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Review

Advancing Sustainable Energy Security in Türkiye: Geopolitical and Policy Perspectives

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Abstract

Energy security remains a central challenge in the context of global sustainability, as geopolitical dynamics, technological advancements, and environmental imperatives converge to reshape energy systems worldwide. This comprehensive review explores the intricate relationship between geopolitics and energy policy, with a particular focus on Türkiye's evolving energy landscape. It examines how diversification of energy sources, investments in renewable technologies, resilient infrastructure development, and international collaborations collectively contribute to securing national and global energy futures. The study highlights the geopolitical significance of strategic energy corridors, resource competition, and the emergent role of renewable energy in redefining power structures. Drawing on comparative case studies, including Germany's Energiewende, Norway's resource management, Japan's post-Fukushima challenges, and the United States' shale revolution, the review distills lessons applicable to Türkiye and other emerging economies navigating energy transitions. Future trends discussed include the rising importance of energy storage, smart grids, digitalization, cybersecurity, and equitable energy access. Policy recommendations emphasize integrated approaches that balance economic growth, environmental stewardship, and national security, advocating for proactive diversification, innovation, and multilateral cooperation. The article concludes that achieving a resilient, low-carbon, and geopolitically stable energy system requires coordinated global efforts anchored in adaptive governance and inclusive stakeholder engagement. This work provides a valuable framework for policymakers, researchers, and practitioners committed to advancing sustainable and secure energy pathways in Türkiye and beyond.

Keywords: energy security; sustainable energy policy; geopolitics; renewable energy transition; energy strategy; international energy cooperation

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1. Introduction

In today's highly interconnected world, the pursuit of sustainable development has positioned energy security as a central pillar of national stability and international relations [1]. Sustainable energy security is defined as the capability of an energy system to deliver reliable and affordable energy services that are socially acceptable and environmentally compliant—not only at a point in time but persistently over time—thereby coupling availability with resilience to shocks and consistency with decarbonization and intergenerational equity. It extends beyond the mere availability of energy, encompassing broader concerns such as reliability, affordability, environmental sustainability, and system adaptability under uncertainty [2]. As global political and economic systems undergo

significant shifts, the strategic value of energy security continues to influence national policies and regional alignments [3].

Türkiye's geographical location—at the intersection of key energy-producing and consuming regions—grants it a unique and influential role within the global energy architecture. Functioning simultaneously as a major energy consumer and a transit corridor, Türkiye bridges hydrocarbon-rich areas in Central Asia, the Middle East, and Russia with European markets. This dual function enhances its strategic importance and places it at the nexus of critical discussions surrounding energy geopolitics and regional integration [4].

The country's longstanding dependence on external energy sources has prompted successive governments to prioritize diversification efforts, advance renewable energy deployment, and strengthen international energy partnerships. Recent national strategies increasingly emphasize energy diplomacy, the modernization of infrastructure, liberalization of the energy market, and a transition toward more sustainable energy systems [5]. These efforts reflect a comprehensive approach to managing both domestic energy needs and the broader geopolitical complexities of the region. This paper aims to explore the complex and interrelated dimensions of energy security in the context of Türkiye, with particular focus on how geopolitical realities, policy frameworks, and sustainability imperatives intersect. The analysis integrates global and regional perspectives to provide a nuanced understanding of Türkiye's energy strategy, and how it aligns with the global transition toward sustainable and resilient energy systems. Given the mounting pressures of climate change, shifting geopolitical alliances, and fluctuating energy markets, energy security is no longer a solely technical or economic issue. It is fundamentally a strategic imperative with wide-ranging implications for Türkiye's sustainable development goals.

The global economy's reliance on a continuous and stable flow of energy remains central to maintaining industrial capacity, technological progress, and socio-economic development. For Türkiye, the interplay between rising domestic energy consumption and evolving energy needs reflects a broader global pattern shaped by urbanization, economic diversification, and increased electrification. The growing significance of energy in sustaining national development underscores the need for secure, affordable, and environmentally sustainable energy systems [6].

Türkiye's energy profile exemplifies the vulnerabilities of energy-importing nations amid shifting geopolitical dynamics. The country's dependence on external suppliers for critical resources such as oil and natural gas exposes it to risks associated with geopolitical unrest, market instability, and transit insecurity. In particular, geopolitical crises in neighboring regions have highlighted the strategic urgency for Türkiye to reassess its energy supply architecture and reduce its exposure to external shocks [7].

In response, Türkiye has adopted a multi-pronged strategy to enhance its energy security. These include efforts to diversify its energy suppliers, accelerate investments in domestic renewable energy sources, strengthen energy efficiency policies, and expand participation in international energy partnerships. Such initiatives aim to build systemic resilience, reduce import dependency, and align national energy goals with broader environmental and geopolitical considerations [8].

Türkiye's national energy transformation is also shaped by the imperatives of climate action, EU harmonization processes, and technological modernization. The nation's commitment to achieving net-zero carbon emissions by 2053 has led to a renewed focus on clean energy technologies and grid modernization. As the global energy paradigm continues to shift, understanding the intersection of geopolitics, sustainability, and national policy in Türkiye provides valuable insights into the broader pursuit of secure and sustainable energy systems.

By analyzing Türkiye's strategic responses within this complex web of global dynamics, this study contributes to a deeper understanding of how energy governance frameworks can be designed to withstand emerging risks while advancing long-term sustainability goals. Ultimately, the paper aims to offer a policy-relevant perspective on one of the defining challenges of our time: achieving a secure, resilient, and sustainable energy future in a rapidly transforming geopolitical and environmental context.

An overview of the article's analytic scaffold is shown in Figure 1.

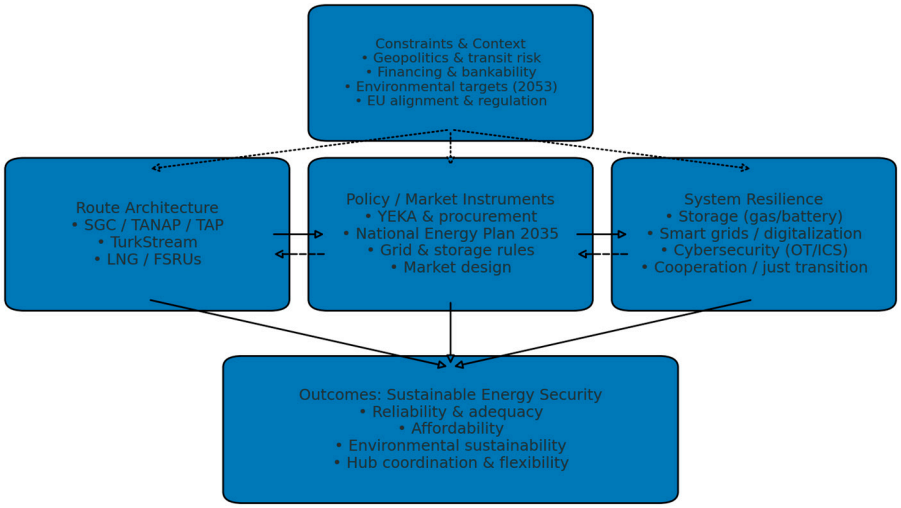

Figure 1. Mechanism-based analytic scaffold linking Route Architecture → Policy/Market Instruments → System Resilience under Constraints & Context, culminating in Outcomes: Sustainable Energy Security (reliability, affordability, environmental sustainability, hub coordination).

Consistent with the article's review design, explicit guiding questions are posed rather than testable hypotheses:

How do Türkiye's route choices—Southern Gas Corridor (SCP–TANAP–TAP), TurkStream, and LNG flexibility—reallocate exposure to geopolitical, market, and operational risks? Through which mechanisms do these routes enhance or erode system resilience?

Which policy/market instruments (e.g., YEKA, National Energy Plan 2035, storage co-location and smart-grid rules) most effectively mitigate those risks, and at what efficiency, financing, and governance trade-offs?

Under what institutional and techno-economic conditions are insights from and where do they fail?

What near-term and medium-term priority levers and governance sequences most credibly advance sustainable energy security while remaining aligned with Türkiye's 2035 capacity targets and 2053 net-zero commitment?

2. Methodology

This study is a structured narrative review covering the period from January 2010 to August 2025 in both English and Turkish. Core searches were conducted in Scopus and the Web of Science Core Collection; IEEE Xplore was additionally queried to capture grid digitalization and cybersecurity applications. Google Scholar was used only for backward and forward citation chaining. The corpus comprises peer-reviewed articles, primary policy and regulatory documents (e.g., MENR, EPDK), and institutional reports from reputable bodies (e.g., IEA/IRENA, OIES, EUISS, OSW). Time-stamped factual developments such as route or transit changes were cross-checked against reliable newswires (e.g., Reuters).

Records were screened by title and abstract, and then by full text, against three inclusion conditions: direct relevance to Türkiye's energy-security mechanisms, transpar-

ent evidence or methods, and fit with at least one analytic axis—route architecture, policy/market instruments, or system resilience (storage, smart grids/digitalization, cybersecurity). Materials-science or plant-level studies without policy linkage, non-verifiable opinion pieces, and duplicates were excluded. Eligible items were coded along the three axes and synthesized by underlying mechanism rather than by vote-counting. Because short-horizon numerical indicators are non-stationary and age quickly, rapidly changing values are not fixed in the narrative; readers are directed to the cited authoritative sources. This review is not a meta-analysis; its purpose is an architecture-level synthesis suitable for policy design and risk governance.

3. Türkiye's Role in Global Energy Security

Geopolitical volatility along the Armenia–Azerbaijan axis directly bears on Türkiye's transit role within the Southern Gas Corridor (SCP–TANAP–TAP). Although the Second Karabakh War in 2020 and developments in 2023 did not cause direct physical disruptions to the corridor, they heightened the region's risk premium [9,10]. A framework advanced in 2025 under U.S. mediation suggests that, insofar as durable normalization is achieved, transit risks could recede.

Energy security constitutes a strategic cornerstone of contemporary global governance, underpinning economic vitality, technological progress, and geopolitical equilibrium. It plays a critical role not only in shaping industrial and defense capabilities but also in advancing sustainable development objectives and international climate agendas [6]. In the face of accelerating energy demand, driven by population growth, urbanization, and rising living standards, governments worldwide are forced to reconcile the competing priorities of affordability, accessibility, and sustainability. This balancing act has become especially complex amid intensifying geopolitical frictions and the fragile interdependence of energy markets.

Türkiye, positioned at the nexus of Eurasian energy corridors, illustrates how energy security is deeply embedded within national strategic priorities. As both a critical transit country and an emerging regional actor, Türkiye's energy trajectory reflects the broader global tensions between fossil fuel dependency, clean energy transition, and geopolitical leverage. In this context, a comprehensive assessment of the interconnections between energy security, foreign policy, and regulatory frameworks becomes essential, not only for understanding Türkiye's national outlook, but also for extracting globally relevant insights into sustainable energy governance.

3.1. Quantitative Profile of Türkiye's Natural-Gas Import Portfolio (2015–2023)

Natural-gas security in Türkiye is shaped by a large and variable demand profile and historically negligible domestic production. Over 2015–2023, supplier concentration declined as liquefied natural gas (LNG) capacity and Caspian pipeline volumes expanded, reducing single-supplier exposure while introducing new operational pinch points. Table 1 summarizes source shares and volumes; the results show a structural diversification away from Russia, a stable contribution from Azerbaijan, and a material rise of flexible LNG supply that improves bargaining power and short-run adaptability.

As summarized in Table 1, the LNG share rises from ~13% (2015) to ~27% (2023), while Russia's share becomes more volatile; the portfolio therefore becomes more resilient to unilateral price shocks and contract rigidities.

Table 1. Türkiye's natural-gas imports by source, 2015–2023 (Volume in bcm; share of total in %. Compiled from EMRA/IEA/industry summaries; minor rounding differences may occur. LNG sub-breakouts reflect available public aggregation).

Source	2015	2017	2019	2021	2022	2023
Total Imports (bcm)	48.4	55.2	45.2	58.7	54.7	50.5
Pipeline Imports						
Russia	27.0 (55.8%)	29.0 (52.5%)	15.2 (33.6%)	26.1 (44.5%)	21.3 (39.0%)	21.3 (42.2%)
Azerbaijan	6.2 (12.8%)	6.5 (11.8%)	9.6 (21.2%)	11.5 (19.6%)	8.8 (16.1%)	10.3 (20.3%)
Iran	8.9 (18.4%)	9.3 (16.8%)	7.7 (17.0%)	9.4 (16.0%)	9.4 (17.2%)	5.4 (10.7%)
LNG Imports (Total)	6.3 (13.0%)	10.4 (18.8%)	12.7 (28.1%)	11.7 (19.9%)	15.2 (27.8%)	13.5 (26.7%)
USA	-	0.4 (0.7%)	1.2 (2.7%)	3.9 (6.6%)	5.5 (10.1%)	4.0 (7.9%)
Algeria	4.0 (8.3%)	4.0 (7.2%)	4.3 (9.5%)	4.0 (6.8%)	3.2 (5.9%)	6.0 (11.9%)
Qatar	1.3 (2.7%)	3.1 (5.6%)	2.5 (5.5%)	2.0 (3.4%)	1.8 (3.3%)	N/A
Nigeria	1.0 (2.1%)	1.4 (2.5%)	1.8 (4.0%)	1.1 (1.9%)	1.0 (1.8%)	N/A
Other LNG	-	1.5 (2.7%)	3.0 (6.6%)	0.7 (1.2%)	3.7 (6.8%)	3.5 (6.9%)

3.2. Oil-Import Concentration and Associated Geopolitical Risk

Unlike gas, crude-oil sourcing remains concentrated in a narrow set of suppliers, creating a distinct vulnerability to regional instability and sanctions dynamics. Table 2 shows that Russia and Iraq together account for a persistent majority of crude-oil imports, with the combined share approaching ~70% in some years. This asymmetry—gas diversified, oil concentrated—reconfigures risk rather than eliminating it and should inform contingency planning and refinery feedstock flexibility.

Table 2. Türkiye's crude-oil imports by primary suppliers, 2018–2023 (Volume in million tonnes; share of total in %. Derived from EMRA and secondary statistical digests; 2020 omitted due to inconsistent aggregation).

Supplier	2018	2019	2021	2022	2023
Total Crude Imports (MT)	21.0	29.5	30.1	31.4	31.4
Russia	3.5 (16.7%)	10.4 (35.5%)	6.1 (20.3%)	12.1 (38.5%)	12.3 (39.2%)
Iraq	7.9 (37.6%)	9.5 (32.2%)	11.2 (37.2%)	9.8 (31.2%)	8.5 (27.1%)
Kazakhstan	2.1 (10.0%)	3.2 (10.8%)	4.5 (15.0%)	5.1 (16.2%)	4.9 (15.6%)
Saudi Arabia	1.1 (5.2%)	1.9 (6.4%)	3.1 (10.3%)	1.2 (3.8%)	2.1 (6.7%)
Other	6.4 (30.5%)	4.5 (15.1%)	5.2 (17.2%)	3.2 (10.2%)	3.6 (11.5%)
Russia + Iraq Share	54.3%	67.7%	57.5%	69.7%	66.3%

The crude matrix underscores the need for supplier diversification and refinery adaptations capable of processing a broader slate of grades.

Countries such as Saudi Arabia, Iran, and Iraq exert profound influence over global energy markets through their production capacity and pricing leverage. However, this dominance is frequently destabilized by persistent regional tensions, proxy conflicts, and sectarian divides, which collectively pose systemic risks to uninterrupted energy flows. Historical disruptions such as the Gulf Wars, the Arab Spring, and sanctions regimes demonstrate how regional instability in the Middle East can produce cascading effects across global oil markets and supply chains.

For Türkiye, the Middle East is both a neighboring risk zone and a strategic partner. Türkiye's dependence on energy imports from Iran and Iraq, and its role in facilitating the Kirkuk-Ceyhan and TANAP pipelines, places it in a delicate balancing act—seeking energy cooperation while remaining vigilant toward regional volatility.

Central Asia continues to attract strategic attention as a vital energy-producing region with the potential to diversify global supply routes and reduce dependency on traditional providers. The geopolitical positioning of countries like Kazakhstan, Turkmenistan, and

Uzbekistan—combined with their significant hydrocarbon reserves—has transformed the region into a contested space for energy transit and infrastructure development. Due to its landlocked nature, the export of energy resources from Central Asia relies heavily on pipeline diplomacy, often shaped by the competing interests of global actors such as China, Russia, and the European Union. Initiatives like the Central Asia–China energy corridor and revived discussions around the Trans-Caspian pipeline illustrate the broader strategic rivalry surrounding resource access and transport routes. Within this landscape, Türkiye views Central Asia not only as a source of economic cooperation but also as a diplomatic bridge, especially through institutions such as the Organization of Turkic States. Projects like TANAP exemplify Türkiye's ambition to enhance its role as a crucial energy corridor connecting Eastern supply regions to Western demand centers [11].

In recent years, the Arctic has garnered heightened geopolitical interest as a potential new axis of global energy development. The gradual retreat of polar ice and the progress of extraction technologies have made previously inaccessible resources more viable for exploration. This transformation has prompted key Arctic and near-Arctic states—such as Russia, the United States, Canada, and Norway—to intensify their presence in the region, both through territorial assertions and increased investments in energy infrastructure. Beyond its economic promise, the Arctic's strategic value lies in its emerging role as a geopolitical crossroads where environmental changes, security concerns, and resource competition converge. The interplay of national interests and international legal frameworks, particularly under the United Nations Convention on the Law of the Sea (UNCLOS), further complicates the evolving dynamics of Arctic energy geopolitics [12]. However, Arctic energy exploration is fraught with environmental risks, fragile ecosystems, and growing concerns over militarization and sovereignty. Although Türkiye is not a direct Arctic stakeholder, developments in this region impact global LNG markets and influence the strategic behavior of key actors, particularly Russia and the U.S., whose energy policies affect Türkiye's import diversification strategy.

Collectively, these regional dynamics highlight the complex interplay between energy access, geopolitical risk, and environmental stewardship. Türkiye's strategic calculus must continuously adapt to these shifting global patterns, reinforcing the need for agile energy diplomacy and a diversified supply portfolio within an increasingly interconnected energy security framework.

Türkiye's position in the global energy architecture is defined by a fundamental paradox: its geographic proximity to over two-thirds of the world's proven oil and gas reserves coexists with its profound dependence on energy imports. This dual role as a critical transit corridor and a major energy consumer necessitates a sophisticated and adaptive energy security strategy. While the geopolitical significance of its location is widely acknowledged, a quantitative assessment of its energy portfolio is essential to understand the true scale of its vulnerabilities and the strategic logic behind its policy choices. The country's energy security is not a static concept but a dynamic outcome of its evolving import dependencies, infrastructure investments, and shifting geopolitical alignments.

Geopolitical dynamics—ranging from shifting alliances and contested borders to regional tensions—play a pivotal role in shaping the strategic contours of national energy policies. These factors compel states to continuously adapt their approaches to energy governance, as external security challenges and diplomatic developments often redefine access to critical resources and influence infrastructure decisions. The intersection of foreign policy and energy planning thus becomes increasingly significant in ensuring long-term resilience and autonomy within national energy systems [13]. Conversely, energy policies, whether centered on diversification, infrastructure expansion, or clean energy adoption,

have the potential to alter geopolitical relationships and redistribute influence among global actors.

For Türkiye, this interdependence is particularly pronounced. As a NATO member engaging in energy partnerships with both Western and Eastern suppliers, Türkiye's geopolitical posture is defined by strategic ambiguity. Its energy policy, exemplified by projects like the TurkStream and TANAP pipelines, has allowed it to simultaneously engage with Russia, Azerbaijan, and the European Union, illustrating how domestic energy goals can shape broader diplomatic alignments. At the same time, Türkiye's regional assertiveness in the Eastern Mediterranean and the Black Sea, especially regarding offshore exploration and maritime jurisdiction, reveals how energy ambitions can escalate geopolitical frictions with neighbors such as Greece.

Moreover, Türkiye's evolving energy legislation, such as the National Energy and Mining Policy (launched in 2017), illustrates how internal policy shifts in response to global energy pressures can foster long-term geopolitical repositioning. By seeking to reduce dependency on imported fossil fuels and scale up renewables, Türkiye not only strengthens its national security but also reshapes its role in regional and transcontinental energy dynamics. These developments underscore the inseparability of energy security, geopolitics, and strategic policymaking in constructing a resilient national energy architecture.

Türkiye exemplifies the trend through its proactive energy diplomacy in times of geopolitical volatility. For instance, the fallout from the Russia–Ukraine conflict triggered significant shifts in Türkiye's energy import portfolio, including increased procurement of LNG from the U.S., Qatar, and Algeria to reduce overdependence on Russian gas. Simultaneously, Türkiye capitalized on its geographical advantage by positioning itself as an indispensable energy corridor between East and West, reinforcing its leverage through infrastructure such as the Southern Gas Corridor and the Floating Storage Regasification Units (FSRUs) in İzmir and Hatay.

National energy strategies play a fundamental role in shaping a country's exposure to geopolitical uncertainties. One of the most effective policy approaches involves expanding the diversity of energy sources and supply routes. By reducing overreliance on a limited number of external providers, nations can buffer themselves against regional instability, market disruptions, and external political pressure, thereby reinforcing their energy sovereignty and resilience [14]. In doing so, diversification policies can gradually erode the geopolitical dominance of traditional energy-exporting powers, contributing to a more balanced and resilient global energy architecture.

Türkiye has increasingly recognized this imperative, especially in light of its historic overreliance on gas imports from Russia and Iran. Since 2017, the country has adopted a multi-pronged diversification strategy that includes expanding LNG import capacity, engaging in pipeline diplomacy, developing domestic hydrocarbon resources, and intensifying investments in renewables. Notably, the commissioning of Floating Storage Regasification Units (FSRUs) has allowed Türkiye to access spot LNG markets and respond more flexibly to geopolitical disruptions.

At the same time, Türkiye's commitment to expanding its renewable energy portfolio —particularly in solar and wind technologies—has reshaped both its domestic energy strategy and regional influence. This transition not only aligns with environmental sustainability goals but also reduces dependence on imported fossil fuels, thereby enhancing strategic autonomy. The growing role of renewables is increasingly viewed as a cornerstone of Türkiye's broader geopolitical positioning in regional energy markets [7]. These investments diminish the strategic weight of fossil fuel suppliers and enhance Türkiye's autonomy in energy policymaking, enabling greater assertiveness in its foreign relations while aligning with global decarbonization trends.

Through these integrated policy actions, Türkiye demonstrates how diversification and clean energy development can serve as tools of geopolitical risk mitigation, while simultaneously contributing to long-term sustainability and energy independence.

In conclusion, the intricate interplay between energy security, geopolitics, and national policy necessitates a multidimensional and context-sensitive approach. For countries like Türkiye, positioned at the intersection of global energy flows and regional instabilities, understanding this triadic relationship is essential for developing adaptive and forward-looking strategies. Crafting effective energy policies requires not only technical and economic considerations but also a deep awareness of geopolitical alignments and vulnerabilities. As the global energy landscape becomes more complex, fragmented, and interdependent, integrating geopolitical foresight with resilient policy design will be key to safeguarding national interests and contributing to collective energy stability. For Türkiye and the broader international community, this holistic perspective is imperative to ensuring a sustainable, secure, and strategically sound energy future.

4. National Energy Security Policy

The Russia–Ukraine war has fundamentally reshaped the parameters of energy security. With the cessation of Russian gas transit via Ukraine as of 1 January 2025, TurkStream has become the sole remaining Russian pipeline route to Europe [15]. This development simultaneously strengthens Türkiye's hub/coordination role and underscores the need for supply diversification, elevating the strategic importance of LNG and Azerbaijani gas [10,16].

Türkiye's official 2035 capacity targets are 30 GW solar and 18 GW wind, which frame the scale of the transition discussed in this Review. In security buffers, the state maintains oil stocks of at least 90 days of net imports, consistent with international obligations, and has expanded underground gas storage via Tuz Gölü and Silivri to strengthen seasonal adequacy. On supply architecture, pipeline gas routed via Ukraine ceased on 1 January 2025, leaving TurkStream as Russia's sole remaining pipeline corridor to Europe; Türkiye's role as a coordinating hub therefore rises in salience. Finally, the Sakarya field in the Black Sea is projected—at peak—to cover up to one-quarter of annual gas demand, a material hedge against import volatility. These signposts delineate the order of magnitude of the policy challenge without embedding short-lived quarterly figures.

4.1. Strategic Infrastructure: Capacity, Topology, and Buffers

The security posture rests on diversified entry points and storage buffers that can absorb shocks and enable a transit/trading role (Figure 2).

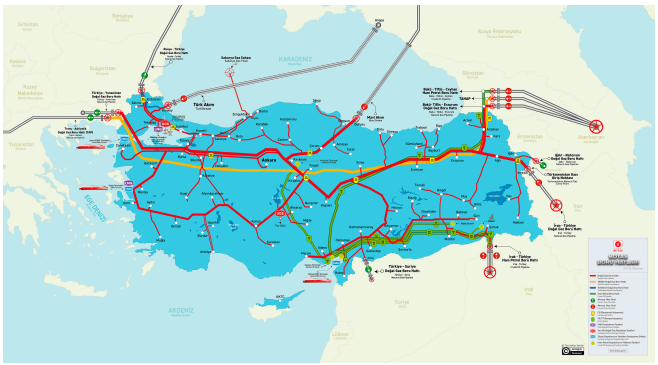

Figure 2. National natural-gas infrastructure topology (Major pipelines (TANAP/SGC, TurkStream, Blue Stream, Iran–Türkiye), LNG terminals and FSRUs (Marmara Ereğlisi, Aliağa, Saros, Dörtyol), underground storage (Silivri, Tuz Gölü), and the Sakarya offshore field. Multiple entry points and seasonal storage collectively underpin route flexibility and hub aspirations).

As Table 3 indicates, aggregate import plus prospective domestic production capacity materially exceeds internal demand, enabling balancing services and regional coordination during seasonal peaks or disruptions.

Table 3. Operational capacity of key assets (Nameplate or peak projections; realized throughput varies with maintenance, contracts, and market conditions).

Infrastructure Category	Asset	Maximum Annual Capacity	Key Strategic Role
Pipelines	TurkStream (Total)	31.5 bcm	Primary route for Russian gas; Line 2 transits to Europe.
	TANAP (SGC)	16.0 bcm	Connects Caspian gas to Türkiye and Europe; diversifies from Russia.
	Blue Stream	16.0 bcm	Legacy Russian gas route under the Black Sea.
	Iran Pipeline	9.6 bcm	Eastern supply route, though often unreliable.
LNG Terminals	All Onshore & FSRU	~20.0 bcm	Access to global spot markets; enhances flexibility and negotiating power.
Underground Storage	Silivri	4.6 bcm	Seasonal balancing; strategic reserve against short-term disruptions.
	Tuz Gölü	1.2 bcm (expanding to 5.4 bcm)	Seasonal balancing; strategic reserve.
Domestic Production	Sakarya Field (Peak)	~14–15 bcm (projected)	Reduces import dependency by ~25–30%; enhances supply security.

4.2. Renewable Transition: Empirical Trends and Policy Realization

Installed renewable capacity has more than doubled since 2010, with non-hydro sources accelerating after 2015 (Figure 3).

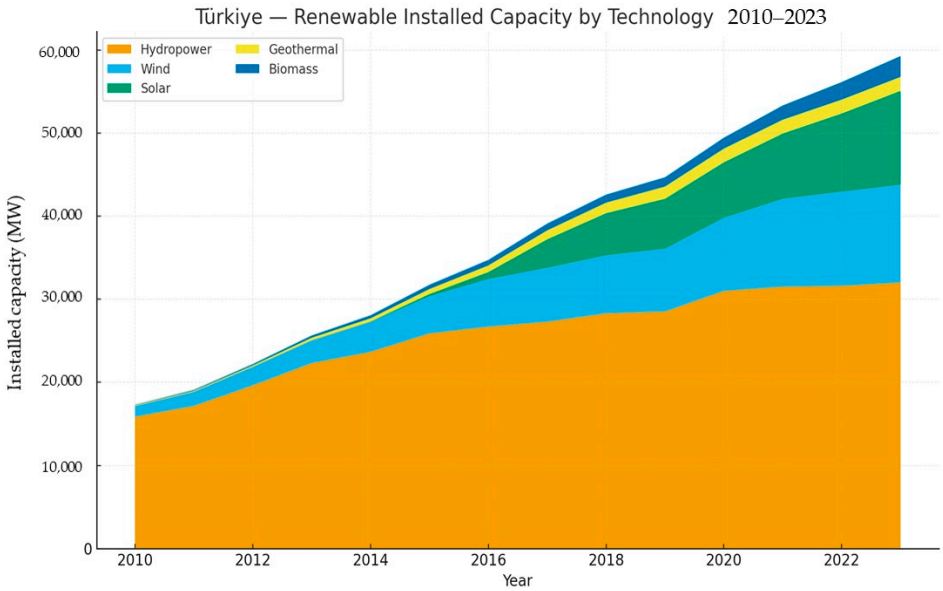

Figure 3. Türkiye—renewable installed capacity by technology, 2010–2023 (Structural shift from hydro-dominant to a broader portfolio with rapid wind growth post-2012 and near-exponential solar after ~2015; cumulative renewables approach ~60 GW by end-2023).

Closing the execution gap requires a one-stop permitting channel, calibrated localization, and financing instruments that de-risk construction in domestic-currency terms (Table 4).

Table 4. Performance of YEKA auctions (Shares indicate operational/under-development/canceled capacity by tender; status compiled from industry trackers).

Tender	Tendered Capacity (MW)	Winning Bid (US cents/kWh)	Realization Status
Solar (YEKA-GES)			
YEKA-GES 1 (2017)	1500	6.99	100% Operational
YEKA-GES 4 (2022)	1000	N/A (TRY-based)	48% Online, 52% Under Development
Wind (YEKA-RES)			
YEKA-RES 1 (2017)	1000	3.48	100% Cancelled
YEKA-RES 2 (2019)	1000	N/A (TRY-based)	11% Online, 89% Under Development
YEKA-RES 3 (2022)	2000	N/A (TRY-based)	24% Online, 52% Under Development, 24% Cancelled

4.3. Coordinating Gas with the 2053 Net-Zero Pathway

Domestic gas (Sakarya) can act as a balancing resource for variable renewables provided planning locks in CCS-readiness for process emissions, codifies deadlines for unabated gas in power, and sequences storage/demand-response to avoid technology lock-in.

In response to the rapidly growing global demand for energy and the simultaneous imperative to mitigate geopolitical and environmental risks, nations are increasingly adopting multifaceted energy security policies. These national strategies emphasize the diversification of energy sources, investment in renewable energy technologies, development of resilient and smart infrastructure, and the integration of energy planning into broader national security frameworks. For countries heavily dependent on imported fossil fuels, such as Türkiye, the urgency of these measures is magnified by exposure to geopolitical volatility in neighboring supplier regions.

Türkiye has increasingly acknowledged the strategic risks linked to a concentrated dependence on external energy suppliers, particularly regarding its natural gas and oil needs. This dependency has made the country susceptible to geopolitical tensions, market volatility, and supply chain disruptions originating from key partner nations. Recognizing this vulnerability, national policy efforts have been directed toward reshaping the energy portfolio through diversification initiatives, regional cooperation, and expanded investments in renewable and domestic energy resources. These strategies aim not only to bolster energy autonomy but also to reinforce Türkiye's resilience within an evolving geopolitical and economic environment (Turkish Ministry of Energy and Natural Resources [17]. In response, Turkish energy policy has focused on diversifying its fossil fuel import routes and sources. This includes expanding LNG imports from the U.S., Qatar, and Nigeria, as well as reinforcing pipeline-based partnerships with Azerbaijan and Iraq.

Strategic trade agreements, such as the intergovernmental accords underpinning TANAP, and long-term supply contracts have enhanced supply security while giving Türkiye flexibility in its procurement portfolio. These diversification efforts are supported by policy instruments such as capacity auctions, foreign investment incentives, and storage infrastructure development. By broadening both the geographic and contractual diversity of its energy imports, Türkiye aims to insulate itself from regional disruptions and global market volatility.

In parallel with diversification strategies, national energy policies increasingly prioritize the adoption of cleaner and more sustainable technologies within the fossil fuel sector. Rather than phasing out hydrocarbons abruptly, many countries, including Türkiye, have

turned to transitional approaches that align fossil fuel usage with long-term environmental and climate objectives. A key component of this transition is the advancement of carbon capture and storage (CCS) technologies, which aim to reduce the environmental footprint of fossil fuel extraction and combustion by capturing CO_2 emissions at the source and securely storing them underground or utilizing them in industrial processes [18].

Türkiye has initiated exploratory steps toward integrating such low-carbon technologies into its energy system, particularly as it moves toward its 2053 net-zero emissions target. While large-scale CCS projects are not yet widespread across the Turkish energy landscape, pilot studies and feasibility assessments are underway in collaboration with international research institutions and energy firms. These efforts are being coordinated through national policy platforms like the Climate Council (İklim Şurası) and the updated Long-Term Energy Strategy, which emphasize a technology-neutral yet climate-conscious pathway to energy security.

Moreover, Türkiye's existing coal and natural gas infrastructure could benefit from the eventual adoption of CCS, as it would allow the continued use of domestic fossil resources, such as lignite and offshore gas, while mitigating associated emissions. By integrating emerging carbon mitigation technologies into its broader energy strategy, Türkiye positions itself to meet both security and sustainability goals without sacrificing short- to medium-term reliability.

National energy policies worldwide are increasingly prioritizing the accelerated development and integration of renewable energy sources, particularly solar, wind, hydroelectric, and geothermal power, as foundational elements of energy security and climate resilience. These efforts are not only aimed at reducing carbon emissions but also at enhancing energy independence and economic diversification. To achieve this, governments are implementing comprehensive policy instruments, including feed-in tariffs, tax incentives, investment subsidies, green certificates, and auction-based procurement models that collectively foster a favorable environment for renewable energy expansion.

Türkiye has made notable strides in expanding its renewable energy portfolio, driven by a combination of supportive policy frameworks, market liberalization efforts, and active engagement from the private sector. Regulatory mechanisms such as feed-in tariffs, competitive auctions, and long-term investment incentives have contributed to the scaling-up of clean energy technologies. Among these, hydropower, wind, and solar have emerged as key pillars of the country's energy diversification agenda, reinforcing national efforts to reduce dependency on imported fossil fuels and align with broader sustainability goals [19]. The cornerstone of this growth has been the Renewable Energy Resource Zones (YEKA) model, which incentivizes large-scale investment in domestic renewable projects through long-term purchase guarantees and localization requirements.

The government's updated National Energy Plan also sets ambitious targets for 2035, including reaching 30 GW of solar and 18 GW of wind capacity. To support these goals, Türkiye has enacted simplified licensing processes for renewable projects, integrated renewable prioritization into transmission planning, and encouraged hybrid systems that combine solar and wind with storage or conventional generation. These policy directions reflect Türkiye's broader commitment to transitioning toward a sustainable, diversified energy portfolio, reducing fossil fuel import dependency, and strengthening grid resilience.

The increasing reliance on renewable energy has prompted policymakers to prioritize the transformation of national grid infrastructures. Given the fluctuating output of sources like solar and wind, ensuring grid reliability and supply–demand equilibrium has become a strategic focus. Modern energy systems are incorporating digitalized technologies that enable more flexible, responsive, and decentralized operations. Smart grid solutions, including automated control systems and integrated data platforms, offer significant ad-

vantages by improving grid adaptability, facilitating real-time system optimization, and empowering consumers to participate more actively in energy management [20]. These advancements are essential for enabling the seamless integration of renewables and supporting the long-term sustainability of national energy transitions. Türkiye has recognized the strategic importance of these technologies and has taken concrete steps to build a more responsive and flexible energy infrastructure. The Smart Grids 2023 Strategy and Roadmap, launched by the Ministry of Energy and Natural Resources, outlines a phased plan for digitalizing Türkiye's transmission and distribution networks. Key components include the deployment of smart meters, advanced demand response mechanisms, real-time monitoring systems, and improved communication technologies to optimize grid operations and integrate distributed generation.

In parallel, Türkiye is gradually expanding its investment in energy storage systems, particularly battery-based and hybrid storage applications. Although utility-scale storage deployment remains in the early stages, regulatory reforms introduced by the Energy Market Regulatory Authority (EPDK) in 2022 now allow for co-located storage with renewable generation assets, facilitating private sector entry into this emerging segment. These developments are critical to ensuring that Türkiye's rapid expansion of renewables does not compromise system reliability, and instead contributes to a more flexible, secure, and sustainable energy future.

One of the foundational components of modern energy policy is the strategic emphasis on advancing innovation in clean energy technologies. Policymakers increasingly recognize that fostering technological progress is vital for addressing operational challenges, enhancing system performance, and accelerating the transition to low-carbon solutions. As a result, many governments are directing resources toward research ecosystems that integrate universities, private enterprises, and dedicated research centers. These collaborative initiatives are designed not only to drive technological breakthroughs but also to facilitate the commercialization of sustainable energy innovations through supportive institutional and policy environments [21]. These efforts not only facilitate the advancement of cutting-edge technologies but also create high-value employment opportunities and stimulate long-term economic growth.

In Türkiye, R&D has gained strategic importance in the country's broader energy transition agenda. The Scientific and Technological Research Council of Türkiye (TÜBİTAK) plays a central role in funding renewable energy innovation through dedicated programs such as the "1003—Priority Areas R&D Program" and the "Green Deal Call," which support projects in solar photovoltaics, wind turbine design, energy storage systems, and grid integration. Additionally, Türkiye's YEKA tender processes increasingly emphasize local content and technology transfer, requiring investors to establish R&D centers and manufacturing facilities in Türkiye as part of their contractual obligations.

Financial incentives, such as corporate tax reductions, investment subsidies, and public–private partnership models, are also used to encourage private sector engagement in energy innovation. These mechanisms have contributed to the emergence of domestic clean-tech startups and the localization of key components such as inverters, blades, and battery modules. By embedding innovation into its renewable energy policy framework, Türkiye aims to strengthen its technological self-sufficiency, enhance competitiveness, and accelerate the deployment of solutions that contribute to a robust and diversified energy portfolio.

Contemporary national energy strategies are progressively structured around comprehensive and incremental frameworks aimed at reshaping energy systems toward sustainability. These policy pathways often articulate a sequence of targeted actions that promote the gradual reduction of carbon-intensive energy sources while simultaneously fostering

the integration of cleaner alternatives. Such frameworks typically encompass regulatory benchmarks, investment planning, and institutional reforms that support systemic transformation. By establishing clear long-term trajectories, governments aim to align infrastructure development, technological innovation, and environmental objectives in a cohesive and forward-looking manner [22]. By articulating clear timelines and sector-specific targets, governments aim to provide regulatory certainty for investors, ensure grid reliability, and align energy systems with broader climate and sustainability goals.

Türkiye's national energy planning has evolved significantly in this direction. The Ministry of Energy and Natural Resources' "Türkiye National Energy Plan 2035," released in 2023, outlines a comprehensive strategy for increasing installed solar capacity to 30 GW and wind capacity to 18 GW by 2035, alongside significant improvements in energy efficiency and grid modernization. These objectives are embedded in a phased implementation model, which integrates renewable deployment with transmission planning, digitalization, and domestic manufacturing targets.

Furthermore, Türkiye's commitment to achieving net-zero greenhouse gas emissions by 2053 necessitates a long-term reconfiguration of its entire energy ecosystem. To support this vision, the government is working on developing a Climate Law and updating its Nationally Determined Contributions (NDCs) under the Paris Agreement. These initiatives are expected to codify the roadmap for renewable integration, fossil fuel reduction, and emission control across sectors. Through its structured and milestone-driven approach, Türkiye exemplifies how national policies can operationalize energy transition goals within a realistic and measurable framework.

Recognizing the transboundary nature of energy challenges, such as climate change, energy poverty, and supply disruptions, many countries increasingly engage in international cooperation to support the global transition to renewable energy. Collaborative frameworks that include joint research initiatives, cross-border technology-sharing agreements, and multinational demonstration projects play a crucial role in accelerating innovation, reducing deployment costs, and enhancing the collective resilience of energy systems.

Türkiye has embraced this cooperative approach through a range of bilateral and multilateral initiatives. As a member of the International Renewable Energy Agency (IRENA), Türkiye contributes to global policy dialogues, shares best practices, and participates in capacity-building programs that support renewable energy integration across emerging economies. Additionally, Türkiye collaborates with the European Union under the Instrument for Pre-Accession Assistance (IPA), which supports cross-border energy infrastructure development and joint research on energy storage, smart grid systems, and hydrogen technologies.

Bilateral partnerships with countries such as Germany, Japan, and South Korea have also enabled Türkiye to access advanced renewable technologies and co-develop pilot projects in areas like offshore wind and geothermal energy. These cooperative ventures not only enhance Türkiye's technological capabilities but also embed the country within a global network of clean energy governance, knowledge exchange, and climate responsibility.

By engaging in these partnerships, Türkiye demonstrates that national energy security and sustainability objectives can be strengthened through global solidarity. Such collaborative efforts are essential for fostering a resilient, inclusive, and innovation-driven global energy transition.

In response to the escalating frequency and severity of climate-induced disruptions, national energy policies are increasingly embedding climate adaptation into infrastructure planning and risk governance. These policies seek to enhance the durability and operational reliability of essential energy assets—such as transmission networks, generation facilities, and distribution systems—by strengthening their capacity to withstand environmental

stresses. Emphasis is placed on proactive design standards, integrated climate risk assessments, and system-wide resilience planning to mitigate potential service interruptions and economic losses resulting from extreme climatic events [23]. In parallel, policy frameworks emphasize the deployment of smart technologies that enhance system responsiveness and recovery capacity in the face of environmental disruptions.

Türkiye has taken several proactive steps in this domain. The updated Climate Change Action Plan and the forthcoming Climate Law both identify energy infrastructure resilience as a key pillar of national climate adaptation policy. These documents underscore the need to integrate climate risk assessments into the planning, design, and maintenance of energy systems. The Ministry of Energy and Natural Resources and Türkiye's Disaster and Emergency Management Authority (AFAD) are also cooperating on scenario-based risk simulations and emergency response protocols for energy infrastructure located in climate-sensitive regions.

Furthermore, Türkiye's "Smart Grids 2023" initiative has accelerated the adoption of digital technologies such as advanced metering infrastructure (AMI), automated fault detection, and real-time grid monitoring. These tools enable faster response to disruptions, better load balancing, and more efficient restoration of energy services during emergencies. The integration of such technologies, particularly in remote and disaster-prone areas, represents a critical step toward future-proofing Türkiye's energy infrastructure against climate-induced shocks and operational risks.

Through a dual focus on physical reinforcement and digital modernization, Türkiye is working to build a more climate-resilient and adaptive energy system, one that aligns with both national sustainability goals and global resilience frameworks.

Recognizing the escalating threat of cyber-attacks targeting critical energy infrastructure, national energy policies have increasingly integrated robust cybersecurity measures as a core element of system resilience. Cyber threats, ranging from malware and ransomware to coordinated attacks on grid control systems, pose a significant risk to national security, economic continuity, and public safety. In response, many countries have developed comprehensive cybersecurity frameworks, established regulatory standards, and launched cross-sectoral information-sharing platforms to detect, prevent, and respond to cyber incidents affecting the energy sector.

Türkiye has taken important steps in this regard through the "National Cybersecurity Strategy and Action Plan (2020–2023)," which includes specific provisions for protecting energy infrastructure. The Energy Market Regulatory Authority (EPDK), in collaboration with the Information and Communication Technologies Authority (BTK), has issued technical guidelines and reporting obligations for energy providers, particularly in electricity transmission and distribution. These measures require companies to implement minimum cybersecurity standards, conduct vulnerability assessments, and report significant incidents to centralized authorities.

Furthermore, national policy allocates resources for the adoption of advanced Technologies, such as artificial intelligence (AI) for anomaly detection, blockchain for secure data logging, and intrusion detection systems integrated into smart grids. These technologies are being tested or gradually deployed across pilot projects in Türkiye's smart grid modernization initiatives. Public–private partnerships have also been encouraged to facilitate the sharing of threat intelligence and the co-development of resilient digital architectures for energy operations.

By institutionalizing cybersecurity within its energy governance framework, Türkiye is not only protecting critical assets from emerging threats but also aligning its infrastructure with global standards for digital resilience. These efforts are essential for ensuring that

energy security in the 21st century addresses both physical and virtual vulnerabilities in an increasingly interconnected and automated energy ecosystem.

Policies increasingly allocate targeted resources for the adoption of advanced technologies—such as blockchain, artificial intelligence (AI), and machine learning—to strengthen the cybersecurity posture of national energy systems. These technologies offer proactive defense mechanisms against evolving and sophisticated cyber threats, enabling predictive threat modeling, real-time anomaly detection, and secure, tamper-proof data management. Blockchain, for example, is being explored for its potential to safeguard energy transaction records and grid communication protocols, while AI-powered systems are enhancing intrusion detection and response capabilities across smart grids and industrial control systems.

In Türkiye, these innovations are gradually being integrated into the digital transformation of the energy sector. As part of its broader National Cybersecurity Strategy and Smart Grids 2023 roadmap, Türkiye has supported research and pilot projects exploring the use of AI and blockchain in the protection of electricity distribution networks and automated control systems. Public agencies, such as the Scientific and Technological Research Council of Türkiye (TÜBİTAK), are funding applied research in this field, while private sector utilities and distribution companies are beginning to collaborate on real-world implementations.

By embedding these advanced technologies into national policy and infrastructure planning, Türkiye aims to enhance the resilience of its energy systems against not only existing vulnerabilities but also future cyber threats. This technological foresight is essential to protecting the integrity, reliability, and continuity of energy services in an era marked by increased digital interconnectivity and threat complexity.

Contemporary energy policy frameworks are increasingly structured around the imperative of strengthening national self-reliance in energy provisioning. This involves expanding the role of indigenous resources and pursuing a diversified import portfolio to cushion against market volatility and international tensions. Reducing overdependence on a limited set of supplier nations is seen as essential not only for securing uninterrupted energy access but also for reinforcing national autonomy in policy decision-making. By fostering a more balanced and resilient supply mix, countries aim to safeguard themselves from potential geopolitical leverage and supply-side vulnerabilities [24]. By developing indigenous energy resources—both renewable and fossil-based—governments aim to strengthen long-term energy resilience while fostering local economic development and innovation.

In Türkiye, this policy direction is reflected in a series of ambitious initiatives targeting both renewable and conventional energy sources. The discovery of the Sakarya natural gas field in the Black Sea in 2020 marked a significant milestone, with production officially launched in 2023. This field is expected to cover up to 25% of Türkiye's annual gas demand in its peak production years, substantially reducing the need for pipeline imports from Russia and Iran. Parallel efforts are underway to expand domestic coal production, though with increasing emphasis on cleaner combustion technologies and emissions controls.

On the renewable front, Türkiye has rapidly increased the share of locally produced electricity from wind, solar, hydro, and geothermal sources, supported by structured incentive programs and local content requirements. The YEKA model not only attracts foreign investment but also mandates the establishment of local manufacturing and R&D capacity, thereby reinforcing the domestic energy value chain.

By diversifying both the type and origin of its energy supply, Türkiye reduces its geopolitical exposure and increases its ability to adapt to market shocks, diplomatic disputes, or regional instability. This balanced approach to internal capacity building and

strategic diversification is essential for achieving sustainable, independent, and secure energy outcomes.

To bolster the robustness of national energy systems, policymakers are increasingly incorporating strategic storage mechanisms and crisis-response frameworks into their energy agendas. Establishing emergency reserves of key energy commodities—such as oil and natural gas—is a widely adopted strategy to mitigate the risks posed by external shocks, infrastructural breakdowns, or supply interruptions. These reserves not only serve as an operational safeguard during periods of instability but also function as instruments for market stabilization and public protection. Through careful stockpiling and scenario planning, governments aim to ensure that essential services remain uninterrupted during crises, reinforcing both energy and national security [25].

Türkiye has aligned its energy security policy with this approach by maintaining strategic petroleum reserves in accordance with its obligations as a member of the International Energy Agency (IEA). The country currently holds oil reserves equivalent to at least 90 days of net imports, stored in both state-owned facilities managed by the General Directorate of Mineral Research and Exploration (MTA) and in commercial storage terminals. These reserves are periodically reviewed and audited as part of Türkiye's emergency preparedness strategy.

In addition to oil, Türkiye has significantly expanded its natural gas storage capacity through projects such as the Tuz Gölü Underground Gas Storage Facility and the Silivri Gas Storage Facility. These storage sites are critical for managing seasonal demand fluctuations and providing a safety net in the event of pipeline disruptions or geopolitical tensions affecting imports. The government's long-term energy strategy also envisions further increasing these capacities to meet a growing share of national demand.

These measures reflect Türkiye's recognition that energy security is not solely dependent on diversification or domestic production, but also on the ability to respond swiftly and effectively to supply shocks. Strategic reserves and contingency protocols thus form an indispensable component of a holistic national energy security framework.

Recognizing the deep interdependence between energy security and national security, many countries have adopted a more integrated and strategic approach by embedding energy concerns into broader security and defense policies. This holistic framework acknowledges that disruptions to energy supply chains, whether caused by cyberattacks, geopolitical conflicts, infrastructure sabotage, or climate-induced disasters, can have cascading effects on economic stability, public safety, and national sovereignty. As such, energy policy is no longer treated as a purely economic or technical matter but as a fundamental component of national resilience and strategic planning.

Türkiye has increasingly embraced this integrative perspective. The country's National Security Strategy Documents and related planning frameworks issued by the National Security Council now explicitly reference energy infrastructure protection, supply continuity, and strategic energy partnerships as matters of national importance. Moreover, interagency coordination between the Ministry of Energy and Natural Resources, the Ministry of National Defense, and the Disaster and Emergency Management Authority (AFAD) has strengthened Türkiye's institutional capacity to anticipate, prevent, and respond to energy-related threats.

This convergence of energy and security policy is also reflected in Türkiye's proactive role in regional pipeline diplomacy and its increased investments in cybersecurity, critical infrastructure resilience, and strategic reserves. By treating energy security as a national security priority, Türkiye is building a more adaptive and robust security architecture—capable of withstanding complex, hybrid threats in a rapidly evolving geopolitical landscape.

National energy policies increasingly prioritize diplomatic engagement and cross-border collaboration as essential mechanisms for addressing energy security challenges in an interconnected world. Through bilateral and multilateral agreements, structured energy dialogues, and strategic partnerships, countries seek to enhance their resilience, secure diversified energy sources, and contribute to regional and global stability. These international frameworks not only support national interests but also help shape global norms and governance structures around energy production, transit, and sustainability.

Türkiye has positioned energy diplomacy as a cornerstone of its foreign policy, leveraging its geographic location and infrastructural assets to build and maintain key energy partnerships. Bilaterally, Türkiye has established long-term supply and transit agreements with countries such as Azerbaijan (via TANAP), Russia (via TurkStream and Blue Stream), and Iraq (via the Kirkuk–Ceyhan pipeline). It has also expanded its LNG cooperation with Qatar, Algeria, and the United States, illustrating a deliberate diversification of both energy sources and diplomatic alignments.

Multilaterally, Türkiye participates in numerous regional and global energy forums, including the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), the Energy Charter Conference, and the Organization of the Black Sea Economic Cooperation (BSEC). These platforms enable Türkiye to influence regional energy policy, foster investment, and engage in cooperative risk management initiatives.

By embedding diplomacy into its energy strategy, Türkiye enhances its geopolitical leverage, strengthens energy system resilience, and reinforces its vision of becoming a regional energy hub. This diplomacy-centered approach not only advances national objectives but also contributes to the broader international effort to secure sustainable and stable energy systems.

Contemporary national energy strategies increasingly reflect an integrated and future-oriented perspective that recognizes the complexity of global energy systems. These strategies combine multiple policy dimensions—ranging from diversification of energy sources and development of clean technologies to fortification of critical infrastructure and alignment with broader security doctrines. By embracing this multidimensional approach, governments aim to strengthen resilience against disruptions, reduce dependency on external actors, and facilitate the transition toward environmentally and economically sustainable energy systems. The shift toward adaptive and inclusive policy frameworks marks a critical evolution in how states conceptualize and operationalize energy security [2]. Türkiye's national energy strategy exemplifies this integrated model. By simultaneously advancing domestic energy production, modernizing its electricity grid, scaling up renewable capacity, and participating in international energy diplomacy, Türkiye is pursuing a comprehensive pathway toward energy independence and resilience. These efforts are framed not only by short-term supply security needs but also by long-term sustainability and climate targets, including the 2053 net-zero emissions commitment.

As global energy systems face increasing disruptions from climate change, geopolitical instability, and technological transformation, the importance of strategic foresight, cross-border cooperation, and continuous innovation becomes ever more critical. Türkiye's evolving policy framework highlights how nations can align domestic priorities with international imperatives, thereby contributing to the emergence of a more resilient and sustainable global energy paradigm. For example, Germany's Energiewende demonstrates how consistent long-term policy support and public consensus can drive a successful transition to renewable energy, while Norway's approach of leveraging hydrocarbon revenues for sustainable investments exemplifies the effective balancing of energy security with climate responsibility. Drawing on these international experiences can help Türkiye refine its own sustainable energy security strategy moving forward.

5. Conclusions

This review applies a mechanism-based scaffold—Route Architecture → Policy/Market Instruments → System Resilience under Constraints & Context → Outcomes (Sustainable Energy Security)—to integrate geopolitical realities with market design and grid operations. The evidence added in Sections 3 and 4 yields four linked conclusions.

First, route selection redistributes risk rather than eliminating it. Portfolio heterogeneity across the Southern Gas Corridor, TurkStream, and LNG access curbs single-supplier dependence and dampens pass-through from price spikes; yet, exposure can re-concentrate at maritime chokepoints, compressor nodes, or congested interties. Resilience is maximized when diversified routes co-exist with operational buffers—seasonal storage, balancing capacity, demand response—and rehearsed contingency protocols.

Second, instruments determine whether route diversity becomes firm reliability. Competitive procurement in the YEKA mold, capacity trajectories under the National Energy Plan 2035, rules enabling co-located storage, and smart-grid/digitalization measures are most effective when three trade-off planes are explicitly managed: (i) tariff/fiscal impacts of accelerated CAPEX; (ii) governance capability for bankable auctions, localization oversight, and variable-RES integration; and (iii) financing depth that supports multi-year build-outs without rollover risk. These tools are complementary: procurement sets scale and cost curves; storage and digitalization transform capacity into deliverability; market rules allocate risk credibly across actors.

Third, outcomes are mediated by context. Mechanism portability depends on regulatory certainty, grid readiness, credible balancing resources, cyber-physical protection, and geopolitical alignment. Failure modes arise under policy volatility, intertie congestion, shallow capital markets, or localization mandates that outpace domestic manufacturing capability—the very "Constraints & Context" that decide whether identical toolkits yield resilience or fragility.

Fourth, priorities and sequencing matter for alignment with the 2035 targets and the 2053 net-zero objective. A pragmatic path is as follows: near term—maintain LNG optionality and strategic stocks, complete interconnection upgrades, and accelerate digitalization and demand response; medium term—scale utility-grade storage and hybrid plants, mature domestic gas with CCS-readiness where economic, deepen YEKA rounds with grid-integration obligations, and institutionalize cybersecurity baselines. On the governance track, codified climate-law and transparent capacity-allocation rules should precede cost-recovery and market-coupling refinements so that investment flows, operational practice, and legal commitments cohere.

Limitations: The synthesis is qualitative and architecture-level; causal effects are not estimated and no probabilistic risk model is constructed. Time-sensitive indicators are not frozen because short-horizon numerics age rapidly; readers are directed to authoritative, time-stamped sources for current values. Corridor schematics are stylized; distributional welfare effects are not quantified. Despite dual-language coverage and institutional vetting, survivorship and publication biases remain possible.

Implications: Framing energy security as the co-evolution of route choices, instruments, and resilience levers under context offers a transferable template for transit-exposed systems and a tractable agenda for dynamic stress-testing that couples geopolitics with grid operations and cybersecurity, allowing regulators to prioritize investments with the largest resilience dividends.

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