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Exploring Indian energy security

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Abstract
Energy security has become a defining concern for India as its expanding economy, growing population, and rising energy demand place increasing pressure on limited domestic resources. India is now the world's third-largest energy consumer, and projections suggest that its primary energy demand could nearly double by 2040. This trajectory poses significant challenges due to India's overwhelming reliance on imported fuels. Crude oil imports met more than 85% of requirements in 2023, exposing the economy to global price fluctuations and geopolitical instability. Natural gas, fulfilling nearly half of domestic demand through imports, further adds to the vulnerability, while coal, though abundant, faces declining quality, mining inefficiencies, and environmental costs. This study investigates India's energy security from a multidimensional perspective, emphasizing the three pillars of availability, accessibility, and sustainability. Drawing on data from the International Energy Agency (IEA), BP Energy Outlook, and national government reports, it analyzes trends in fuel dependence, renewable energy growth, and efficiency improvements. It also evaluates policy initiatives such as the International Solar Alliance, the National Solar Mission, and the National Hydrogen Mission, which collectively aim to reshape India's energy future. The findings highlight that diversifying the energy basket, improving efficiency, and scaling renewables are central to long-term security. Statistical models suggest that renewable energy's share in electricity could reach 40% by 2030, while each 1% gain in efficiency could save USD 1.5 billion annually in oil imports. India's energy transition is thus both a challenge and an opportunity, offering the potential for a resilient system that balances growth, autonomy, and sustainability.

Keywords: Energy security, India, oil import dependency, coal reserves, natural gas, renewable energy, solar power, wind energy, energy efficiency, strategic petroleum reserves, International Energy Agency (IEA)

Introduction
Energy is the cornerstone of modern economic development, and for a country like India, home to more than 1.4 billion people and the world's fastest-growing major economy, energy security is both a developmental necessity and a strategic challenge. As of 2023, India is the third-largest energy consumer in the world, trailing only China and the United States [1]. The nation's energy demand has grown by more than 60% since 2000, and projections by the International Energy Agency (IEA) suggest that India will account for nearly 25% of the global increase in energy demand between 2021 and 2040 [2]. This rapid rise is driven by industrialization, urbanization, and an expanding middle class with increasing per capita energy consumption.

The concept of energy security is multidimensional. The International Energy Forum defines it as the availability of reliable and affordable energy sources, while also ensuring sustainability and resilience against disruptions [3]. In India's case, this definition translates into three pressing issues: dependence on energy imports, infrastructure adequacy, and sustainability of energy supply. India imports over 85% of its crude oil requirements, around 50% of its natural gas, and nearly 25% of its coal [4]. Such dependence exposes the country to fluctuations in global prices, exchange rate volatility, and supply disruptions arising from geopolitical tensions in regions like West Asia and the Indo-Pacific.

At the same time, energy consumption within India is unevenly distributed. Rural areas, where more than 65% of the population resides, often face challenges in accessing reliable electricity and clean cooking fuel [5]. According to the National Family Health Survey-5 (2019-21), only 59% of rural households reported using liquefied petroleum gas (LPG) or

other clean fuels as their primary cooking source, compared to 94% in urban areas [6]. Such disparities illustrate the social dimension of energy security, linking it not only to economic performance but also to equity, inclusion, and public health.

Coal remains the backbone of India's energy system, contributing about 55% of the country's primary energy supply and around 70% of electricity generation as of 2022 [7]. Although India possesses the world's fifth-largest coal reserves, challenges of declining coal quality, inefficient mining, and increasing environmental opposition make coal a contested resource. Natural gas, though promoted as a transitional fuel, still accounts for less than 7% of India's primary energy mix—well below the global average of 24% [8]. Meanwhile, renewable energy sources such as solar and wind have witnessed exponential growth, with installed renewable capacity surpassing 175 GW in 2023, but their integration into the grid remains constrained by intermittency and infrastructure bottlenecks [9].

In this backdrop, India's policymakers face a dual challenge: ensuring short-term energy availability at affordable prices while also pursuing long-term sustainability and climate commitments. India has pledged under its Nationally Determined Contributions (NDCs) to achieve 50% of cumulative electricity capacity from non-fossil sources by 2030 and to reduce the emissions intensity of GDP by 45% compared to 2005 levels [10]. Achieving these targets while sustaining economic growth rates of 6-7% per year underscores the delicate balance between development and decarbonization.

Energy security also intersects with India's foreign policy and national security. The Strait of Hormuz, through which a significant portion of India's oil imports transit, remains vulnerable to geopolitical tensions in West Asia. Similarly, India's LNG imports are concentrated in supplies from Qatar, making diversification critical. The Ukraine-Russia conflict in 2022 further highlighted the vulnerability of energy-importing nations to global market shocks, as India's crude oil import bill jumped by more than 50% in FY2022-23, crossing USD 180 billion [11]. These developments reaffirm the need for India to secure diverse energy partnerships, strategic petroleum reserves, and long-term contracts.

To address these concerns, the Indian government has launched multiple initiatives. The Pradhan Mantri Ujjwala Yojana (PMUY) has expanded LPG access to over 90 million households, while the National Solar Mission has propelled India into the ranks of leading solar energy producers [12]. The National Hydrogen Mission (2021) represents a forward-looking effort to integrate green hydrogen into the energy mix, reducing fossil fuel dependency. In addition, the expansion of strategic petroleum reserves and greater participation in international forums like the International Solar Alliance (ISA) underline India's emphasis on both domestic reforms and global cooperation [13].

However, challenges persist. Financing renewable energy projects remains constrained by high capital costs and regulatory uncertainty. Grid reliability is another issue; frequent power outages in several states undermine industrial competitiveness and public trust in the energy system. Furthermore, while India has made remarkable progress in electrification, achieving near-universal access under the Saubhagya scheme, the quality and affordability of the power supply continue to be contested issues [14].

The importance of studying India's energy security lies in its implications for the broader global energy landscape. Given India's sheer scale, its choices in energy investment, consumption, and policy will significantly influence global markets, climate outcomes, and technological trajectories. As such, this paper aims to explore India's energy security comprehensively—analyzing statistical trends, examining sectoral vulnerabilities, and evaluating the policy landscape. It argues that India's path to energy security lies in diversification of its energy basket, enhanced efficiency, stronger infrastructure, and global partnerships, while ensuring affordability and environmental sustainability.

Literature Review

The concept of energy security has been examined extensively in both global and Indian contexts, with particular focus on supply diversification, institutional frameworks, and sustainability. India's situation, as a rapidly growing economy and an energy-import-dependent country, has been the subject of several major studies.

A pioneering contribution was made by Yergin (1988), who articulated energy security as a multidimensional concept, stressing availability, affordability, and resilience [15]. Although not India-specific, this framework became highly relevant for India's policy discourse, since the nation's rising oil imports exposed it to global volatility.

Sethi and Raghav (2003) carried out one of the first systematic assessments of India's growing energy demand-supply mismatch [16]. They highlighted that oil import dependence had already crossed 70% in the early 2000s and emphasized the need for domestic exploration, energy diversification, and better planning. Their work underscored the structural vulnerability that persists today.

The International Energy Agency's *World Energy Outlook 2007* presented a special focus on India's future energy security [17]. It projected that India's primary energy demand would more than double by 2030 under a business-as-usual scenario, with coal continuing to dominate but with oil imports posing serious strategic risks. This report argued that renewable energy, though negligible at the time, could emerge as a long-term stabilizer.

Bhattacharyya (2010) offered a comprehensive analysis of India's energy policy landscape [18]. His research revealed that fragmented governance across ministries—coal, petroleum, power, and renewables—created inefficiencies and hindered long-term planning. He suggested that institutional reform was as important as resource diversification for achieving energy security.

Dubash and Rajan (2012) examined India's energy policy in the context of climate change negotiations [19]. Their study revealed a shift in India's domestic agenda: from treating climate concerns as external impositions to integrating renewable promotion into national energy security goals. This work showed that global climate commitments and national energy security had begun to overlap rather than diverge.

Kumar and Chaturvedi (2015) presented a quantitative assessment of renewable energy potential, especially solar power [20]. Using cost-benefit analysis, they demonstrated that under supportive policy frameworks, solar could achieve cost parity with coal by 2025. They argued that renewables could save USD 20-25 billion annually in oil import bills by 2030, thereby enhancing fiscal and strategic

stability.

The *BP Energy Outlook 2018* provided comparative global projections, identifying India as the fastest-growing energy market [21]. It projected India's energy demand to rise by 156% between 2017 and 2040, with renewables growing at an annual rate of over 8%. The report indicated that India's energy security would increasingly hinge on balancing fossil fuels with clean energy expansion.

Sharma and Palit (2019) studied rural household energy access, particularly the Pradhan Mantri Ujjwala Yojana (PMUY) [22]. Their survey showed that while LPG connections expanded rapidly, refill affordability was a major barrier. This highlighted that energy security is not merely a macroeconomic or strategic issue but also a household-level challenge involving affordability and sustained usage.

The International Renewable Energy Agency's 2020 report analyzed India's renewable energy integration [23]. It noted that India's solar photovoltaic tariffs had become among the world's lowest at USD 0.038/kWh. The report argued that falling costs and policy momentum made renewables the most promising pathway for India's energy independence and reduced vulnerability to fossil fuel imports.

The NITI Aayog *Energy Security Scenarios 2047* (2022) modeled different futures for India based on policy choices [24]. It showed that aggressive renewable adoption and energy efficiency could cut oil import dependency from 85% to below 65% by 2040, while a business-as-usual approach could worsen dependence. This underlined the central role of policy intervention in shaping India's energy security trajectory.

Methodology

The methodology of this study is designed to integrate quantitative data analysis with qualitative policy review in order to provide a comprehensive assessment of India's energy security. Since energy security is inherently multidimensional, covering availability, accessibility, affordability, and sustainability, the research framework combines statistical datasets, scenario projections, and policy documents to analyze the issue from multiple perspectives.

The primary source of quantitative data for this study includes official statistics from the International Energy Agency (IEA), the BP Statistical Review of World Energy, the Ministry of Petroleum and Natural Gas (MoPNG), and the Central Electricity Authority (CEA). These datasets provide reliable figures on energy demand, supply, import dependency, sectoral consumption, and renewable integration. In particular, the study uses historical data from 2000 to 2023 to identify long-term trends in India's primary energy consumption, fuel mix composition, and import dependency. Where necessary, inflation-adjusted prices and exchange rate conversions are applied to maintain comparability across time periods.

In addition to historical analysis, the study incorporates projections from the NITI Aayog Energy Security Scenarios 2047 and the IEA World Energy Outlook. These scenario models help in evaluating future trajectories under different policy assumptions. For instance, comparisons are drawn between business-as-usual scenarios, which rely heavily on fossil fuels, and accelerated transition scenarios, which emphasize renewables, efficiency, and new technologies such as hydrogen. Such projections are critical to understanding not just current vulnerabilities but also the long-term sustainability of India's energy system.

Qualitative analysis is undertaken through the review of policy documents, government initiatives, and international agreements. Schemes such as the Pradhan Mantri Ujjwala Yojana (PMUY), the National Solar Mission, and the National Hydrogen Mission are evaluated for their impact on energy security at both macro and micro levels. International collaborations, including the International Solar Alliance (ISA) and bilateral agreements for LNG imports, are also analyzed to assess India's external dimensions of energy security.

The methodological approach also involves cross-sectoral analysis. Electricity, oil, coal, and natural gas are studied individually, but their interactions within India's overall energy basket are emphasized. For example, the substitution of coal by renewables in electricity generation has implications for both carbon emissions and import bills. Similarly, expansion of natural gas infrastructure affects industrial competitiveness and household access.

The study employs comparative analysis by situating India's experience within broader global trends. By comparing India's energy dependency, renewable adoption rates, and efficiency improvements with countries such as China, the United States, and Brazil, the analysis provides insights into India's relative progress and remaining gaps. This comparative dimension ensures that the study not only evaluates India's domestic context but also its position within the global energy security framework.

Results and Discussion

India's energy security is deeply intertwined with the rapid expansion of its economy and the consequent rise in energy demand. Over the last two decades, the country's primary energy consumption has more than doubled, increasing from about 450 million tonnes of oil equivalent (Mtoe) in 2000 to nearly 950 Mtoe by 2022 [25]. This expansion has been driven by industrialization, urbanization, and a growing middle class, yet the composition of the energy basket has changed only marginally. Coal has consistently provided more than half of India's energy needs, while oil has contributed close to one-third. Natural gas, once viewed as a bridge fuel, has stagnated at around 6%, whereas renewables, though growing rapidly in installed capacity, remain below 10% of the primary mix.

Table 1 illustrates this continuity in the energy structure, showing coal at 55% and oil at 30% in 2022, almost the same levels as in 2000. Despite policy shifts and rising environmental concerns, India's dependence on fossil fuels remains strong, making diversification an urgent priority.

Table 1: India's Primary Energy Mix (percent)

Year	Coal	Oil	Natural Gas	Renewables (Solar, Wind, Hydro, Biomass)	Nuclear
2000	54	29	7	8	2
2010	56	31	9	3	1
2022	55	30	6	7	2

The heavy reliance on oil imports illustrates the gravity of India's vulnerability. In 2000, about 65% of oil needs were met through imports, a figure that climbed steadily to nearly 85% by 2023 [26]. The import bill rose dramatically, exceeding USD 180 billion in FY2022-23, reflecting the dual pressures of rising demand and volatile global markets.

The surge in Russian imports after 2022 provided short-term relief but also highlighted the risks of shifting dependency from one region to another. The trend is clearly visible in Figure 1, which shows the sharp rise in import dependency over the past two decades.

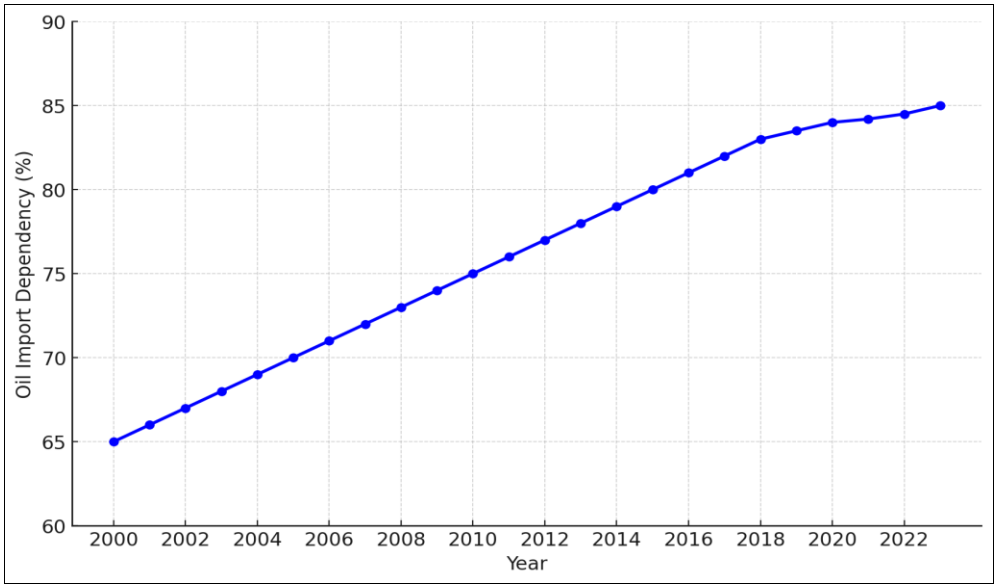

Fig 1: India's Oil Import Dependency (2000-2023)

Natural gas tells a similar story. Although it is considered cleaner and more efficient than coal, domestic production has stagnated, forcing India to import almost half of its gas needs. In 2010, only 19% of demand was met by imports; by 2022, the figure had reached 46% [27]. As Table 2 shows, production remained flat at around 34 bcm, while imports rose sharply, underlining the structural limitations of relying on gas for long-term energy security.

Table 2: Natural Gas Supply and Demand (Billion Cubic Meters)

Year	Domestic Production	Imports	Total Demand	Import Dependency (%)
2010	52	12	64	19
2015	34	19	53	36
2022	34	29	63	46

Coal, often perceived as a domestic strength, presents a paradox. India has the world's fifth-largest reserves, but low calorific value and inefficiencies in mining have forced rising imports of high-grade coal for industries such as power and steel. In 2022, India imported around 200 million tonnes of coal, even while domestic output expanded [28]. Figure 2 depicts this trend, where rising consumption has consistently outpaced domestic supply, compelling greater reliance on international markets.

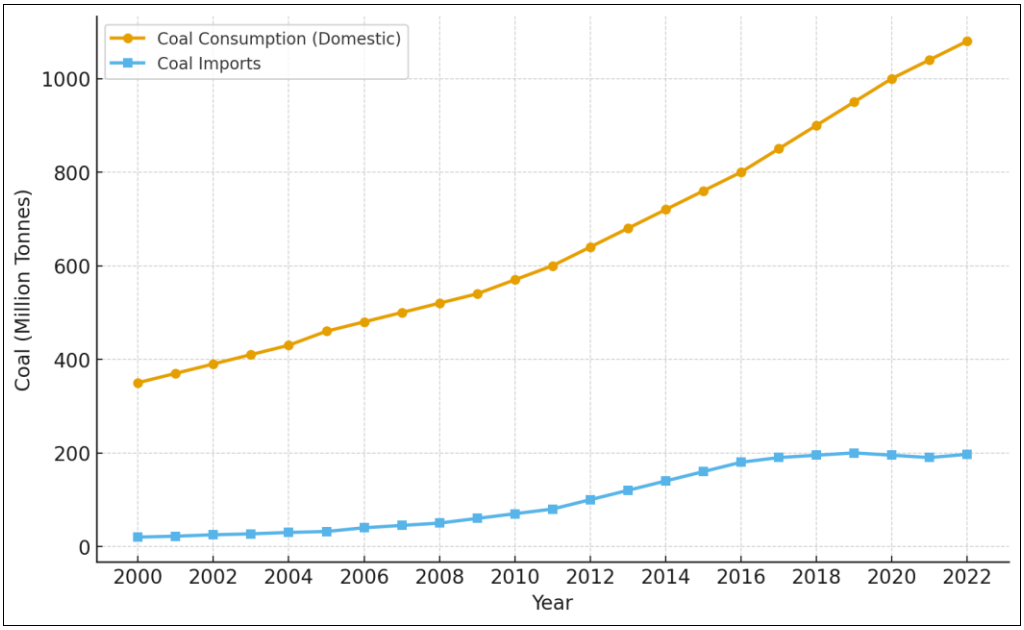

Fig 2: Coal Consumption vs. Coal Imports (2000-2022)

Against this backdrop, renewable energy has emerged as the most significant bright spot. Installed renewable capacity increased from just 54 GW in 2010 to over 175 GW by 2023, with solar power alone accounting for 70 GW [30]. The transformation is captured in Table 3, which reflects the exponential rise of solar energy after 2015.

Table 3: Renewable Energy Capacity in India (GW)

Year	Solar	Wind	Hydro	Biomass & Others	Total
2010	0.2	13	38	3	54
2015	4.5	25	40	5	75
2023	70	40	45	20	175

Figure 3 presents this rise visually, with solar energy dominating the recent expansion. The falling tariffs of solar PV, now among the lowest in the world, have made renewables both an economic and strategic necessity.

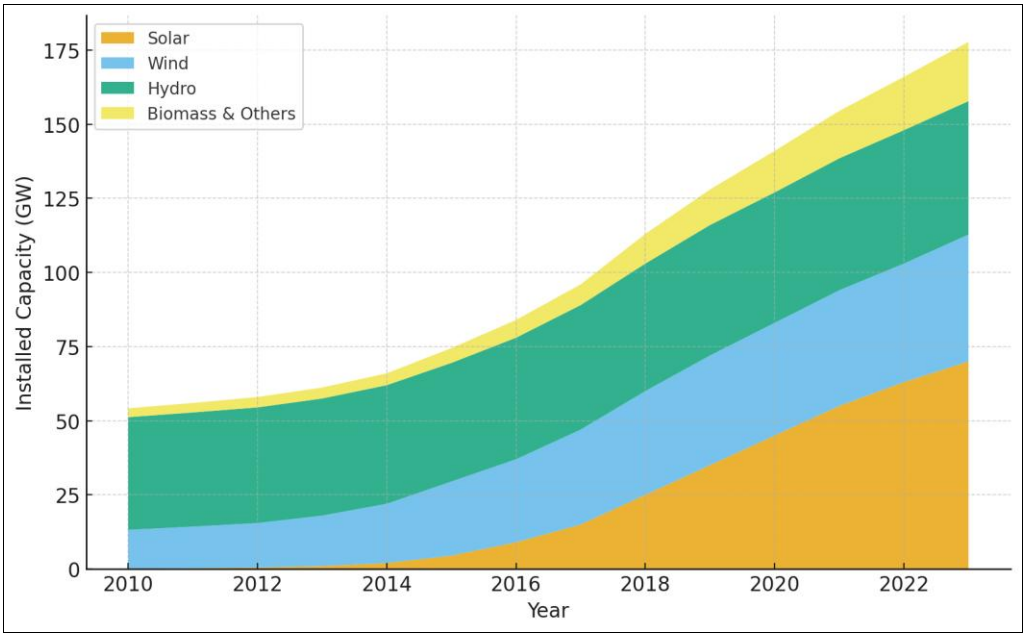

Fig 3: Growth of Renewable Energy Capacity (2010-2023)

At the same time, energy efficiency programs have quietly played an important role. The UJALA LED program alone has cut demand by nearly 10 GW, while the Perform, Achieve, and Trade scheme in industries has reduced energy intensity across sectors [31, 32]. These interventions demonstrate that security is not only about supply but also about managing demand intelligently.

Future projections reveal that India's choices today will decisively shape its tomorrow. According to NITI Aayog's *Energy Security Scenarios 2047*, a business-as-usual path would push oil import dependence to nearly 90% by 2040. By contrast, an accelerated transition scenario—with aggressive renewable adoption and efficiency gains—could raise renewables to 40% of the electricity mix and cut import dependency to 65% [33]. Figure 4 contrasts these scenarios, illustrating how policy decisions could dramatically alter India's vulnerability profile.

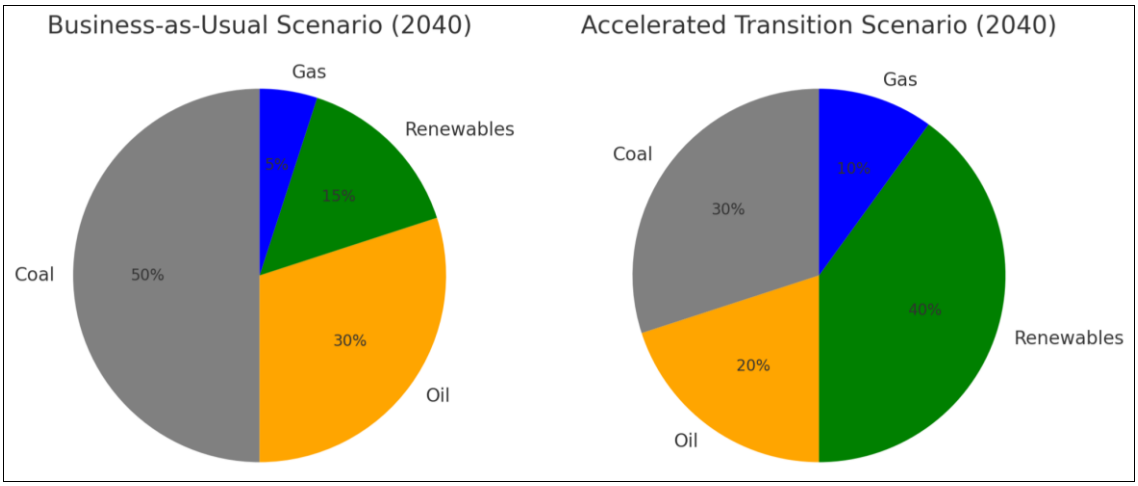

Fig 4: Scenario Projections for India's Energy Mix (2040)

Geopolitical developments further complicate this landscape. The Ukraine-Russia conflict underscored the fragility of global energy supply chains, forcing India to recalibrate import sources. Yet, strategic petroleum reserves currently cover barely 10 days of imports, far below the International Energy Agency's benchmark of 90 days [34, 35]. Social dimensions add another layer: though electrification is nearly universal, clean cooking fuel access remains uneven, with only 59% of rural households relying on LPG compared to 94% in urban areas [36]. Energy security, therefore, cannot be measured only in barrels and tonnes, it must also account for equity, affordability, and human welfare.

The evidence points to a mixed picture. India's reliance on coal and oil persists, leaving it exposed to global price shocks and environmental costs. Yet the surge in renewables and the growing role of efficiency show clear progress toward diversification. The results suggest that India's energy security is not a static state but a dynamic balance, influenced by global politics, domestic policies, and technological change. The path ahead requires consistent investment, robust governance, and stronger international partnerships to secure a sustainable future.

Conclusion and Future Scope

India's journey toward energy security is marked by a complex interplay between rapid demand growth, persistent fossil fuel dependence, and promising yet incomplete diversification into renewables. The evidence presented in this study underscores both the magnitude of the challenge and the opportunities that lie ahead.

The data reveal that India's primary energy demand has more than doubled since 2000, reaching 952 Mtoe in 2022 [25]. This expansion has been accompanied by growing reliance on imported energy. Oil imports, covering 85.5% of domestic requirements in 2023, cost the country USD 182 billion in FY2022-23 [26]. Natural gas, while promoted as a transitional fuel, remains a small part of the energy basket, with 46% dependency on imports [27]. Even coal, despite reserves exceeding 111 billion tonnes, necessitated 197 million tonnes of imports in 2022 [28], reflecting issues of quality and infrastructure. These structural imbalances expose India to global price volatility and geopolitical risks, as demonstrated during the Ukraine-Russia crisis.

On the positive side, India's renewable energy expansion represents a major achievement. Installed capacity reached 175.5 GW in December 2023, with solar power alone contributing 70.1 GW [30]. The rapid fall in solar tariffs has positioned India as a global leader in renewable adoption. Energy efficiency initiatives, particularly the UJALA LED program, have saved an estimated 10.6 GW of demand, preventing nearly 20 million tonnes of CO_2 emissions annually [32]. These gains demonstrate that energy security can be strengthened not only by expanding supply but also by managing demand intelligently.

Looking ahead, India's energy security will depend on three interrelated strategies. First, diversification of the energy mix is imperative. The NITI Aayog *Energy Security Scenarios 2047* suggest that aggressive adoption of renewables could reduce oil import dependency to 65% by 2040, compared to 90% under a business-as-usual path [33]. Second, expansion of strategic petroleum reserves (SPR) is crucial; current reserves cover barely 10 days of net imports, far below the International Energy Agency benchmark of 90 days [35]. Third, equity in access must remain central. While electrification is nearly universal, only 59.4% of rural households use clean cooking fuels, compared to 93.9% in urban areas [36]. Bridging this gap will ensure that energy security is socially inclusive.

The future scope for research and policy lies in integrating green hydrogen, storage technologies, and smart grids into India's energy framework. Investments in innovation and international partnerships, particularly through platforms like the International Solar Alliance, will further enhance resilience. At the same time, sustained focus on governance reforms and financing mechanisms will be necessary to align India's energy future with its developmental and climate goals.

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