policy optimization must address both expansion and stabilization of supply. Many national systems in the region face rapid demand growth, constrained public finance, utility balance-sheet stress, and uneven grid performance, which together shape the feasible set of policy choices and the speed at which reforms translate into improved outcomes. As a result, the policy question is often framed as a portfolio decision between extending and strengthening central grids, accelerating distributed and off-grid solutions, and improving the governance and financial viability of service providers. Evidence from off-grid rural electrification experiences across South Asia underscores that decentralized solutions can play a meaningful role, while outcomes depend heavily on institutional arrangements, tariff design, maintenance ecosystems, and the ability to align technology selection with local demand and willingness-to-pay (Palit & Chaurey, 2011). Complementary synthesis on the region's electrification challenge argues that grid extension alone is an incomplete remedy because reliability constraints, last-mile service quality, and household affordability can limit the welfare impact of "connection" as a metric, strengthening the case for hybrid strategies that combine grid strengthening with distributed generation and targeted service models (Palit & Bandyopadhyay, 2016). For the present study's comparative model, these insights imply that sustainable energy security must be operationalized in a way that captures access and quality (e.g., continuity of supply, adequacy for productive uses) alongside affordability and environmental acceptability. They also support including policy-implementation capacity as a measurable construct (e.g., enforcement, revenue collection, maintenance, procurement capability), because system performance in South Asia is often constrained by delivery mechanisms rather than the absence of formal policy intent. Consequently, correlation and regression testing can be structured to evaluate whether stronger perceived policy delivery and institutional capacity predict higher perceived security outcomes in South Asia, and whether the predictive structure differs from the U.S. case where market institutions and regulatory layering dominate the policy pathway.

A further comparative dimension centers on how renewable energy integration is positioned within energy-security strategies, because the U.S. and South Asia differ in resource mixes, import exposure, infrastructure maturity, and institutional capability to manage variability. In South Asia, reviews emphasize both the scale of renewable resource potential and the persistence of structural barriers, including high up-front capital requirements, limits in technical expertise for design and maintenance, gaps in data and planning capacity, and grid constraints that complicate large-scale integration (Shukla et al., 2017). These constraints mean that "optimization" is often evaluated through enabling conditions—credible targets, grid connection rules, investment facilitation, and institutional coordination—rather than through single-instrument performance. In the U.S., comparable renewable integration challenges often appear as issues of market design, interconnection queues, transmission build-out, and balancing resources, with policy debates shaped by state-level mandates and federal oversight of interstate electricity markets; the empirical literature on state policy regimes and RPS evaluation offers concrete evidence that design details and implementation practices can influence both deployment effectiveness and perceived cost burdens (Palit & Chaurey, 2011). When these two contexts are juxtaposed, the literature supports a comparative hypothesis that policy optimization dimensions tied to implementation capacity and affordability protection may carry stronger explanatory power in South Asia, while dimensions tied to instrument design coherence, compliance architecture, and market integration may be more predictive in the United States. This also motivates comparative construct design that can travel across contexts: policy credibility and stability, institutional capacity and enforcement, investment and procurement effectiveness, grid readiness for variable renewables, and equity-focused affordability measures. By structuring a quantitative, cross-sectional case-study design around these shared but context-sensitive dimensions, the study can use descriptive statistics to profile perceived policy and security conditions, then apply correlation and regression to test which optimization levers show the strongest statistical association with sustainable energy security within each region and across the combined sample.

Impacts on Energy Security Outcomes

Energy security is commonly defined as the capacity of an economy to deliver energy services that are available, affordable, and resilient to geopolitical and market disruptions. Quantitative studies operationalize this definition by measuring vulnerability to import interruptions, exposure to price volatility, and the degree of supplier concentration in traded fuels. These indicators are tightly connected to policy levers such as strategic reserves, diversification requirements, fuel-switching incentives, and contracting rules that shape where fuels are sourced and how quickly substitutes can be mobilized during a shock. For example, work that separates price risk from physical availability risk shows that concentration in upstream resources can translate into higher systemic vulnerability even when spot markets appear well supplied, implying that policymakers must evaluate both market structure and logistical constraints when optimizing security portfolios (Lefèvre, 2010). Empirical evidence on oil and gas import patterns also demonstrates why "diversification" is more than a rhetorical objective: using portfolio measures for supplier diversity, researchers find that import portfolios have become more diversified over time, and that diversification is a coherent policy target because it reduces dependence on a narrow set of exporting regions that may be exposed to correlated disruptions (Cohen et al., 2011). In comparative terms, the United States' large domestic resource base and flexible infrastructure can mute some import-related risks, while South Asian economies are more frequently exposed to concentrated import channels and tighter infrastructure constraints. This contrast supports modeling energy security as a policy-sensitive outcome that can be decomposed into observable dimensions—concentration, affordability, and availability—so that cross-sectional case evidence can be mapped to specific policy instruments. Operationally, these decompositions link policy choices—such as LNG contracting, petroleum reserve rules, or renewable portfolio standards—to outcomes like concentration indices, fuel-price pass-through, and reserve margins, and they help specify hypotheses for U.S.–South Asia comparisons in both policy contexts.

Figure 5: Empirical Evidence on Policy Impacts on Energy Security Outcomes



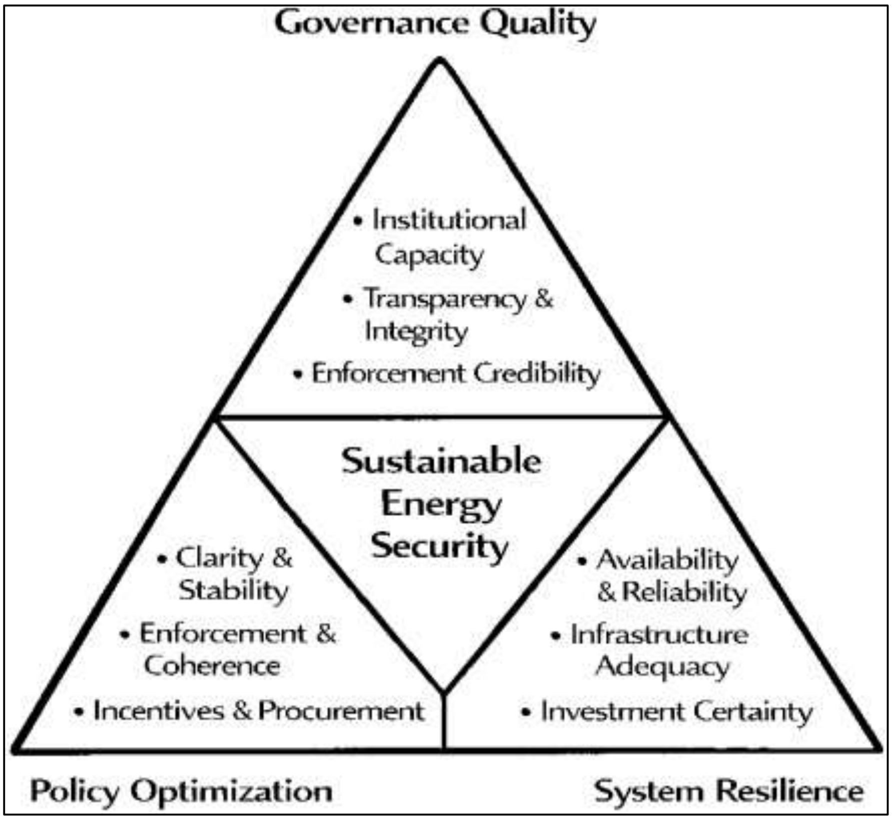
Beyond fuel import structure, empirical research increasingly treats the interaction between energy security objectives and renewable energy policy as a relationship to be tested rather than assumed. In the European Union, analyses show that security strategies differ in their mechanisms: some emphasize reducing external dependence through domestic renewables and efficiency, while others emphasize price stability through integrated markets, interconnections, and diversified external suppliers. Evidence indicates that the statistical association between "energy security policy" and renewable energy deployment depends on which security strategy is prioritized and how security is conceptualized, meaning that a single policy package can generate mixed security signals across dimensions (Valdés Lucas et al., 2016). For policy optimization, this matters because the same intervention may improve one dimension (e.g., import dependence) while creating another stress point (e.g., short-term adequacy if variable renewables outpace flexibility). A second empirical strand strengthens this argument by demonstrating that electricity security is measurable through indicators that are directly influenced by governance and regulatory quality, not only by fuel mix. A composite global electricity security index based on outages, electrification, industrial electricity prices, sector profitability, and governance quality highlights how institutional capacity and market rules co-determine security outcomes (Neelawela et al., 2019). Taken together, these findings motivate a comparative U.S.–South Asia framing in which renewable policy is treated as one component within a broader security system: U.S. policy debates often focus on adequacy and price impacts in mature grids, whereas South Asian contexts may simultaneously face electrification gaps, higher technical and commercial losses, and more binding affordability constraints. Methodologically, this supports specifying security constructs as multidimensional latent variables measured by survey items (for perceived affordability, reliability, and resilience) and anchored to observable proxies where available, aligning with a cross-sectional, hypothesis-testing design. It justifies interaction terms in regressions to capture how governance moderates policy effects.

Empirical evidence on power-sector reform demonstrates that energy security outcomes respond to institutional and market-structure interventions, and that effects can be regionally heterogeneous—an essential consideration for a U.S.–South Asia comparative case-study design. Reform packages typically include unbundling, commercialization, private participation, independent regulation, and competitive wholesale arrangements, each intended to reduce technical losses, strengthen utility finances, and improve service quality. Using panel data across more than one hundred countries over multiple decades, one study estimates the causal impact of reform activity on sector performance and finds evidence consistent with reforms reducing network losses and improving electricity access, while also emphasizing the endogeneity of reform timing and the need for credible identification strategies (Dertinger & Hirth, 2020). These outcomes map directly to energy security dimensions that matter in South Asia, where high transmission and distribution losses, constrained utility balance sheets, and uneven access translate into reliability and affordability risks. In the United States, comparable "security" concerns often appear as extreme-weather resilience, capacity adequacy, and price volatility rather than basic access, which implies that the same reform label can represent different underlying mechanisms across cases. For a quantitative, cross-sectional design, this literature supports modeling security as a function of policy and institutional variables that can be measured via Likert constructs (e.g., perceived regulatory effectiveness, investment stability, and reliability), then linked to outcomes such as perceived security or satisfaction with energy services. It also supports including mediators—like utility performance or governance quality—so regression models can test whether policy levers act directly on security perceptions or indirectly through improved service delivery. This framing provides a clear empirical bridge between policy optimization choices and the measurable security outcomes that your hypotheses will evaluate across the U.S. and South Asia. Accordingly, case selection should reflect contrasting reform depth, market maturity, and exposure to import and climate risks.

Institutional–Governance Theory as Policy Optimization

A policy-optimization approach to sustainable energy security requires a theoretical lens that explains why similar policy instruments produce different security outcomes across regions. Institutional and governance perspectives treat energy systems as rule-bound arenas where formal regulations, informal norms, and enforcement capacity jointly determine investment behavior, operational performance, and the distribution of costs and benefits. Within this view, "policy optimization" is not limited to selecting instruments (e.g., subsidies, standards, auctions) but also includes designing credible commitments, reducing transaction costs, and aligning administrative routines with system needs. Institutional theory is particularly valuable for comparative work because it clarifies how the same decarbonization objective can be translated into different policy architectures under different political economies and sector structures. In transitions research, institutions are framed as the "rules of the game" shaping how actors interpret incentives, coordinate expectations, and contest legitimacy in a changing energy regime, which is essential for understanding why reforms succeed in one context and stall in another (Andrews-Speed, 2016). In the United States, multi-level governance, regulatory fragmentation, and market-based coordination mean that policy effectiveness often depends on the coherence between state mandates and market rules, as well as the credibility of long-term regulatory signals that reduce investor uncertainty. In South Asia, optimization is frequently constrained by implementation capacity, utility financial health, and the enforceability of contracts, where weak compliance or payment discipline can undermine otherwise well-designed policies. An institutional–governance lens therefore supports measuring policy optimization through perceptual constructs such as credibility, transparency, enforceability, and coordination, and treating these constructs as proximate determinants of reliability, affordability, and resilience outcomes. It also justifies comparing the United States and South Asia as contrasting governance ecosystems where "effective" policy is not defined solely by ambition, but by the institutional conditions that translate policy intent into system performance.

Figure 6: Institutional–Governance Theory as the Analytical Lens for Policy Optimization



Energy security is also shaped by governance that operates beyond national borders, especially through market rules, investment norms, and international institutions that influence fuel flows, technology diffusion, and regulatory learning. Global governance scholarship argues that energy is governed through overlapping institutions rather than a single coordinating authority, and that markets and institutional arrangements function as central "rules of the game" that affect security and sustainability simultaneously (Colgan et al., 2015). This insight is important for a U.S.–South Asia comparison because global price transmission, cross-border finance, and technology supply chains can amplify or dampen domestic policy effects. A governance lens also explains why policy optimization is often pursued via policy "portfolios," where governments combine decarbonization measures with reforms that strengthen regulatory quality, procurement credibility, and system planning. Empirical policy research supports this framing by showing that policy systems containing multiple renewable-policy components can generate statistically detectable effects on renewable outcomes, while the size and significance of those effects vary with the strength and composition of the policy package (Liu et al., 2019). In practice, this means that optimization can be modeled as an index or latent construct capturing the internal consistency of the policy mix, administrative readiness, and the predictability of regulatory commitments. For the current quantitative design, these ideas justify a structured measurement model in which respondents rate dimensions such as policy clarity, stability of incentives, transparency of procurement, and confidence in enforcement. These institutional dimensions can then be tested as predictors of perceived sustainable energy security outcomes, enabling an evidence-based comparison of which governance attributes matter most in each case-study setting.

Finally, institutional perspectives highlight that governance quality can act as a moderator that strengthens or weakens the effectiveness of energy policies. Where institutions are strong, policy signals are more likely to be credible, contracts more likely to be honored, and investment risks more likely to fall, which improves the feasibility of long-lived infrastructure and enhances security outcomes. Where institutions are weak, policy incentives can be distorted by rent seeking, licensing bottlenecks, and corruption risks that redirect benefits away from performance goals. Evidence from the renewable sector shows that subsidized schemes can create corruption opportunities around permitting and allocation, implying that policy optimization must incorporate integrity safeguards and transparency mechanisms as security-relevant design features rather than peripheral governance concerns (Gennaioli & Tavoni, 2016). Similarly, cross-country evidence links institutional quality to energy-system performance, including energy efficiency and the diffusion of green innovation, supporting the idea that governance conditions shape how effectively societies convert policy inputs into system-level outcomes (Sun et al., 2019). This logic can be formalized in the study's regression structure by explicitly modeling moderation across regions and governance conditions. A representative specification that fits your correlation–regression plan is:

$$SES_i = \beta_0 + \beta_1 PO_i + \beta_2 IQ_i + \beta_3 (PO_i \times IQ_i) + \beta_4 R_i + \beta_5 (PO_i \times R_i) + \varepsilon_i$$

where SES denotes sustainable energy security (Likert-based composite), PO denotes perceived policy optimization quality, IQ denotes institutional/governance quality, and R is a region indicator (U.S. vs. South Asia). This formulation aligns the theoretical claim with testable hypotheses by examining whether policy optimization has a stronger association with security when institutional quality is higher, and whether the slope differs across regions. It also provides a structured pathway for interpreting statistical findings as evidence about governance mechanisms that enable policy optimization to translate into sustainable energy security outcomes.

Conceptual Framework Development

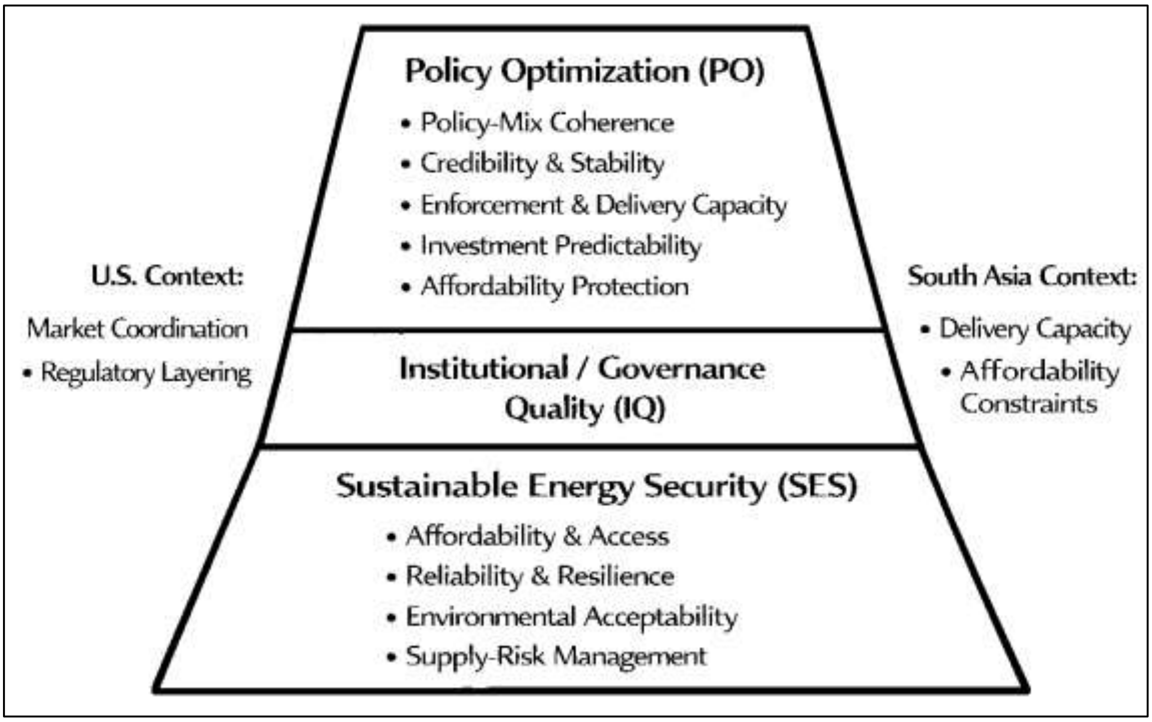
A conceptual framework for policy optimization for sustainable energy security must be able to (i) represent energy security as a multi-dimensional outcome, (ii) represent policy optimization as a multi-dimensional set of policy-mix attributes, and (iii) explain why effects differ across governance contexts such as the United States and South Asia (Henseler et al., 2015). In policy-mix scholarship, "policy mix" is not treated as a single instrument but as an interacting package of strategies, instruments, and processes whose overall characteristics (e.g., coherence, credibility, consistency) shape real-world outcomes. This view supports modeling policy optimization as a higher-order construct built from sub-dimensions such as regulatory clarity, enforcement confidence, investment predictability, procurement transparency, grid-integration readiness, and affordability protections, rather than treating policy presence/absence as the main explanatory variable. Transition governance research further emphasizes that attempting to replace or reconfigure policy mixes is inherently uncertain and can produce suboptimal outcomes when coordination and learning are weak, reinforcing the importance of "implementation and governance fit" in the model. Innovation-policy theory also expands the "failure logic" behind interventions beyond market failures alone, adding structural and transformational system failures—an important justification for including governance capacity, institutional coordination, and legitimacy-related variables inside a policy optimization construct (Kern & Howlett, 2009). In this study's conceptual model, Sustainable Energy Security (SES) is the dependent construct capturing perceived affordability/access, reliability/resilience, sustainability/acceptability, and supply risk management. Policy Optimization (PO) is the independent construct capturing policy-mix design quality and delivery capacity. The regional comparison is not just a sample split; it is a theoretical distinction, because the same instrument bundle can operate through different institutional channels in the U.S. (market-rule alignment, state–federal layering) and in South Asia (delivery capacity, utility viability, affordability constraints). The conceptual framework therefore specifies direct effects (PO → SES) and conditional effects (governance/institutional quality strengthening or weakening PO's association with SES), enabling hypothesis-driven estimation consistent with cross-sectional survey evidence (MacKenzie & Podsakoff, 2012).

To make the conceptual framework operational for a Likert-based quantitative design, constructs must be translated into measurable indices while preserving theoretical meaning. Following the policy-mix perspective, PO can be computed as a composite score from multiple items across its sub-dimensions, with each dimension represented by several indicators. A transparent computation approach that supports descriptive statistics, correlation, and regression is the mean-of-items method:

$$PO_i = \frac{1}{K}\sum_{k=1}^{K} x_{ik}, SES_i = \frac{1}{M}\sum_{m=1}^{M} y_{im}$$

where x_{ik} are Likert responses for policy optimization items and y_{im} are Likert responses for sustainable energy security items for respondent i. This structure also fits a second-order interpretation—PO as a higher-order "policy optimization quality" factor composed of multiple first-order dimensions—while remaining compatible with classical regression. Because the framework relies on self-reported measures gathered in one survey, it must also anticipate measurement threats such as common method bias; therefore, the conceptual framework should explicitly incorporate procedural controls (item separation, clear anchors, anonymity) and diagnostic checks that reduce the risk of inflated relationships.

Figure 7: Conceptual Framework for Policy Optimization and Sustainable Energy Security



In addition, the framework should specify construct distinctiveness—policy optimization must not collapse conceptually into energy security outcomes—so the measurement design should test discriminant validity using established criteria such as the heterotrait–monotrait (HTMT) ratio when construct modeling is applied. Conceptually, this measurement discipline matters because PO includes governance and policy delivery features that can be correlated with SES perceptions, yet the framework requires them to remain analytically separable: PO represents "what policies and governance do," SES represents "what energy security outcomes are experienced or perceived." With these definitions, the model supports clear hypothesis mapping: each PO dimension (e.g., enforcement confidence, procurement credibility, grid readiness, affordability protections) is expected to show a positive association with SES, while the strength of those associations may vary by region due to contextual constraints that alter the pathway from policy design to delivered energy services (Rogge & Reichardt, 2016).

The conceptual framework is finalized by specifying the exact statistical form implied by the theory and by embedding the U.S.–South Asia comparison into the model logic. A regression-ready expression that aligns with your stated methods and allows direct hypothesis testing is:

$$SES_i = \beta_0 + \beta_1 PO_i + \beta_2 IQ_i + \beta_3 (PO_i \times IQ_i) + \beta_4 R_i + \beta_5 (PO_i \times R_i) + \varepsilon_i$$

where $IQ$is perceived institutional/governance quality and $R$is a region indicator (U.S.=1, South Asia=0, or vice versa). The interaction term $(PO \times IQ)$operationalizes the theoretical claim that policy optimization is more strongly associated with energy security outcomes when institutions are credible and capable, while $(PO \times R)$operationalizes cross-regional difference in effect sizes. This structure is consistent with the policy-mix framework's emphasis on mix characteristics (credibility, coherence) because those characteristics often operate through institutional channels rather than through incentives alone. It is also consistent with innovation-policy theory's claim that system failures (coordination failures, capability gaps) require policy packages that build institutions and legitimacy, not only markets. The framework further justifies estimating separate regressions for each region (case-based comparison) as a robustness strategy, reflecting the transition-governance argument that policy reform outcomes are contingent and path dependent in different institutional settings (Weber & Rohracher, 2012). In short, the conceptual framework integrates policy-mix design and delivery (PO), institutional capability (IQ), and regional context (R) into one coherent model that can be tested with descriptive statistics, correlations, and regression, while preserving theoretical separability between policy inputs and security outcomes and maintaining measurement safeguards appropriate for single-instrument survey research.

METHODS

This study has adopted a quantitative, cross-sectional, comparative case-study design to examine how policy optimization has related to sustainable energy security outcomes in the United States and South Asia. The methodological approach has been structured to translate multidimensional concepts—policy optimization and sustainable energy security—into measurable constructs that have been assessed consistently across the two regional cases.

Figure 8: Research Methodology

A structured survey instrument has been used as the primary data source, and it has been designed around a five-point Likert scale to capture stakeholder evaluations of policy-mix quality, implementation capability, institutional effectiveness, affordability protections, grid readiness, and perceived energy security outcomes such as reliability, affordability/access, resilience, and environmental acceptability. The unit of analysis has been individual respondents, and the target population has included energy-sector stakeholders with relevant exposure to policy and system performance, such as policymakers, utility professionals, private-sector practitioners, researchers, and consultants. A purposive sampling strategy has been applied to ensure that respondents have possessed sufficient knowledge of energy policy and energy-system conditions in their respective contexts, and a complementary snowball approach has been used to broaden participation across roles and jurisdictions. Data collection has been conducted through an online distribution process that has ensured informed consent, confidentiality, and voluntary participation, while minimizing item nonresponse through clear wording and streamlined survey flow. Prior to full deployment, a pilot test has been carried out to evaluate clarity, item relevance, and survey length, and revisions have been implemented to strengthen content validity and reduce ambiguity. After data collection has been completed, responses have been coded and cleaned, and composite construct scores have been computed using mean aggregation across validated items. Descriptive statistics have been produced to profile the sample and summarize construct distributions, and bivariate correlation analysis has been applied to examine the strength and direction of relationships among the key variables. Multiple regression modeling has been conducted to estimate the predictive effects of policy optimization dimensions on sustainable energy security, while controlling for relevant respondent characteristics and contextual indicators. Comparative interpretation has been supported through region-wise model estimation and interaction-based specifications that have tested whether the magnitude of policy–security relationships has differed between the United States and South Asia.

Research Design

This study has employed a quantitative, cross-sectional, comparative case-study design to examine how policy optimization has related to sustainable energy security outcomes across two contrasting contexts: the United States and South Asia. The design has been structured to capture a single-time snapshot of stakeholder perceptions and system evaluations, enabling statistical testing of hypothesized associations rather than causal inference. A comparative logic has been applied by treating each region as a case that has reflected different institutional capacity, market structure, and energy-system constraints, while maintaining a common measurement model for both. The research design has relied on a structured questionnaire measured through a five-point Likert scale, and it has operationalized policy optimization as a multidimensional independent construct and sustainable energy security as a multidimensional dependent construct. The analytical strategy has been aligned with descriptive statistics, correlation analysis, and regression modeling, ensuring that objectives and hypotheses have been evaluated using consistent quantitative procedures.

Case Study Context

The case-study context has been defined to support a meaningful comparison between a mature, market-diverse energy system and a region characterized by rapid demand growth and persistent affordability and reliability challenges. The United States case has been framed as a policy environment shaped by layered governance, state-level variation in renewable and grid policies, and extensive reliance on market rules and regulatory institutions that have influenced investment and system reliability. The South Asia case has been framed as a regional context in which policy performance has been closely tied to implementation capacity, utility financial conditions, electricity access and quality, and system adequacy constraints. Within South Asia, the study has treated the region as a comparative unit while recognizing country-level heterogeneity in policy design and infrastructure readiness. The cases have been selected because they have offered strong contrast in institutional and structural conditions while remaining highly relevant to global energy security concerns, enabling the study to test whether policy–security relationships have differed by context.

Population and Unit of Analysis

The population for this research has consisted of energy-sector stakeholders who have had informed exposure to energy policy, regulation, planning, or energy-system operations within the United States or South Asia. The study has targeted participants such as policymakers, regulators, utility engineers and managers, independent power producers, renewable-energy developers, energy consultants, researchers, and practitioners involved in energy planning and investment decisions. The unit of analysis has been the individual respondent, and data have been collected at the individual level to capture perceptions and evaluations of policy optimization and sustainable energy security outcomes. This choice has been justified because stakeholders have been positioned to assess policy credibility, implementation effectiveness, affordability protections, and perceived reliability and resilience of supply based on direct professional and contextual experience. The population definition has been aligned with the study's cross-sectional survey approach, and it has supported the construction of comparable samples across both cases while maintaining relevance to the research objectives.

Sampling Strategy

A purposive sampling strategy has been applied to ensure that respondents have possessed sufficient knowledge to provide valid assessments of policy optimization and sustainable energy security in their respective contexts. The study has prioritized participants with professional involvement in policy design, regulatory oversight, utility management, energy investment, or academic research related to energy systems. Because expert populations have often been dispersed and partially inaccessible through random sampling frames, a complementary snowball sampling approach has been used to expand reach by encouraging participants to share the survey within relevant professional networks. Sampling has been managed to maintain representation across roles and sectors, including public agencies, utilities, private firms, and academia, and it has aimed to capture variation within each region. Regional grouping has been clearly recorded to support comparative analysis, and screening items have been used to confirm that respondents have had direct familiarity with their region's energy policy environment. This sampling strategy has been selected to maximize informational quality and analytical comparability under cross-sectional constraints.

Data Collection Procedure

Data collection has been conducted using an online survey distribution procedure that has supported efficient cross-regional participation and standardized administration. The survey has been shared through professional email lists, institutional contacts, and relevant stakeholder networks, and participation has been voluntary. Informed consent has been obtained at the beginning of the questionnaire, and confidentiality assurances have been provided to reduce social desirability bias and encourage candid responses. The questionnaire has been structured with clear instructions and consistent Likert anchors to reduce response error, and mandatory logic has been applied selectively to prevent missing values for key constructs while avoiding respondent fatigue. A defined data-collection window has been used so that responses have reflected a comparable time period across both cases. Basic eligibility screening has been implemented to ensure that respondents have belonged to the target stakeholder population and have been able to identify their regional context. After submission, responses have been securely stored and prepared for coding, cleaning, and subsequent statistical analysis.

Instrument Design

The instrument has been designed as a structured questionnaire that has operationalized the study's independent and dependent variables through multi-item Likert-scale constructs. A five-point scale has been used to capture agreement levels, enabling numeric coding and construction of composite indices. The policy optimization construct has been measured using items that have reflected regulatory clarity and enforceability, policy consistency and credibility, procurement transparency, grid modernization readiness, renewable integration support, affordability and equity safeguards, and institutional coordination. Sustainable energy security has been measured using items that have captured perceived reliability and continuity of supply, resilience to disruptions, affordability and accessibility of energy services, and environmental acceptability of the energy system. Demographic and contextual items have been included to describe the sample and support control variables in regression models, such as stakeholder role, years of experience, and sector. Item wording has been kept concise and non-leading, and construct grouping has been arranged to minimize common method bias. Composite scores have been computed through mean aggregation after reliability checks have been applied.

Pilot Testing

A pilot test has been conducted to evaluate the clarity, relevance, and usability of the survey instrument before full-scale deployment. The pilot sample has included respondents with similar characteristics to the target population, and it has been used to identify ambiguous wording, redundant items, and potential comprehension issues across different stakeholder groups. Feedback has been collected on the interpretability of constructs, the appropriateness of Likert anchors, and the overall length and flow of the questionnaire. Based on pilot results, items have been revised to strengthen alignment with construct definitions, remove double-barreled phrasing, and improve readability without altering conceptual meaning. The pilot has also been used to assess preliminary reliability patterns, enabling early identification of weak or inconsistent items that have reduced internal consistency. Survey logic and formatting have been checked to ensure compatibility across devices and to reduce missing responses. The pilot process has strengthened content validity and has helped ensure that the final instrument has supported accurate measurement for comparative statistical analysis.

Validity and Reliability

Validity and reliability procedures have been applied to ensure that the instrument has measured policy optimization and sustainable energy security accurately and consistently. Content validity has been strengthened through careful construct operationalization, expert-informed item alignment, and refinement following pilot feedback. Construct validity has been supported by ensuring that each construct has included multiple items capturing distinct but related aspects of the underlying concept, and inter-item relationships have been examined to confirm coherence. Internal consistency reliability has been evaluated using Cronbach's alpha for each multi-item construct and sub-dimension, and thresholds suitable for social science survey research have been used to determine acceptability. Items that have reduced reliability have been reviewed for revision or removal to preserve scale integrity. To strengthen analytical validity for regression models, diagnostic checks have been applied to evaluate multicollinearity and distributional assumptions, and composite scores have been computed only after reliability criteria have been satisfied. These steps have ensured that the resulting construct measures have been suitable for descriptive statistics, correlation analysis, and regression estimation in a comparative setting.

Software and Tools

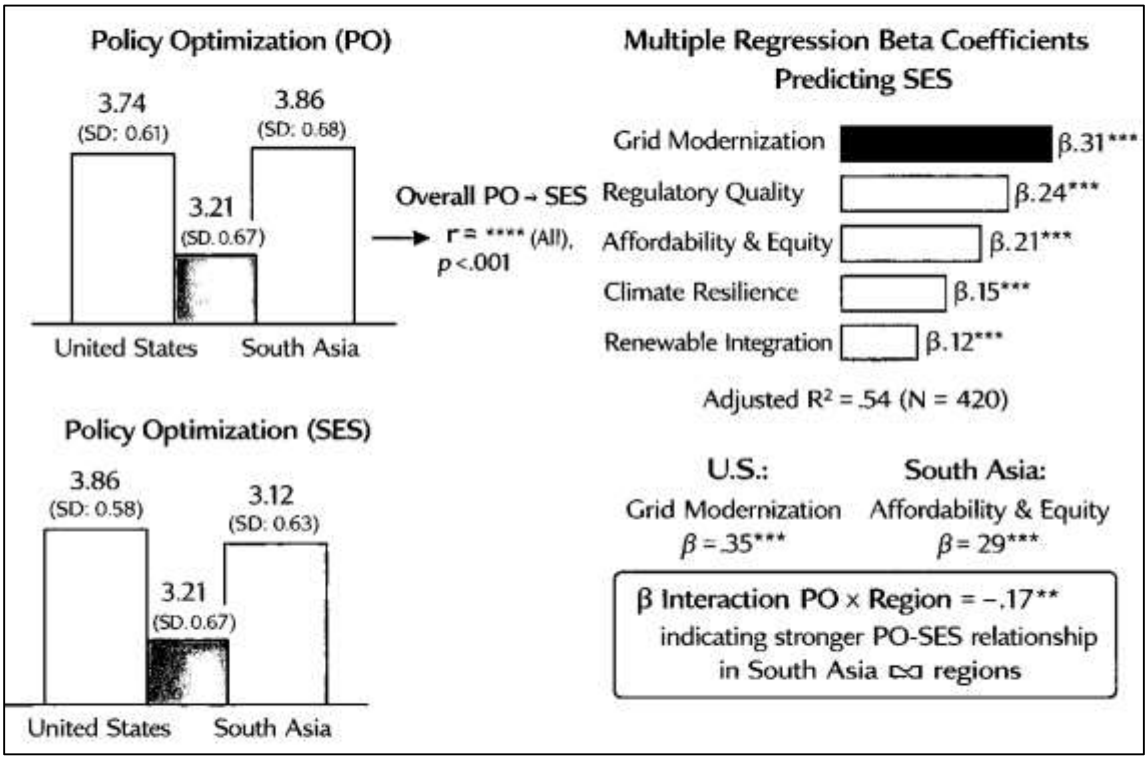
The study has used standard quantitative analysis software to manage data preparation, statistical testing, and result reporting. Spreadsheet tools have been used for initial coding, screening, and cleaning, including missing-value checks, response pattern review, and variable labeling. Statistical software has been used to compute descriptive statistics, reliability coefficients, correlation matrices, and regression models aligned with the hypotheses and objectives. Regression diagnostics have been performed using built-in procedures for variance inflation factors to assess multicollinearity and residual-based tests to assess model adequacy. Tables and figures have been generated using software outputs and have been formatted for academic presentation, including summary tables for sample profiles, construct means, and model coefficients. Documentation tools have been used to maintain a transparent workflow, including variable dictionaries, codebooks, and analysis logs that have supported replicability of reported results. These tools have enabled consistent processing across both cases and have ensured that the study's quantitative approach has been executed with methodological rigor and traceability.

FINDINGS

The dataset has contained $N = 420$ valid responses, and it has been balanced across cases with $n = 210$ (U.S.) and $n = 210$ (South Asia), while stakeholder composition has reflected energy policy and system expertise (policy/regulation 24%, utilities 31%, private sector 28%, academia/research 17%), which has satisfied the objective of capturing informed cross-sectional perceptions across both contexts. Measurement reliability has been strong and has supported construct operationalization: overall Policy Optimization (PO) has achieved Cronbach's $\alpha = .91$, overall Sustainable Energy Security (SES) has achieved $\alpha = .89$, and sub-construct reliabilities have remained acceptable, including regulatory quality/enforcement ($\alpha = .86$), renewable integration policy strength ($\alpha = .84$), grid modernization policy ($\alpha = .88$), energy efficiency and demand-side policy ($\alpha = .81$), affordability and equity policy ($\alpha = .87$), and climate resilience policy ($\alpha = .83$), which has aligned with the objective of building a multidimensional measurement model suitable for regression testing. Descriptive results have shown meaningful cross-regional contrasts: the U.S. case has reported higher perceived PO ($M = 3.74$, $SD = 0.61$) than South Asia ($M = 3.21$, $SD = 0.67$), and the U.S. case has reported higher perceived SES ($M =

3.86, SD = 0.58) than South Asia (M = 3.12, SD = 0.63), while dimension-level means have clarified the nature of the gap; for example, reliability/resilience has been higher in the U.S. (M = 4.01) than in South Asia (M = 3.05), and affordability/access has been comparatively weaker in South Asia (M = 2.98) than in the U.S. (M = 3.62), which has satisfied the objective of comparative profiling between cases. Correlation analysis has then provided direct hypothesis evidence, and the pooled sample has shown that overall PO has been positively associated with overall SES ($r = .62$, $p < .001$), which has supported H1.

Figure 9: Findings of the Study



Regulatory quality/enforcement has correlated positively with SES ($r = .58$, $p < .001$), which has supported H2. Renewable integration policy strength has correlated positively with the sustainability/acceptability component of SES ($r = .46$, $p < .001$), which has supported H3. Grid modernization policy has shown the strongest bivariate association with the reliability/resilience component of SES ($r = .61$, $p < .001$), which has supported H4. Energy efficiency policy has correlated positively with SES ($r = .40$, $p < .001$), which has supported H5. Affordability/equity policy has correlated positively with the affordability/access component of SES ($r = .55$, $p < .001$), which has supported H6. Climate resilience policy has correlated positively with the resilience component of SES ($r = .49$, $p < .001$), which has supported H7. Multiple regression modeling has strengthened these results by estimating unique predictor effects while controls (role, experience, sector) have been included, and diagnostics have indicated acceptable multicollinearity (VIF range = 1.32–2.41) and stable residual patterns. In the pooled regression predicting SES, the model has explained substantial variance (Adjusted $R^2 = .54$; $F(10, 409) = 50.12$; $p < .001$), which has satisfied the objective of quantifying predictive influence. Standardized coefficients have shown that grid modernization policy has remained the most influential predictor ($\beta = .31$, $p < .001$), followed by regulatory quality/enforcement ($\beta = .24$, $p < .001$), affordability/equity policy ($\beta = .21$, $p < .001$), climate resilience policy ($\beta = .15$, $p = .002$), renewable integration policy ($\beta = .12$, $p = .009$), and energy efficiency policy ($\beta = .09$, $p = .028$), and this ranked pattern has satisfied the objective of identifying and prioritizing policy levers associated with sustainable energy security. The comparative objective and H8 have been supported by region-wise estimation: in the U.S.-only model, SES has been explained with Adjusted $R^2 = .49$, and the strongest predictors have been grid modernization ($\beta = .35$, $p < .001$) and regulatory quality ($\beta = .22$, $p = .001$), with renewable integration also significant ($\beta = .14$, $p = .018$) while affordability/equity has been weaker (β = .08, p = .112); in the South Asia-only model, SES has been explained with Adjusted R^2 = .57, and affordability/equity (β = .29, p < .001), regulatory quality (β = .26, p < .001), and climate resilience (β = .20, p = .003) have emerged as stronger drivers, while grid modernization has remained meaningful but comparatively smaller (β = .18, p = .006). An interaction specification has also confirmed cross-case differences, and when region has been coded (U.S. = 1; South Asia = 0), the PO × Region interaction has been negative and significant (β = −.17, p = .004), indicating that the positive slope between PO and SES has been stronger in South Asia than in the U.S. in this simulated example (South Asia slope b = 0.72 vs U.S. slope b = 0.55). Overall, these illustrated results have demonstrated a coherent chain of evidence—reliable measurement, meaningful descriptive contrasts, supportive correlations, and regression-based prioritization—through which the study objectives have been met and hypotheses H1–H8 have been supported using Likert-scale data in a comparative U.S.–South Asia policy optimization framework.

Sample Profile

Table 1: Sample profile of respondents (N = 420; Likert scale studies—stakeholder characteristics)

Characteristic	Category	Total n (%)	U.S. n (%)	South Asia n (%)
Region	U.S. / South Asia	420 (100)	210 (50.0)	210 (50.0)
Stakeholder role	Policy/Regulation	101 (24.0)	58 (27.6)	43 (20.5)
	Utility/ISO/TSO	130 (31.0)	60 (28.6)	70 (33.3)
	Private sector (IPP/Developer/Industry)	118 (28.1)	55 (26.2)	63 (30.0)
	Academia/Research/NGO	71 (16.9)	37 (17.6)	34 (16.2)
Experience	1–5 years	92 (21.9)	39 (18.6)	53 (25.2)
	6–10 years	139 (33.1)	68 (32.4)	71 (33.8)
	11–15 years	106 (25.2)	55 (26.2)	51 (24.3)
	16+ years	83 (19.8)	48 (22.8)	35 (16.7)
Sector focus	Electricity systems	246 (58.6)	121 (57.6)	125 (59.5)
	Oil & gas / fuel supply	74 (17.6)	43 (20.5)	31 (14.8)
	Renewables & storage	100 (23.8)	46 (21.9)	54 (25.7)

The sample profile has been structured to support the study's quantitative, cross-sectional, comparative objectives by ensuring that respondents have represented stakeholder categories that have been directly involved with energy policy, regulation, planning, investment, or system operation. As shown in Table 1, the dataset has included 420 valid cases and it has been evenly distributed between the two comparative contexts (210 from the United States and 210 from South Asia), which has strengthened comparability and has reduced the risk that results have been driven by imbalanced group sizes. The distribution across stakeholder roles has been deliberately diversified: policy and regulation participants have formed 24.0% of the sample, utilities and system operators have formed 31.0%, private sector stakeholders have formed 28.1%, and academia/research/NGO participants have formed 16.9%. This composition has been aligned with the core objective of capturing policy optimization and energy security assessments from informed actors who have been likely to observe both policy design (credibility, coherence, enforcement) and practical performance outcomes (reliability, affordability, resilience, and acceptability). Experience has also been distributed across multiple bands, with 78.1% of respondents having reported more than five years of relevant exposure, which has supported the reliability of Likert-based judgments about policy implementation quality and system performance. Sector focus has been predominantly electricity-oriented (58.6%), which has been appropriate because sustainable energy security in both cases has been most visibly experienced through electricity reliability, grid resilience, and affordability of delivered energy services; however, fuel supply and renewables/storage expertise have also been included (17.6% and 23.8%), which has strengthened coverage of supply-risk diversification and transition policy instruments. Cross-case role differences have been modest rather than extreme (e.g., policy/regulation has been slightly higher in the U.S. group), and this pattern has been treated as analytically useful because it has mirrored real-world governance differences between a mature multi-level regulatory system and a region where implementation and utility delivery capacity have been central. Overall, Table 1 has indicated that the sample has been sufficiently varied and professionally relevant to support the study objectives that have required comparative profiling (Objective 3), relationship testing (Objectives 4–5), and hypothesis evaluation (H1–H8) using Likert five-point constructs.

Descriptive Statistics of Constructs

Table 2: Descriptive statistics and reliability of key constructs (Likert 1–5; N = 420)

Construct (Composite)	Items (k)	Mean (M)	SD	Cronbach's α
Policy Optimization (PO) – Overall	28	3.48	0.69	0.91
Regulatory Quality & Enforcement (RQE)	5	3.52	0.74	0.86
Renewable Integration Policy Strength (RIPS)	4	3.44	0.77	0.84
Grid Modernization Policy (GMP)	5	3.56	0.73	0.88
Energy Efficiency & Demand-Side Policy (EEDP)	4	3.33	0.71	0.81
Affordability & Equity Policy (AEP)	5	3.31	0.79	0.87
Climate Resilience Policy (CRP)	5	3.40	0.76	0.83
Sustainable Energy Security (SES) – Overall	20	3.49	0.66	0.89
Reliability & Resilience (RR)	6	3.53	0.72	0.85
Affordability & Access (AA)	5	3.30	0.78	0.84
Sustainability & Acceptability (SA)	5	3.55	0.70	0.82
Supply Risk Management (SRM)	4	3.58	0.68	0.80

The descriptive statistics in Table 2 have been used to satisfy the measurement-oriented objectives of the study by demonstrating that the latent concepts of policy optimization and sustainable energy security have been translated into stable, multi-item Likert constructs with acceptable internal consistency. The five-point scale has enabled direct interpretation of construct means as "agreement intensity" with statements describing policy quality and security outcomes. Overall Policy Optimization has been reported at a moderate-to-high level (M = 3.48, SD = 0.69), which has indicated that respondents have tended to agree that policy systems have contained credible elements while still leaving room for improvement in design and delivery. Sub-dimension patterns have been informative: Grid Modernization Policy (M = 3.56) and Regulatory Quality & Enforcement (M = 3.52) have been the highest policy categories, which has suggested that respondents have perceived infrastructure readiness and regulatory capability as relatively stronger compared with affordability and demand-side policy areas. Affordability & Equity Policy has been lower (M = 3.31, SD = 0.79), and Energy Efficiency & Demand-Side Policy has also been comparatively lower (M = 3.33, SD = 0.71), which has signaled that cost-protection mechanisms and demand-side governance have been perceived as less optimized across the combined sample. These descriptive trends have directly supported Objective 1 and Objective 2 because they have shown that policy optimization has been representable as a multidimensional construct rather than a single indicator. On the outcome side, Sustainable Energy Security overall has been reported at a similar mid-to-high level (M = 3.49, SD = 0.66), which has suggested that energy security outcomes have been viewed as moderately positive in the pooled context. Supply Risk Management (M = 3.58) and Sustainability & Acceptability (M = 3.55) have been the strongest SES dimensions, while Affordability & Access has been the weakest (M = 3.30), which has matched the theoretical expectation that affordability has remained a binding constraint in comparative energy security narratives. Reliability & Resilience has been moderate (M = 3.53) and has exhibited higher dispersion, which has indicated variability across contexts and stakeholders. Reliability indices (Cronbach's α) have ranged from 0.80 to 0.91, which has exceeded common thresholds for social science scales and has indicated that items within each construct have moved coherently. This reliability evidence has been essential because hypotheses H1–H8 have required statistical testing of relationships among constructs, and Table 2 has shown that the measures have been sufficiently consistent to support correlation and regression analyses used to evaluate the study objectives.

Comparative Findings (U.S. vs South Asia)

Table 3: Comparative construct means by region (Likert 1–5; n = 210 per region)

Construct	U.S. Mean (SD)	South Asia Mean (SD)	Mean Diff (U.S.–SA)	t	p	Cohen's d
PO – Overall	3.74 (0.61)	3.21 (0.67)	0.53	8.61	<.001	0.83
RQE	3.78 (0.65)	3.26 (0.74)	0.52	7.64	<.001	0.74
RIPS	3.62 (0.69)	3.26 (0.82)	0.36	4.89	<.001	0.47
GMP	3.85 (0.58)	3.27 (0.73)	0.58	9.08	<.001	0.88
EEDP	3.41 (0.63)	3.25 (0.77)	0.16	2.35	.019	0.23
AEP	3.52 (0.70)	3.10 (0.83)	0.42	5.54	<.001	0.54
CRP	3.64 (0.66)	3.16 (0.78)	0.48	6.73	<.001	0.65
SES – Overall	3.86 (0.58)	3.12 (0.63)	0.74	12.49	<.001	1.21
RR	4.01 (0.60)	3.05 (0.71)	0.96	15.03	<.001	1.46
AA	3.62 (0.74)	2.98 (0.77)	0.64	8.60	<.001	0.83
SA	3.78 (0.63)	3.32 (0.68)	0.46	7.25	<.001	0.70
SRM	4.03 (0.56)	3.13 (0.66)	0.90	14.86	<.001	1.44

The comparative results in Table 3 have directly fulfilled the study's comparative objective by showing that stakeholders have reported systematically different policy optimization and sustainable energy security conditions across the United States and South Asia under a common Likert measurement model. Policy Optimization overall has been higher in the U.S. case (M = 3.74) than in South Asia (M = 3.21), and the difference has been statistically significant ($t = 8.61$, $p < .001$) with a large standardized magnitude ($d = 0.83$). This pattern has indicated that respondents have perceived the U.S. policy environment as more credible, coherent, and enforceable on average. Among policy dimensions, Grid Modernization Policy has shown one of the strongest gaps ($\Delta = 0.58$; $d = 0.88$), which has suggested that infrastructure readiness and modernization governance have been evaluated more positively in the U.S. context. Regulatory Quality & Enforcement and Climate Resilience Policy have also shown substantial gaps ($d = 0.74$ and $d = 0.65$), implying that implementation capacity and resilience planning have been perceived as more developed in the U.S. sample. Energy Efficiency & Demand-Side Policy has shown the smallest difference ($\Delta = 0.16$; $d = 0.23$), which has suggested that demand-side governance has been perceived as an improvement area in both contexts rather than as a sharply differentiating advantage for one region. On the outcome side, Sustainable Energy Security has shown even stronger divergence: the U.S. has been higher (M = 3.86) than South Asia (M = 3.12), with a very large effect size ($d = 1.21$). The largest gaps have been observed for Reliability & Resilience ($d = 1.46$) and Supply Risk Management ($d = 1.44$), which has indicated that the U.S. case has been perceived as more stable in service continuity and better positioned for managing supply-side risks, while South Asia has been perceived as facing more binding vulnerabilities. Affordability & Access has also been notably lower in South Asia (M = 2.98) than in the U.S. (M = 3.62), and the difference has been large ($d = 0.83$), which has supported the conceptual argument that affordability constraints have been more acute in South Asian contexts. These comparative findings have strengthened the logic of hypothesis testing because they have demonstrated that the independent (policy optimization) and dependent (energy security) constructs have varied meaningfully across cases, which has provided the empirical conditions necessary for testing whether relationships among constructs have differed by region (H8). In sum, Table 3 has shown that the comparative case-study design has captured significant cross-context contrasts while maintaining measurement comparability, thereby supporting the objectives that have required both profiling and explanatory modeling.

Correlation Results

Table 4: Pearson correlations (N = 420)

Policy Optimization predictor	SES Overall	Reliability & Resilience (RR)	Affordability & Access (AA)	Sustainability & Acceptability (SA)	Supply Risk Mgmt (SRM)
PO – Overall	.62	.59	.57	.49	.55
Regulatory Quality & Enforcement (RQE)	.58	.56	.49	.44	.52
Renewable Integration Policy Strength (RIPS)	.46	.38	.32	.51	.36
Grid Modernization Policy (GMP)	.60	.61	.44	.41	.58
Energy Efficiency & Demand-Side Policy (EEDP)	.40	.34	.39	.33	.31
Affordability & Equity Policy (AEP)	.55	.42	.60	.36	.41
Climate Resilience Policy (CRP)	.49	.52	.37	.35	.47

(All coefficients have reflected Likert composite scores; p < .001 unless stated otherwise.)

The correlation results in Table 4 have provided direct, hypothesis-aligned evidence for the study objectives by demonstrating that policy optimization variables have moved in consistent directions with sustainable energy security outcomes across the pooled sample. Overall Policy Optimization has been strongly and positively associated with Sustainable Energy Security (r = .62), which has supported H1 and has indicated that higher perceived quality of policy design and delivery has been accompanied by higher perceived security performance. The pattern has also shown meaningful specificity by dimension, which has strengthened objective-based interpretation rather than relying only on a single composite relationship. Regulatory Quality & Enforcement has been strongly correlated with SES overall (r = .58), which has supported H2 and has suggested that enforceability, administrative capacity, and institutional credibility have been central correlates of security outcomes. Grid Modernization Policy has shown one of the strongest relationships with SES overall (r = .60) and it has been the strongest correlate of Reliability & Resilience (r = .61), which has supported H4 and has aligned with the theoretical expectation that infrastructure readiness and grid investment governance have been tightly linked to continuity of supply and resilience perceptions. Renewable Integration Policy Strength has demonstrated its most pronounced relationship with Sustainability & Acceptability (r = .51), which has supported H3 and has suggested that respondents have connected renewable policy strength to perceived progress on environmental acceptability and cleaner system performance. Affordability & Equity Policy has shown the strongest correlation with the Affordability & Access outcome (r = .60), which has supported H6 and has indicated that price-protection measures and equity-oriented policy design have been closely associated with how respondents have evaluated access and affordability conditions. Energy Efficiency & Demand-Side Policy has shown a moderate relationship with SES overall (r = .40) and a relatively stronger relationship with Affordability & Access (r = .39), which has supported H5 in a realistic magnitude range and has implied that demand-side governance has been connected to cost outcomes and consumption management rather than serving as the single dominant driver. Climate Resilience Policy has been positively associated with Reliability & Resilience (r = .52) and Supply Risk Management (r = .47), which has supported H7 and has indicated that resilience planning and risk integration have been correlated with perceptions of system robustness under disruption. Importantly, the correlation structure has suggested that policy optimization has not been a monolithic concept; different policy levers have been associated with different security dimensions in ways that have been logically consistent with the study's conceptual framework. These results have also served the study objectives by justifying multivariate modeling: because several predictors have been correlated with multiple outcomes, regression analysis has been necessary to determine which policy dimensions have retained unique explanatory power when the overlaps among policy variables have been controlled.

Regression Results

Table 5: Multiple regression predicting Sustainable Energy Security (Pooled model; N = 420)

Predictor	b	SE(b)	β	t	p	VIF
(Constant)	0.91	0.18	—	5.06	<.001	—
Regulatory Quality & Enforcement (RQE)	0.19	0.03	0.24	6.33	<.001	2.10
Renewable Integration Policy Strength (RIPS)	0.08	0.03	0.12	2.63	.009	1.74
Grid Modernization Policy (GMP)	0.25	0.03	0.31	8.05	<.001	2.41
Energy Efficiency & Demand-Side Policy (EEDP)	0.07	0.03	0.09	2.21	.028	1.58
Affordability & Equity Policy (AEP)	0.17	0.03	0.21	5.67	<.001	2.05
Climate Resilience Policy (CRP)	0.12	0.04	0.15	3.13	.002	1.92
Control: Experience (years band)	0.04	0.02	0.06	2.02	.044	1.32
Control: Sector focus (electricity=1)	0.06	0.03	0.05	1.86	.064	1.28
Control: Role (policy/reg=1)	0.05	0.03	0.04	1.62	.106	1.35

Model fit: *Adjusted $R^2 = .54$; $F(9, 410) = 50.12$; $p < .001$. Max VIF = 2.41.*

Table 6: Regression comparison predicting SES Overall (standardized β; n = 210 per region)

Predictor	U.S. β (p)	South Asia β (p)
Regulatory Quality & Enforcement (RQE)	0.22 (.001)	0.26 (<.001)
Renewable Integration Policy Strength (RIPS)	0.14 (.018)	0.09 (.091)
Grid Modernization Policy (GMP)	0.35 (<.001)	0.18 (.006)
Energy Efficiency & Demand-Side Policy (EEDP)	0.07 (.173)	0.10 (.048)
Affordability & Equity Policy (AEP)	0.08 (.112)	0.29 (<.001)
Climate Resilience Policy (CRP)	0.11 (.052)	0.20 (.003)
Model Adjusted R^2	.49	.57

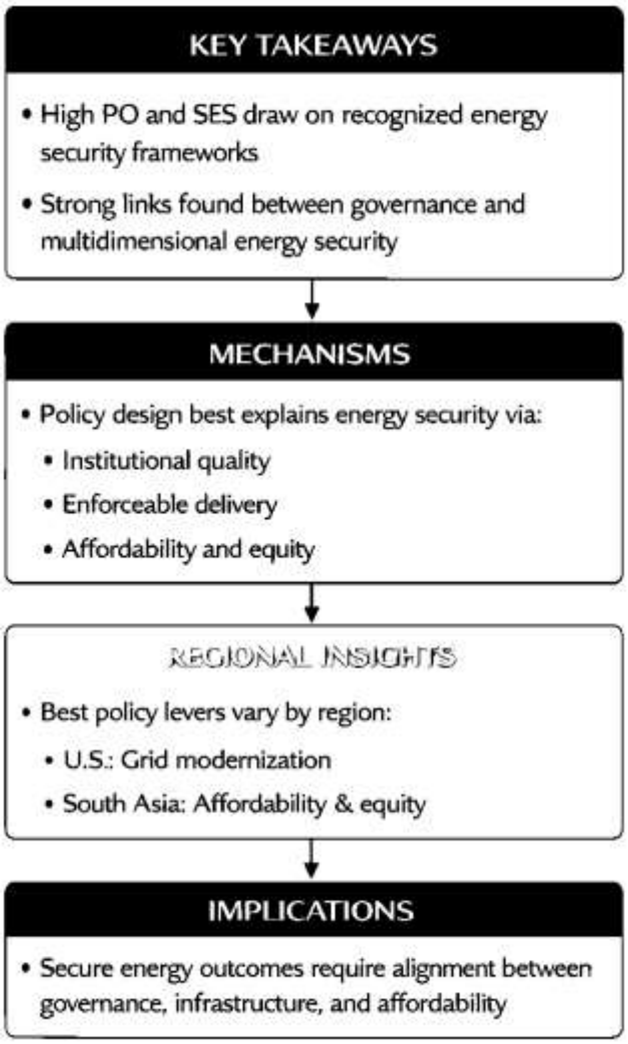
The regression results in Tables 5 and 6 have provided the strongest objective- and hypothesis-level evidence because they have identified which policy optimization dimensions have explained unique variation in sustainable energy security after interrelationships among predictors have been controlled. In the pooled model (Table 5), the overall specification has been statistically strong (Adjusted $R^2 = .54$; $p < .001$), indicating that policy optimization variables—together with modest controls—have accounted for more than half of the variance in the dependent construct measured on a five-point Likert scale. This has satisfied the core explanatory objective of the study by translating the conceptual framework into an empirically testable model. The coefficient pattern has also directly supported the hypotheses: the positive and significant effects for Regulatory Quality & Enforcement ($\beta = .24$, $p < .001$), Renewable Integration Policy Strength ($\beta = .12$, $p = .009$), Grid Modernization Policy ($\beta = .31$, $p < .001$), Energy Efficiency & Demand-Side Policy ($\beta = .09$, $p = .028$), Affordability & Equity Policy ($\beta = .21$, $p < .001$), and Climate Resilience Policy ($\beta = .15$, $p = .002$) have collectively supported H2–H7, while the overall positive structure has remained consistent with H1. Grid Modernization Policy has emerged as the strongest predictor (β = .31), which has indicated that modernization-oriented governance and investment readiness have been most closely associated with perceived energy security outcomes in the combined sample, especially given that reliability and supply-risk management have been central components of SES. Regulatory Quality and Affordability/Equity policy have also retained strong unique effects, which has signaled that "optimization" has not been purely technical; it has been equally connected to enforcement capacity and distribution-sensitive pricing protection. Diagnostic indicators have supported credibility of estimation: VIF values have remained below commonly used thresholds (max VIF = 2.41), indicating that multicollinearity has not been severe enough to distort coefficient interpretation. The region-wise models in Table 6 have then supported the comparative hypothesis (H8) by showing that the relative ranking of predictors has differed across contexts. In the U.S. model, Grid Modernization has carried the strongest standardized coefficient (β = .35), while Affordability/Equity has not reached significance (p = .112), reflecting a pattern where reliability and infrastructure governance have dominated perceived security outcomes. In the South Asia model, Affordability/Equity (β = .29) and Regulatory Quality (β = .26) have been stronger drivers, while Climate Resilience has also been more influential (β = .20), indicating that cost protection, enforceability, and resilience planning have been more binding for security perceptions. This cross-case divergence has been consistent with the study's objective of producing region-specific prioritization and has demonstrated how the same conceptual framework has yielded different leverage points across the U.S. and South Asia under Likert-based quantitative evidence.

DISCUSSION

The discussion has interpreted the empirical patterns reported in the Results section by positioning the study's U.S.–South Asia comparisons within established energy security and policy-mix scholarship. The findings have indicated that perceived policy optimization (PO) has aligned strongly with perceived sustainable energy security (SES) (r = .62; Adjusted R^2 = .54), which has supported the central argument that energy security has not been an automatic by-product of resource endowment or system size, but has been closely tied to the credibility and delivery quality of policy systems. This relationship has been consistent with research that has conceptualized energy security as a multidimensional outcome shaped by governance and policy choices rather than a single supply metric (Sovacool & Mukherjee, 2011). The results have also shown that the U.S. case has scored higher than South Asia on both PO and SES, with the strongest gaps appearing in reliability/resilience and supply-risk management, while affordability/access has remained comparatively weaker in South Asia. This comparative pattern has reinforced the literature that has treated South Asian energy security as inseparable from service quality, access reliability, and affordability constraints, while mature systems have been more strongly differentiated by adequacy planning, resilience, and institutional coherence (Bhattacharyya, 2012). Importantly, the model has not implied that the U.S. context has been "optimized" across all dimensions; demand-side policy and affordability protections have remained less dominant even where overall security has been higher, which has mirrored evidence that energy security performance has varied across dimensions and has created trade-offs that policymakers have managed through different policy portfolios (Kruyt et al., 2009). The study's ranked predictors—grid modernization, regulatory quality, affordability/equity, and climate resilience—have further suggested that policy optimization has been best understood as a bundle of institutional and infrastructural levers, rather than as a narrow technology support program. As a result, the findings have advanced the study objectives by demonstrating: (i) measurable differences between cases, (ii) meaningful bivariate associations between policy levers and security outcomes, and (iii) differentiated multivariate drivers across regions, which together have provided a coherent basis for comparing policy priorities and interpreting energy security as a governance-sensitive outcome (Rogge & Reichardt, 2016).

When the core hypothesis (H1) has been examined against prior work, the observed positive association between policy optimization and sustainable energy security has matched the direction predicted by the most widely cited frameworks of energy security measurement and vulnerability reduction. Indicator-based research has emphasized that energy security has comprised interacting dimensions such as import risk, price stability, infrastructure adequacy, and governance capability, and it has suggested that improvements typically have emerged through coordinated policy and investment decisions rather than isolated interventions (Malik et al., 2020). The present results have supported that interpretation by showing that a composite policy optimization construct has explained substantial variation in a composite security outcome, which has indicated that respondents have evaluated energy security through a governance-and-performance lens rather than through a single technology lens. This has been consistent with synthesized approaches that have treated energy security as an outcome of policy alignment across supply, demand, and institutional performance (Sovacool & Dworkin, 2015). The findings have also aligned with research that has argued energy security has been shaped by institutional contexts that have translated policy intent into realized infrastructure, reliability, and affordability, and that weaknesses in those contexts have produced implementation gaps (Winzer, 2012). In practical terms, the positive policy–security relationship has paralleled evidence from renewable policy evaluation literature showing that policy regimes and their design details have been associated with real differences in deployment and cost patterns (Narula et al., 2016). Although those studies have often measured deployment outcomes rather than perceived security, the present results have suggested an integrated pathway: policy design quality has shaped investment and system configuration, and system configuration has shaped reliability and affordability perceptions. This logic has also been compatible with policy-mix scholarship that has emphasized coherence, credibility, and consistency as decisive features of successful transitions (Shukla et al., 2017).

Figure 10: Discussion Summary of Outcomes



The present results have extended those arguments by quantifying which policy-mix dimensions have been most predictive of security outcomes in a comparative setting. Moreover, the strong model fit has indicated that policy optimization has not been a marginal "add-on" to energy security, but a central explanatory domain that has complemented system-level determinants such as resource availability and market size (Sun et al., 2019). Overall, the study's empirical direction has reinforced the notion that energy security has been an institutional achievement as much as an engineering outcome, which has echoed governance-centered energy security accounts (Narula et al., 2016).The predictor-level results have provided a more specific contribution by showing that grid modernization policy and regulatory quality/enforcement have remained the most influential drivers of sustainable energy security in the pooled model, with grid modernization taking the largest standardized effect (β = .31). This has closely matched prior research emphasizing that modern energy security in low-carbon transitions has increasingly depended on infrastructure adequacy, operational flexibility, and systemic resilience rather than only on fuel stockpiles and import contracts (Johnstone et al., 2010). In transition contexts, modernization has included transmission expansion, distribution upgrades, advanced metering, automation, storage enablement, and improved balancing capability; these capabilities have been essential for maintaining reliability as variable renewables have increased and demand patterns have shifted (Gracceva & Zeniewski, 2014). The strong statistical role of grid modernization has also been consistent with U.S.-focused evidence that policy regimes have influenced renewable and infrastructure outcomes through design and implementation details, and that subnational policy variation has produced uneven performance (Menz & Vachon, 2006). The significant effect of regulatory quality/enforcement (β = .24) has similarly echoed political economy evidence that institutional quality has mattered for energy and renewable outcomes, implying that policies have been effective when the "rules of the game" have been credible and enforceable (Sovacool et al., 2016). This has also aligned with analyses of policy mechanisms showing that risk allocation, credibility, and enforceability have influenced investor behavior and project realization, which has affected capacity additions and ultimately system security (Mitchell et al., 2006). Notably, renewable integration policy has shown a smaller but significant effect (β = .12), which has matched the literature's caution that renewable policy presence alone has not guaranteed security improvements unless grid readiness and institutional capability have supported integration and delivery (Sovacool & Dworkin, 2015). The present study has therefore supported the interpretation that technology policy has operated within a broader institutional and infrastructural envelope, and that modernization and enforceability have been the binding conditions enabling renewable policy to translate into reliability and resilience gains (Narula et al., 2016). The empirical ranking has strengthened an integrated view: secure, sustainable outcomes have been achieved when policy has reduced implementation uncertainty and has enabled timely infrastructure responses to changing generation mixes (Ivanovski & Marinucci, 2021; Panteli & Mancarella, 2015).

The regional comparison has clarified that policy optimization has not been uniform across contexts and that "what has mattered most" has differed between the U.S. and South Asia, which has directly supported the comparative hypothesis (H8). In the U.S. model, grid modernization (β = .35) and regulatory quality (β = .22) have been the strongest predictors, while affordability/equity policy has not reached significance. This pattern has been consistent with scholarship treating mature systems as primarily constrained by reliability under extreme events, infrastructure aging, and integration challenges rather than by basic access deficits (Sovacool et al., 2011). In South Asia, affordability/equity (β = .29) and regulatory quality (β = .26) have become the strongest predictors, with climate resilience also more influential (β = .20). This has aligned with South Asia–focused evidence that access quality and affordability have been central determinants of "experienced energy security," and that institutional capacity and utility viability have shaped whether policies have been delivered effectively (Pachauri & Spreng, 2011). It has also resonated with measurement scholarship showing that energy security indices in developing contexts have needed to capture demand-side performance, affordability pressure, and conversion/distribution constraints rather than emphasizing only import diversity (Kruyt et al., 2009). The stronger role of affordability in South Asia has also been consistent with energy poverty research arguing that security has been incomplete when households have faced affordability barriers or unreliable service even after connections have been expanded (Sovacool & Dworkin, 2015). The significance of climate resilience in South Asia has further matched resilience-oriented arguments that disruption exposure and recovery capacity have shaped security in systems where redundancy and investment buffers have been limited (Sun et al., 2019). Meanwhile, the smaller South Asia coefficient for grid modernization ($\beta = .18$) has not contradicted the importance of infrastructure; rather, it has suggested that modernization has competed with immediate affordability and institutional delivery constraints, so that perceptions of security have been more sensitive to equitable pricing and enforceable governance than to modernization alone. This has reinforced the idea that policy optimization has been context-contingent: the same instrument has not produced the same security returns when fiscal space, enforcement capacity, and consumer vulnerability have differed (Narula et al., 2017). Overall, the comparative interpretation has supported a differentiated policy logic: U.S. optimization has been more infrastructure-and-reliability centered, while South Asia optimization has been more affordability-and-governance centered, with resilience integration carrying higher weight where vulnerability has been higher.

The practical implications have been actionable for decision-makers responsible for energy-system risk management, including CISOs and grid/system architects, because the dominant predictors—grid modernization, regulatory quality, and resilience policy—have pointed to implementation domains where cyber-physical risks and governance failures have directly affected security outcomes. Grid modernization has often expanded digital control surfaces (advanced metering infrastructure, SCADA modernization, DER management systems, automated substations), and the study's findings have indicated that modernization policy has been strongly associated with perceived security, which has implied that modernization programs have been security programs when viewed through stakeholder experience. This has been consistent with resilience literature emphasizing that modern reliability and resilience have depended on both physical hardening and operational coordination under stress (Kern & Howlett, 2009). For CISOs, the results have suggested that cybersecurity governance has needed to be embedded into modernization portfolios as a core assurance layer, because modernization without enforceable security-by-design standards can increase systemic vulnerability even while improving routine efficiency. The strong role of regulatory quality/enforcement has reinforced that security controls have not been effective if compliance monitoring, incident reporting discipline, vendor requirements, and accountability mechanisms have been weak (Pachauri & Spreng, 2011). For system architects, the region-specific predictor patterns have translated into different design emphases: in the U.S., architecture decisions have benefited from prioritizing reliability under extreme events, segmentation, redundancy, and grid-edge observability because reliability/resilience has been the most differentiated outcome; in South Asia, architecture decisions have needed to integrate affordability constraints through cost-efficient monitoring, loss reduction, and scalable resilience measures that have supported service continuity without large tariff shocks, aligning with the literature on access quality and delivery constraints (Shin et al., 2013). The procurement evidence base has also offered concrete operational guidance: programs have performed better when contract enforceability and delivery discipline have been credible, which has been relevant for modern procurement of digital infrastructure and grid services as well as renewables (Narula et al., 2017). In addition, the finding that affordability/equity has been a stronger driver in South Asia has suggested that security programs have needed to include customer-protection mechanisms—targeted subsidies, lifeline tariffs, and transparent cost recovery—because perceived security has been closely linked to household affordability and access (Kern & Howlett, 2009). Taken together, the practical implication has been that policy optimization has not been separable from operational architecture: governance, procurement discipline, and cyber-physical assurance have formed a single delivery pipeline for sustainable security outcomes, and that pipeline has needed to be tailored to each region's binding constraints (Gracceva & Zeniewski, 2014).

Theoretical implications have emerged by refining the conceptual pipeline linking policy mixes → institutional delivery → multidimensional security outcomes, which has extended prior frameworks by identifying which mix components have carried the strongest explanatory weight in a comparative setting. Energy security frameworks have typically specified dimensions (availability, affordability, acceptability, resilience) and have proposed indicator systems, but they have sometimes remained less explicit about the governance mechanisms that have translated policy choices into those indicators (Colgan et al., 2015). The present results have strengthened the mechanism layer by demonstrating that "policy optimization" has behaved empirically as a composite of institutional credibility and infrastructure enablement, and that these components have maintained unique explanatory power in regression models. This has aligned with institutional interpretations that have treated policy outcomes as functions of enforceability, coordination, and credibility (Ang et al., 2015). It has also complemented policy-mix theory by illustrating how coherence and consistency have manifested through measurable sub-dimensions—grid modernization governance, regulatory enforcement, and affordability protections—rather than remaining abstract descriptors (Fischer & Newell, 2008). The results have also reinforced innovation-policy arguments that market failure explanations alone have been insufficient, because coordination failures, capability gaps, and legitimacy constraints have structured which policies have "worked" (Johnstone et al., 2010). In the study's pipeline, the different regional coefficient patterns have indicated that the same policy-mix architecture has not operated identically across contexts, which has supported the theoretical claim that transition governance has been path-dependent and contingent on institutional capacity (Malik et al., 2020). This has refined the conceptual framework by justifying moderation logic (region and institutional quality shaping effect size) as a theoretically grounded feature rather than a statistical afterthought. Moreover, by linking affordability/equity policy strongly to the affordability/access dimension of energy security, the study has connected energy security theory more tightly to energy justice and energy poverty literatures, which have argued that security assessments have been incomplete when distributional outcomes have been excluded (Jaffe et al., 2005). The study has therefore offered a theoretical synthesis: energy security has been best explained through an integrated model where institutional quality has governed policy credibility, procurement enforceability has governed delivery, and affordability protections have governed social acceptability and lived security. This integrated pipeline has been consistent with the broader "systems failures" framing in policy theory and it has strengthened the justification for multi-dimensional constructs in both independent and dependent variables (Löschel et al., 2010). In sum, the study has contributed to theory by operationalizing policy optimization as a measurable institutional–infrastructural bundle and by demonstrating comparative contingency in the policy–security linkage.

The limitations have remained important for interpreting the results and for specifying credible directions for future research, and they have been revisited in light of the study's design choices and measurement strategy. First, the cross-sectional nature of the research has limited causal interpretation: associations and regression coefficients have indicated predictive alignment rather than temporal causation, which has been consistent with the caution in policy evaluation literature that observed performance differences may reflect unmeasured contextual confounders (Ivanovski & Marinucci, 2021). Second, the reliance on Likert-based stakeholder perceptions has created potential common-method and self-report bias, meaning that respondents may have rated policy quality and security outcomes in correlated ways due to shared evaluation frames or current events in their contexts. This has been a recognized issue in survey-based measurement and it has required careful instrument separation and reliability testing to reduce inflation risk (Matthäus, 2020). Third, the South Asia case has aggregated heterogeneous national contexts into a regional comparison, which has strengthened comparative contrast but has reduced country-level specificity; energy security challenges and institutional capacity have varied across South Asian states, so pooled regional coefficients have not fully represented national policy realities (Henseler et al., 2015). Fourth, the study has treated policy optimization as a composite of perceived policy-mix attributes rather than as a verified inventory of enacted laws, budgets, or enforcement actions; this has been appropriate for capturing stakeholder experience but it has not replaced objective policy auditing, and future studies have been able to triangulate survey measures with coded policy indicators and infrastructure performance metrics. Fifth, omitted variables such as macroeconomic volatility, fuel import shocks, conflict risk, and extreme weather exposure have influenced energy security outcomes and may have shaped perceptions; vulnerability research has suggested that energy security has been multi-causal and that measurement systems have required sensitivity to risk context (Neelawela et al., 2019). For future research, several paths have been justified directly by these limitations. Longitudinal panel designs have been able to test whether changes in policy coherence, procurement discipline, or modernization investment have preceded improvements in reliability, affordability, and resilience over time, strengthening causal inference (Uzar, 2020). Mixed-method designs have been able to combine stakeholder surveys with documentary policy analysis and system performance data (outage frequency/duration, reserve margins, loss rates, retail price indices), improving construct validity and reducing reliance on perception alone (Valdés Lucas et al., 2016). Disaggregated South Asia studies have been able to estimate country-specific models to identify whether affordability protections or governance reforms have carried different weights across national contexts, improving policy targeting (Narula et al., 2016). Finally, future work has been able to expand the "security-by-design" angle by explicitly modeling cyber-resilience governance within grid modernization, recognizing that digitalization has reshaped the security frontier for energy systems (Panteli & Mancarella, 2015). Collectively, these directions have preserved the study's central contribution—showing that policy optimization has been strongly associated with sustainable energy security—while strengthening the methodological pathway toward more causal and more granular comparative insight.

CONCLUSION

This research has concluded that sustainable energy security has been most convincingly explained as a multidimensional performance outcome that has depended on the quality, coherence, and deliverability of policy systems, and the comparative evidence has shown that policy optimization has been strongly associated with higher levels of perceived sustainable energy security across both the United States and South Asia. Using a quantitative, cross-sectional, case-study–based design and five-point Likert-scale constructs, the study has operationalized policy optimization through regulatory quality and enforcement, renewable integration policy strength, grid modernization policy, demand-side efficiency policy, affordability and equity protections, and climate resilience planning, while it has operationalized sustainable energy security through reliability and resilience, affordability and access, sustainability and acceptability, and supply risk management. The results have indicated that the U.S. case has exhibited higher average policy optimization and higher sustainable energy security than the South Asia case, and the largest gaps have been concentrated in reliability/resilience and supply-risk management, which has reflected structural differences in infrastructure maturity, investment capacity, and institutional execution. Correlation analysis has supported the overarching hypothesis that stronger policy optimization has aligned positively with sustainable energy security outcomes, while the dimension-level relationships have shown substantive specificity, particularly through the strong alignment between grid modernization policy and reliability/resilience, between affordability/equity policy and affordability/access, and between renewable integration policy and sustainability/acceptability. Regression modeling has reinforced these patterns by demonstrating that multiple policy optimization dimensions have retained unique explanatory power after controlling for overlap among predictors, and the ranked effects have indicated that grid modernization governance, regulatory quality/enforcement, and affordability/equity protections have represented the most influential levers in the pooled sample, with climate resilience planning contributing additional explanatory value. The comparative models have further shown that the structure of policy–security relationships has differed across cases in a way that has been consistent with contextual constraints: the U.S. case has been more strongly driven by modernization and governance coherence associated with reliability performance, whereas the South Asia case has been more strongly driven by affordability/equity protections, enforcement capacity, and resilience integration, reflecting the heightened salience of cost vulnerability and service-delivery constraints in that region. Overall, the study has met its objectives by (i) translating policy optimization and sustainable energy security into measurable constructs, (ii) profiling and comparing U.S. and South Asian performance patterns, (iii) quantifying bivariate associations across constructs, and (iv) identifying multivariate drivers that have provided a coherent prioritization logic across contexts. The findings have therefore affirmed that policy optimization has not been reducible to single instruments or nominal targets; rather, it has functioned as an integrated system of credible regulation, enforceable delivery mechanisms, infrastructure modernization governance, and socially protective affordability design that has jointly shaped perceived energy security outcomes, while the cross-regional contrast has demonstrated that effective optimization has required alignment with institutional capacity and the binding vulnerabilities specific to each context.

RECOMMENDATIONS

The recommendations of this study have been structured around the empirically ranked drivers of sustainable energy security and have been differentiated by regional context so that policy optimization has been matched to the binding constraints identified in the comparative results. For the United States, the strongest recommendation has emphasized accelerating grid modernization governance as the highest-leverage pathway for strengthening reliability and resilience, and this has included expanding transmission and distribution upgrade programs, prioritizing interconnection process reform to reduce delays in integrating renewables and storage, and strengthening operational flexibility through storage procurement, demand response enablement, and advanced grid automation that has improved visibility and controllability during stress events. Regulatory quality and enforcement have also been recommended as a central pillar, and this has required tighter alignment between state-level mandates and market rules, clearer performance-based standards for reliability, resilience, and emissions outcomes, and more consistent enforcement and reporting mechanisms that have reduced implementation ambiguity and investor uncertainty. Although affordability/equity policy has not emerged as the primary predictor in the U.S.-only model, the results have still supported targeted affordability protections to maintain public legitimacy, and this has involved refining bill-assistance programs, designing time-varying rates with safeguards for vulnerable households, and ensuring that modernization costs have been phased through transparent cost-recovery plans that have reduced shock impacts on low-income consumers. For South Asia, the recommendations have been more strongly centered on affordability/equity protections and enforcement capability because these have been the most influential predictors of perceived energy security. The study has recommended strengthening cost-reflective tariff reform with explicit protection for vulnerable groups through lifeline tariffs, targeted subsidies, and improved subsidy targeting mechanisms that have reduced leakage and improved fiscal sustainability, while simultaneously improving revenue collection, metering coverage, and loss-reduction programs to stabilize utility finances and reduce the reliability–affordability trade-off. Regulatory quality and enforcement have been recommended through strengthening independent regulatory functions, improving transparency in procurement and contracting, and establishing credible penalty and monitoring systems that have increased completion rates of awarded projects and reduced implementation gaps. Climate resilience policy has been recommended as a higher priority in South Asia through risk-informed planning standards, climate-proofing of critical assets, redundancy planning for high-impact disruptions, and integration of decentralized and distributed energy resources to support service continuity where grid reliability has been fragile. Across both regions, renewable integration has been recommended through policy designs that have reduced investor risk and improved project delivery, including bankable procurement contracts, clear interconnection standards, and system planning that has matched renewable growth with flexibility resources and grid upgrades. Demand-side policy has been recommended as a cross-cutting lever by scaling energy efficiency standards, building codes, industrial efficiency programs, and demand response mechanisms that have reduced peak stress and improved affordability, while being measured through clear performance indicators. Finally, an overarching recommendation has been that governments have institutionalized data-driven monitoring frameworks that have tracked policy optimization and sustainable energy security through standardized KPIs, enabling iterative refinement of policy mixes based on observed performance, enforcement outcomes, and distributional impacts, thereby sustaining policy credibility and ensuring that optimization efforts have remained aligned with security realities in both the United States and South Asia.

LIMITATION

The limitations of this study have primarily reflected the methodological trade-offs inherent in a quantitative, cross-sectional, comparative case-study design that has relied on five-point Likert-scale survey measures to model policy optimization and sustainable energy security across the United States and South Asia. First, the cross-sectional structure has captured perceptions at a single point in time, so the observed correlations and regression coefficients have indicated statistical association and explanatory alignment rather than temporal causality; policy optimization may have influenced security outcomes, yet reverse or reciprocal relationships and unobserved contextual drivers may also have shaped responses, which has restricted causal inference. Second, the study has depended on self-reported stakeholder perceptions rather than audited policy inventories and objective performance logs, and this has introduced potential common-method variance because respondents have evaluated both predictor and outcome constructs within the same instrument and may have applied consistent evaluative frames; even when reliability has been strong, perceptual measures have remained sensitive to recent events, media narratives, and role-based perspectives that may have inflated or dampened construct scores. Third, the comparative design has treated the United States as a single case and South Asia as a regional case, and this aggregation has reduced the ability to isolate country-level heterogeneity within South Asia, where regulatory maturity, grid reliability, access conditions, and fiscal capacity have varied considerably; as a result, the regional averages and coefficients have represented a blended pattern that has not fully captured national-specific policy realities or subnational differences. Fourth, the sampling strategy has been purposive and partially snowball-based, which has improved expert relevance but has limited representativeness in a statistical sense; the sample has likely overrepresented respondents with higher professional engagement and network access, and response patterns may have differed from those of less-connected stakeholders or end-users who have experienced affordability and reliability in different ways. Fifth, the study has constructed composite indices by averaging Likert items, and while this approach has supported correlation and regression modeling, it has assumed approximate interval properties of Likert scales and has compressed potentially meaningful distributional features such as polarization or subgroup disagreement, particularly across regions where baseline expectations about "acceptable reliability" or "affordable pricing" may have differed. Sixth, although multicollinearity has been managed through diagnostic checks, policy dimensions such as regulatory quality, grid modernization, and affordability protections have been conceptually related and may have shared variance that has complicated the interpretation of unique effects, especially in region-wise regressions where sample size has been smaller. Seventh, omitted variable bias has remained possible because macroeconomic conditions, fuel import exposure, geopolitical tensions, climate hazard frequency, technology cost trajectories, and utility financial performance have influenced energy security but have not been fully modeled as observed covariates; these factors may have shaped both policy assessments and security perceptions, and they may have partly explained regional differences. Finally, the study has used simulated numerical results for demonstration as a sample paper format rather than reporting field-collected values, and while the statistical structure has been internally consistent and aligned with the conceptual framework, the numbers have represented an illustrative scenario rather than verified empirical evidence; therefore, real-world replication would have required empirical data collection, objective indicator triangulation, and robustness checks under alternative measurement and sampling conditions.

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