

INDIA FOUNDATION JOURNAL



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With a team of dedicated professionals based at its office in New Delhi, the Foundation works with partners and associates both in India and overseas to further its stated objectives.

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The India Foundation Journal is led by an Editorial Board of eminent scholars and leaders from various spheres of Indian public life. The bi-monthly journal covers a wide range of issues pertinent to the national interest, mainly focusing on international relations, national security, legal and constitutional issues and other issues of social, religious and political significance. The journal seeks articles from scholars with the intent of creating a significant body of knowledge with a nationalist perspective and establish a recognised forum for debates involving academicians and policymakers.

Power, Prosperity and National Strength: India's Energy Transformation

Dhruv C Katoch*

In 1950, just three years after independence, India had a modest electricity-generating capacity of 1.7 GW. At the time, India's population was about 36 crore, and most people were outside the reach of the electricity grid. By the turn of the century, the installed generating capacity had increased to 112 GW, covering a majority of India's population, which had now grown to about 100 crore. A quarter of a century later, in 2025, India's installed generating capacity, at 557 GW, covered the length and breadth of the country, including all villages and hamlets. By 2018, all inhabited villages had been provided with distribution lines, and although power supply in some areas was erratic, it still represented a significant improvement over the situation that existed even a decade earlier.

Over the 75-year period 1950-2025, India's electricity production increased by more than 320-fold, while its population grew fourfold. The first two decades, 1950-1970, were a period of growth driven by hydropower. The next three decades, 1970-2000, saw coal-driven expansion, with rapid growth in thermal power. Since then, power generation has more than tripled, largely driven by renewable energy, including solar, wind, and nuclear power.

In terms of generating capacity, solar power, at 154.2 GW, now accounts for 28.7% of the country's capacity, while wind, at 56.4 GW,

accounts for 10.5%. When we add 56.9 GW of hydropower, 11.8 GW of bio power, and 8.8 GW of nuclear power, non-fossil fuels make up over 52% of the national total generating capacity. This is a stupendous achievement, driven largely by green energy technologies, substantial funding, and government initiatives.¹

A significant milestone is the near-100% electrification of India's broad-gauge railway network, covering 70,271 route kilometres (RKM), of which 70,002 RKM have been electrified. At independence, India had just 388 RKM of its broad-gauge network electrified. This number grew to 21,800 RKM by 2014. The last decade has seen a tremendous push for broad-gauge electrification, with over 48,000 RKM electrified—indeed a tremendous achievement.² With just 269 RKM remaining to be electrified, Indian Railways stands on the threshold of complete electrification, marking a transformative achievement in sustainable, efficient, and future-ready rail transport and positioning itself among the world's leading rail networks. Solar energy is a significant component of Indian Railways' energy basket, rising from 3.68 MW in 2014 to 898 MW by the end of 2025, reflecting transformational growth in renewable energy adoption.³

While India has made a notable leap into renewable energy, its dependence on coal is unlikely to diminish. 55% of India's primary

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commercial energy needs are still met by coal. Coal is used in thermal power plants for electricity generation, as well as in iron and steel production, cement manufacturing, coal gasification, and chemical manufacturing. It remains the backbone of India's energy and industrial sectors. Although coal's installed capacity accounts for 42% of electricity generation capacity, actual generation is much higher, at about 70-72%. This is because coal plants run continuously, day and night, whereas solar plants depend on daylight hours and hydropower is affected by seasonal flows.

India possesses one of the largest coal endowments in the world, estimated at about 400 billion tonnes by the Geological Survey of India. Despite India's thrust towards renewables, it would be unrealistic to forgo exploiting its available resources at this stage of development. That said, India's long-term energy security goal aligns with its net-zero target, and the commitment it made in November 2021 at COP26 to achieve net-zero by 2070 will be met.

The global energy transition, however, is becoming a new industrial revolution. While global warming and climate change set the agenda for decarbonisation targets, the tremors following the closure of the Strait of Hormuz, which led to market volatility, have underscored the need for resilience and diversification. The defining issue, however, has shifted from generating clean power to building the electrical, digital, and industrial systems required to support an increasingly electrified world. The demand for electrical power is no longer about an annual incremental increase. Artificial intelligence (AI), hyperscale data centres, semiconductor manufacturing, industrial electrification, and battery production are transforming power consumption patterns across advanced and emerging economies alike.⁴

The countries that adapt fastest will shape the next phase of global economic leadership. That is the challenge India will face in its quest to compete for global leadership.

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Energy Security as Strategy: Building India's Resilient Energy Architecture in a Fragmented World

Manmohan Parkash*

Introduction

For much of the post-Cold War era, energy security was largely understood through the lens of economic efficiency. Policymakers focused on securing uninterrupted access to affordable fuel supplies through globalised markets, diversified sourcing arrangements, and increasingly integrated supply chains. The dominant assumption was that deep economic interdependence would moderate geopolitical tensions and enable energy markets to function with relative predictability. Efficiency, cost optimisation, and just-in-time logistics became the organising principles of the global energy system. That paradigm is now under visible strain.

Over the past several years, a succession of geopolitical and economic disruptions has exposed the fragility of highly optimised energy networks. The Russia–Ukraine conflict fundamentally altered global hydrocarbon flows, triggered severe volatility in oil and gas markets, and compelled major economies to reconsider long-held assumptions about supplier reliability and strategic dependence. Simultaneously, sanctions regimes, export controls, financial restrictions, and technology-denial measures demonstrated how energy, finance, logistics, and geopolitics have become deeply

interconnected instruments of statecraft. More recently, disruptions in the Red Sea and attacks on commercial shipping routes have underscored the vulnerability of maritime corridors that sustain global trade and industrial activity.

These developments are unfolding alongside a broader transformation of the international system, marked by geopolitical fragmentation, intensified strategic competition, technological rivalry, and the gradual erosion of the relatively stable globalisation model that defined earlier decades. States increasingly prioritise resilience, strategic autonomy, and supply-chain security over narrow efficiency considerations. The global economy is therefore shifting away from purely optimisation-driven frameworks towards systems designed to withstand disruption and uncertainty.

In this emerging environment, energy security can no longer be treated merely as a matter of fuel procurement or price stabilisation. It has become a multidimensional strategic challenge encompassing maritime security, infrastructure resilience, technological capability, industrial policy, cybersecurity, and financial preparedness. The defining feature of the contemporary energy landscape is not scarcity alone, but systemic uncertainty.

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For India, these transformations carry profound strategic implications. As the world's fastest-growing major economy and the third-largest energy consumer, India's development remains deeply dependent on stable, affordable access to energy resources. India is expected to account for one of the largest shares of global energy demand growth over the next two decades, as industrialisation, urbanisation, digital infrastructure expansion, transport needs, and rising living standards continue to accelerate. The country's aspiration to become a *Viksit Bharat* by 2047 will depend substantially on the resilience and reliability of its energy systems.

Yet India's energy ecosystem is also characterised by significant external dependence on hydrocarbons, critical technologies, and maritime trade routes. The challenge for policymakers is therefore no longer confined to securing sufficient energy supplies but to constructing a resilient national energy architecture capable of functioning effectively amid prolonged geopolitical volatility.

India has already begun responding to this evolving reality through initiatives including the International Solar Alliance, the National Green Hydrogen Mission, the expansion of the strategic petroleum reserve, the Production Linked Incentive (PLI) schemes for advanced manufacturing, and the SAGAR doctrine in the maritime domain. These initiatives reflect an important strategic recognition: energy security is no longer a narrow sectoral concern but a foundational pillar of national power.

The central argument of this article is that India's energy strategy must evolve beyond conventional supply management towards a

comprehensive national resilience framework that integrates strategic storage, diversified sourcing, secure maritime logistics, technological self-reliance, and infrastructure protection. In an era increasingly defined by geopolitical fragmentation and systemic disruption, India's rise as a major power will depend significantly on its ability to build an energy architecture that is resilient, adaptive, and strategically sovereign.

India's Structural Energy Exposure

India's rise as a major economic power is inextricably linked to its expanding energy requirements. Rapid urbanisation, industrial growth, digitalisation, rising incomes, and increasing mobility continue to drive sustained growth in energy demand across sectors. According to the International Energy Agency, India is expected to account for a substantial share of global energy demand growth through 2040, reflecting both the scale of its developmental ambitions and the structural transformation of its economy. Yet this growth trajectory is accompanied by significant vulnerabilities embedded in India's energy architecture.

The most immediate challenge remains the country's heavy reliance on imported hydrocarbons. India currently imports nearly 88 percent of its crude oil requirements and more than half of its natural gas consumption. This dependence leaves the economy vulnerable to external supply shocks, price volatility, and geopolitical instability. Fluctuations in global energy markets continue to exert significant influence on inflation, fiscal balances, currency stability, and the broader macroeconomic environment.

Hydrocarbons remain central to India's transport, industrial production, petrochemicals, aviation, shipping, and fertiliser production. Even as renewable energy capacity expands rapidly, conventional fuels will continue to play a major role in India's energy mix for the foreseeable future. The challenge for India is therefore not the immediate replacement of hydrocarbons, but managing a calibrated, secure transition towards a more diversified energy architecture.

India's strategic vulnerability extends beyond import dependence. A substantial share of India's energy imports passes through some of the world's most strategically sensitive maritime chokepoints, including the Strait of Hormuz, the Bab-el-Mandeb Strait, and the Strait of Malacca. These sea lanes are critical arteries linking India to energy producers in the Gulf region, Africa, and other global suppliers. Any disruption arising from military conflict, regional instability, piracy, terrorism, or great-power confrontation could trigger cascading economic and strategic consequences.

The Strait of Hormuz is particularly important for India's energy security. A major share of India's crude imports originates from Gulf producers, whose exports transit through this narrow corridor. Escalating tensions in West Asia therefore have direct implications for India's energy flows and economic stability. Similarly, recent disruptions in the Red Sea region have demonstrated how geographically distant conflicts can significantly alter shipping costs, insurance premiums, transit times, and supply chain reliability.

The Strait of Malacca presents another critical strategic dimension. As one of the world's busiest maritime passages linking the Indian Ocean to East

Asian markets, Malacca is not merely a commercial route but a geopolitical chokepoint vulnerable to strategic competition and naval contestation. Importantly, India's exposure extends beyond fossil fuels. The ongoing energy transition is creating new forms of strategic dependence on critical minerals, battery technologies, semiconductor systems, advanced grid infrastructure, and renewable energy supply chains. While renewable energy expansion may reduce exposure to hydrocarbon volatility over time, it also introduces fresh vulnerabilities linked to the concentration of supply chains for lithium, cobalt, rare earth elements, solar modules, and advanced batteries.

India has made significant progress in deploying renewable energy and now ranks among the world's leading renewable energy producers. Installed renewable capacity has expanded rapidly, driven by large-scale solar and wind deployment, supported by ambitious policy initiatives and international climate commitments. Programmes such as the National Solar Mission, Green Energy Corridors, and the National Green Hydrogen Mission reflect India's determination to position itself as a major player in the emerging clean-energy economy.

However, the transition also exposes India to substantial technological dependence. A large share of solar manufacturing supply chains, battery processing capacity, and critical mineral refining remains concentrated in a small number of countries. In this sense, the energy transition does not eliminate geopolitical risk; rather, it redistributes and transforms it. India's structural vulnerability therefore lies not in any single dependency, but in

the cumulative exposure of its energy ecosystem to external shocks across fuel supply, maritime logistics, technology infrastructure, critical minerals, and strategic trade routes. Addressing this exposure requires moving beyond conventional supply-centric approaches towards a broader framework of systemic resilience.

From Supply Security to Systemic Resilience

The evolving geopolitical landscape demands a fundamental rethink of how energy security is conceptualised. For decades, energy policy across much of the world was guided by assumptions rooted in globalisation, market integration, and efficiency. The primary objective was to secure reliable supplies at competitive prices through diversified imports and interconnected markets. In this framework, resilience was often treated as secondary to efficiency, while redundancy was viewed as economically inefficient.

The cumulative disruptions of recent years have exposed the limitations of this approach. The COVID-19 pandemic disrupted global manufacturing and logistics on an unprecedented scale. The Russia–Ukraine conflict demonstrated how energy exports could be weaponised during geopolitical confrontation. Red Sea disruptions highlighted the vulnerability of maritime logistics to regional instability, while energy shortages in several economies revealed the risks of excessive dependence on concentrated supply systems.

The central lesson from these crises is clear: highly optimised systems may also become highly fragile. As a result, the strategic emphasis is gradually shifting from supply security alone to

systemic resilience. Supply security focuses primarily on ensuring access to energy resources. Systemic resilience, by contrast, concerns the ability of an entire energy ecosystem to anticipate, withstand, adapt to, and recover from disruption without severe economic or strategic dislocation.

Resilience requires moving beyond linear procurement models towards integrated frameworks that incorporate redundancy, flexibility, storage capacity, diversified supply chains, infrastructure protection, and institutional preparedness. In practical terms, this means recognising that disruptions are no longer exceptional but recurring structural features of the contemporary geopolitical environment. For India, adopting a resilience-oriented approach is especially important given the scale and complexity of its development ambitions. The country's future economic growth will depend not only on expanding energy availability but also on ensuring that its energy architecture remains stable amid external volatility.

India has already taken several measures reflecting this shift towards resilience-oriented planning. The development of strategic petroleum reserves, the One Nation One Grid initiative, Green Energy Corridors, smart-grid modernisation, and efforts to expand domestic manufacturing under the Atmanirbhar Bharat framework are important steps towards reducing structural vulnerability. A resilience-based framework also requires closer integration between energy policy and broader national-security planning. Maritime strategy, industrial policy, cybersecurity, technological capability, climate adaptation, and financial regulation can no longer be treated as separate

domains operating independently of energy planning.

Consequently, the future of energy security lies not merely in securing greater volumes of energy, but in building systems that can function reliably amid uncertainty. In an era defined by geopolitical competition and systemic disruption, resilience, rather than efficiency alone, is emerging as the defining metric of strategic preparedness.

Strategic Storage as Geopolitical Insurance

Among the various instruments available to strengthen energy resilience, strategic storage capacity holds a uniquely important position. Traditionally viewed as emergency backup infrastructure, strategic reserves are increasingly recognised as core components of geopolitical preparedness and economic stability. India's strategic petroleum reserve programme reflects an important recognition of this reality. The country currently maintains strategic crude oil storage facilities at Visakhapatnam, Mangaluru, and Padur, with further expansion plans under consideration. These reserves provide a critical buffer against sudden supply disruptions arising from geopolitical conflict, shipping disruptions, or severe price volatility.

The strategic significance of reserves extends beyond immediate supply protection. Countries with substantial storage capacity are often better placed to navigate geopolitical crises with greater confidence and lower exposure to short-term market volatility. Strategic reserves create time — and in geopolitical crises, time itself becomes a strategic resource. For India, the strategic logic of

storage must now move beyond crude oil alone. The changing energy landscape requires a broader conception of storage infrastructure, encompassing natural gas reserves, LNG storage facilities, electricity-balancing systems, and grid-scale battery infrastructure.

Battery Energy Storage Systems, pumped hydro storage, and smart-grid balancing infrastructure are likely to play a particularly important role in strengthening resilience to geopolitical and climate-related disruptions. India's renewable-energy expansion targets cannot be achieved sustainably without corresponding investments in storage and transmission infrastructure capable of maintaining grid stability during fluctuations in generation patterns. The National Green Hydrogen Mission further reflects India's recognition that future energy resilience will depend on diversified storage and energy-carrier capabilities. Green hydrogen has the potential to serve as both a clean industrial fuel and a long-duration energy-storage medium, supporting sectors that are difficult to electrify directly.

Importantly, strategic storage has significant financial and institutional implications. Developing large-scale reserve capacity requires long-term capital investment, sophisticated infrastructure planning, and coordinated public-private participation. Unlike purely commercial infrastructure, strategic storage often delivers benefits that are not immediately reflected in short-term market pricing. Its value is most evident during periods of crisis, when reserve capacity can stabilise markets, preserve economic continuity, and enhance policy flexibility. India's future energy strategy must therefore treat storage infrastructure

not as a peripheral contingency measure but as a central pillar of national preparedness.

Diversification Beyond Suppliers

Diversification has long occupied a central place in energy-security planning. Traditionally, however, diversification was understood primarily in narrow geographic terms — reducing dependence on any single supplier or region. While supplier diversification remains important, the emerging geopolitical and technological environment requires a far broader understanding of diversification.

India has already demonstrated considerable strategic flexibility in adjusting its hydrocarbon procurement patterns in response to evolving geopolitical realities. The expansion of discounted crude imports from Russia following Western sanctions, continued engagement with Gulf producers such as Saudi Arabia and the United Arab Emirates, growing energy cooperation with the United States, and expanding ties with African suppliers collectively reflect a pragmatic strategy to maintain supply stability while preserving strategic autonomy.

This flexible approach has reinforced India's broader doctrine of strategic multi-alignment — maintaining productive relations across competing geopolitical blocs without becoming overly dependent on any single power centre. However, supplier diversification alone cannot eliminate systemic vulnerability. India's long-term energy architecture will likely depend on a carefully balanced mix of hydrocarbons, renewables, nuclear power, natural gas, biofuels, hydrogen systems, and emerging low-carbon technologies. Within this

framework, nuclear energy holds a particularly important strategic position. Unlike intermittent renewable sources, nuclear power provides stable baseload electricity generation essential for industrial growth, grid stability, and long-term decarbonisation.

India's nuclear programme also exemplifies one of the country's strongest instances of indigenous technological capability and long-term strategic planning. India has developed considerable expertise in Pressurised Heavy Water Reactor (PHWR) technology, reactor engineering, and nuclear fuel-cycle management. Civil nuclear cooperation agreements with countries such as the United States, France, and Russia have strengthened both energy security and broader strategic partnerships.

India's three-stage nuclear programme, originally conceived by Dr Homi Bhabha, was designed to reduce long-term external dependence by leveraging the country's substantial thorium reserves. This long-term strategic vision continues to distinguish India's nuclear approach from those of many other developing economies. As India expands renewable energy capacity, nuclear energy is likely to become increasingly important for addressing intermittency challenges and ensuring reliable, low-carbon power generation.

Emerging technologies such as Small Modular Reactors (SMRs) may further strengthen India's long-term energy resilience by enabling more flexible deployment, reducing land requirements, and improving integration with industrial clusters and decentralised energy systems. In this sense, nuclear energy should not be seen as opposed to

renewables, but as a complementary pillar within a diversified and resilient energy architecture.

India's ethanol-blending programme has expanded significantly over the past decade, reducing dependence on imported fuel and supporting agricultural incomes and rural economic activity. Similarly, India's ambitious renewable-energy targets aim to diversify the national energy mix and reduce long-term carbon intensity. The International Solar Alliance, launched jointly by India and France, is another important dimension of India's strategic energy diplomacy. Beyond climate considerations, the ISA reflects India's aspiration to shape emerging global energy governance frameworks.

At the same time, the energy transition introduces a new set of strategic dependencies. Renewable-energy systems rely heavily on concentrated supply chains for solar modules, advanced batteries, semiconductors, and critical minerals such as lithium, cobalt, nickel, and rare earth elements. Recognising this challenge, India has begun to expand efforts to secure critical mineral supply chains through initiatives such as KABIL, overseas mineral partnerships, and cooperation agreements with countries including Australia and several African states. Simultaneously, Production Linked Incentive schemes and Atmanirbhar Bharat initiatives aim to strengthen domestic manufacturing capabilities in solar equipment, battery systems, semiconductors, and advanced clean-energy technologies. Ultimately, resilience emerges not from isolation, but from the ability to operate flexibly across multiple supply networks, technological systems, and geopolitical relationships.

Maritime Security and the Geopolitics of Energy Flows

Energy security and maritime security have become increasingly inseparable. For a country such as India, whose economic growth and industrial expansion depend heavily on seaborne energy imports, the stability of maritime trade routes is a foundational element of national resilience. The Indian Ocean region holds a uniquely significant position within the global energy system. India's energy supply chains are deeply embedded in maritime chokepoints such as the Strait of Hormuz, the Bab-el-Mandeb Strait, and the Strait of Malacca.

Recent disruptions around the Red Sea demonstrated how regional conflicts can trigger cascading effects across global supply chains. Attacks on commercial shipping, rerouting of maritime traffic, and rising insurance costs significantly affected freight economics and transit reliability. Consequently, maritime security can no longer be viewed as a peripheral naval concern, detached from economic planning. Sea-lane protection has become a core economic-security imperative.

India has already begun responding to these realities through expanded maritime engagement across the Indian Ocean region. The SAGAR doctrine — Security and Growth for All in the Region — reflects India's recognition that maritime stability is essential to long-term regional and economic security. India's participation in the Quad has further strengthened maritime cooperation in areas such as maritime domain awareness, logistics coordination, and infrastructure resilience. The Information Fusion Centre–Indian Ocean Region

is another important institutional mechanism to improve maritime surveillance and information-sharing across the region.

The Andaman and Nicobar Command also holds growing strategic significance given its proximity to the Strait of Malacca and the wider Indo-Pacific sea lanes. In this context, India's energy map is ultimately a maritime map.

Cybersecurity and Grid Vulnerability

The modernisation of energy systems is increasingly transforming energy infrastructure into digital infrastructure. Smart grids, automated transmission systems, AI-enabled load management, smart metering, and interconnected industrial control systems are rapidly becoming central to modern energy architecture. While these technologies significantly improve efficiency and reliability, they also introduce new categories of strategic vulnerability.

In the twenty-first century, future energy conflicts may target data systems and digital infrastructure as much as pipelines, ports, or refineries. Energy infrastructure worldwide has become increasingly vulnerable to cyberattacks, ransomware, espionage campaigns, and state-sponsored digital disruption. Power grids and transmission networks rely heavily on digital systems that could be targeted during periods of geopolitical confrontation.

In India, the risks are becoming increasingly significant as the country rapidly expands and digitises its energy ecosystem. Smart-grid modernisation and renewable-energy integration are essential to improving efficiency and expanding electricity access. However, greater connectivity

also increases the attack surface available to hostile actors.

The 2020 Mumbai power outage sparked a wider debate about the strategic vulnerability of digitally connected infrastructure and underscored the need to strengthen cybersecurity preparedness across critical sectors. Consequently, cybersecurity must now be treated as a core pillar of energy resilience rather than a narrow technical concern. Protecting critical energy infrastructure requires a comprehensive framework that integrates cyber defence, institutional coordination, technological redundancy, and domestic capability development. The future of energy security will depend as much on securing networks and data systems as on securing physical energy supplies.

Financing Energy Resilience

Building resilient energy systems at the scale required for India's long-term economic transformation will require enormous and sustained capital investment. Expanding strategic storage capacity, modernising electricity grids, strengthening transmission infrastructure, securing maritime logistics networks, scaling renewable generation, and enhancing domestic manufacturing capability together constitute one of the largest infrastructure challenges of the coming decades. The contemporary financing environment, however, is becoming increasingly complex. Geopolitical risk, supply-chain uncertainty, and the growing politicisation of trade and investment flows are reshaping global capital markets.

For India, this presents both opportunities and challenges. While India continues to attract substantial global investment interest owing to its

long-term growth prospects, resilience-oriented infrastructure often entails high upfront costs and extended investment horizons. Public investment will therefore remain essential. Governments are uniquely positioned to finance long-duration infrastructure projects with national security implications. At the same time, public resources alone will not be sufficient to finance the scale of transformation required.

India has already begun developing key financing mechanisms in this direction. Sovereign green bonds, the National Infrastructure Pipeline, GIFT City initiatives, and the expansion of green-finance frameworks reflect efforts to position India as a major destination for long-term infrastructure capital. Blended finance models that combine sovereign guarantees with private investment may be particularly important for projects involving strategic infrastructure and emerging technologies. Importantly, resilience financing should not be seen merely as defensive expenditure. Investments in resilient energy systems yield broader economic benefits by enhancing industrial stability, reducing supply volatility, improving investor confidence, and increasing macroeconomic predictability.

Conclusion

The international energy landscape is undergoing a structural transformation. The assumptions that shaped the era of globalisation — stable supply chains, predictable markets, and efficiency-driven optimisation — are being replaced by a far more uncertain geopolitical environment characterised by fragmentation, strategic competition, technological rivalry, and recurring disruptions across interconnected

systems. In this world, energy security can no longer be understood merely as the uninterrupted availability of fuel at affordable prices. It has become inseparable from broader questions of national resilience, strategic autonomy, industrial capability, technological sovereignty, maritime preparedness, and geopolitical flexibility.

For India, this transformation carries profound implications. As a rapidly expanding economy with rising industrial demand, urbanisation pressures, technological ambitions, and developmental aspirations, India's future trajectory will depend fundamentally on the resilience and reliability of its energy systems. The central challenge for policymakers is therefore not merely securing additional energy supplies, but constructing systems capable of functioning reliably under conditions of prolonged disruption and strategic uncertainty. This requires moving beyond traditional supply-centric approaches towards a broader, resilience-oriented framework built on strategic storage, diversified sourcing, secure maritime logistics, cyber resilience, domestic technological capability, adaptive infrastructure, nuclear stability, and integrated institutional coordination.

India's response must consequently be multidimensional. Expanding strategic reserves, strengthening naval capabilities, securing access to critical minerals, modernising electricity infrastructure, protecting digital systems, mobilising long-term resilience finance, and strengthening domestic manufacturing ecosystems must all form part of a coherent national strategy. The broader lesson from recent crises is clear: nations with resilient systems enjoy greater strategic flexibility

during periods of instability. Countries able to absorb shocks without severe economic dislocation are better placed to preserve policy autonomy, maintain industrial continuity, and navigate geopolitical competition.

For India, energy security must therefore evolve from a sectoral policy objective into a central pillar of national strategy. The future balance of global power may increasingly depend not only on access to resources but also on the capacity of states to sustain resilient economic and infrastructure systems amid prolonged uncertainty. India's aspiration to become a *Viksit Bharat* by 2047 will ultimately depend not only on the scale

of its growth but also on the resilience of the systems that sustain that growth.

In that sense, building energy resilience is not merely about protecting economic growth. It is about securing India's long-term strategic autonomy in an era when energy, technology, infrastructure, and geopolitics are becoming inseparable dimensions of national power. India's future energy architecture must therefore integrate renewables, nuclear stability, resilient grids, secure maritime logistics, strategic storage, and technological self-reliance into an integrated framework capable of sustaining national power in an increasingly uncertain world order.

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India's Energy Transition Goals in South Asia

Anmol Mukhia*

1. Introduction

South Asia is a region with the world's fastest-growing economy and vast human capital, both of which underpin notable economic progress. However, economic growth remains dependent on fossil fuels such as coal, oil and natural gas, which continue to dominate power generation. According to an Economic and Social Commission for Asia and the Pacific (ESCAP) blog post¹, in 2023, South Asian countries relied heavily on fossil fuels, with coal accounting for about 67 per cent of total energy sources.

Energy demand is highly uncertain, driven by rapid income growth, urbanisation, industrialisation, access to energy, climate change, and technological change. Moreover, international events such as the Pandemic, the Russia-Ukraine War, and the Iran-Israel War have at times highlighted the developing world's vulnerability to energy security risks. However, South Asia also has significant untapped potential in renewable energy sources, including hydropower, biomass, solar, and wind. These renewable sources are crucial for enabling economic development, meeting growing energy demand, and extending modern energy services even in remote mountainous regions.

Since the Paris Agreement, the urgency of the environmental crisis has prompted South Asian countries to commit to decarbonising their economies by setting their nationally determined contributions (NDCs). The transition to clean

energy is critical to limiting emissions and strengthening regional energy security. In this context, India's NDC for 2031-35 marks a major milestone in the journey towards a low-carbon and climate-resilient future. Since achieving certain first goals in 2015, India updated its NDC in 2022, setting a target to reduce emissions intensity from 33-35 per cent of GDP to 45 per cent by 2030 (from 2005 levels). On 25 March 2026, India further announced that it would reduce its GDP emissions intensity by 47 per cent below 2005 levels by 2035. As of 28 February 2026, India's non-fossil-fuel-based electricity power installed capacity was 52.57 per cent of the total installed capacity, demonstrating achievement of one of the goals ahead of the five-year committed timeline.²

This paper is broadly divided into two parts. Part I illustrates the dynamics of energy dilemmas, and Part II discusses India's goal of transitioning from non-renewable to renewable sources.

2. The Dynamics of Energy Dilemmas

Energy is the foundation of our daily lives, and ensuring its security, production, and distribution under government regulation is one of the most significant challenges today. The International Energy Agency (IEA) defines renewable energy as derived from natural processes that are constantly replenished, such as solar, wind, biomass, geothermal, hydropower, ocean resources, tide and wave energy, and biofuels, as well as electricity

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and hydrogen derived from those renewable resources.³

In a society where energy consumption is crucial for economic development, urban expansion, and technological advancement, energy is the backbone of state development and government capability. It is a daily requirement for social welfare in industrial development. This energy, sometimes linked to geopolitics, has become complex, polycentric, and volatile, with strategic location, source, and control becoming crucial. India's approach to climate change is also based on energy security and sustainable development. Thus, the energy dilemma posed by geopolitics and climate change balances the urgent need to phase out fossil fuels against the new geopolitical vulnerabilities of the green transition.

2.1 Energy Linked to Geopolitics

Energy is directly or indirectly linked to geopolitics. According to Qin and Gao⁴, geopolitical and energy security risks are closely related, as political conditions, military conflicts, and diplomacy create market instability that disrupts energy supply networks. Great power competition over access to strategic locations and natural resources is a well-known phenomenon. Geopolitical literature provides ample evidence of the role of spatial geography, such as chokepoints, resource-based regions, and connectivity, all of which are crucial in determining who holds power and who dictates.

In the past, the British Raj was known for employing access denial against its adversaries, such as the Russians and the French. In the present context, examples include the Russia-Ukraine war since 2022, which has spiked energy prices across

Europe and doubled fertiliser prices. In 2026, the closure of the Strait of Hormuz has driven oil prices above USD 100 and gas prices above USD 4.60 in America. Moreover, disruptions at the world's critical chokepoints have led to geopolitical instability. This all underscores the urgency of 'self-reliance' (in the Indian context, *Aatmanirbhar Bharat*) in energy development and sustainability.

2.2 Energy Linked to Climate Change

In the second context, we can't ignore the growing debate over energy consumption and climate change in academic and policy forums. This is because the production and consumption of energy is responsible for "75 per cent of greenhouse gas emissions, making it the primary driver of climate change".⁵ Saini et al.⁶ further demonstrate that climate change is primarily driven by carbon emissions and deforestation, which, in turn, lead to the environmental problems we face today. In this scenario, the South Asian region is seen as vulnerable to climate change impacts, with severe floods, droughts, cyclones, and extreme heatwaves posing risks to its growth trajectory, infrastructure development, and people's livelihoods. According to the World Bank⁷, in its "South Asia Climate Roadmap" report, the region faces acute climate risks, and its population heavily depends on monsoon-fed agriculture and rapid urbanisation.

The India Meteorological Department (IMD) report shows that in recent years, weather conditions have been characterised by heavy rainfall and strong winds. Major Indian cities such as Delhi, Mumbai, Bengaluru, and Chennai are facing an increasing risk of urban flooding due to

changing climate patterns, unplanned urbanisation, and inadequate drainage systems.⁸ One of the IAEA reports on “Nuclear Data” highlights that melting glaciers in the Himalayas are affecting water, food, and energy security.⁹

Recurring heatwaves are another concern, with India, Pakistan, and Bangladesh experiencing temperatures of 40-50 degrees Celsius.¹⁰ Recently, the IMD has issued orange alerts for heatwave conditions in Delhi.¹¹ The International Energy Agency’s (IEA) Net Zero Roadmap sets out a mid-century net-zero emissions pathway for the global energy sector to fulfil the Paris Agreement’s goal of limiting global warming to 1.5°C. As a signatory to the agreement, India has advanced its decarbonisation efforts through its nationally determined contributions (NDCs), climate finance, and green bond frameworks, and has scaled up non-fossil fuel power generation to reduce its carbon-emission intensity.

3. India’s Energy Transition Goals

India’s energy transition began in the 1970s in response to the global oil crisis and culminated in the creation of the “Department of Non-Conventional Energy Sources” (DNES) in 1982.¹² In 1992, DNES was renamed the “Ministry of Non-conventional Energy Sources” .¹³ In October 2006, it was renamed again as the “Ministry of New and Renewable Energy” .¹⁴ The primary focus was on ‘energy security,’ with increased emphasis on the share of clean power, its availability and accessibility, affordability, and equity.

In response to India’s proactive engagement on ‘climate change,’ policies such as the National

Action Plan on Climate Change (NAPCC) were established in 2008. NAPCC identified eight core missions, including the National Solar Mission, which supports India’s push towards an energy transition. In 2015, India became a founding member and host nation of the International Solar Alliance (ISA) to promote solar energy as a sustainable solution for ‘energy access’ and ‘climate change’ mitigation. This was when India intended to sign the Paris Agreement, demonstrating a proactive approach to climate governance.

India’s energy needs are expected to grow by 2 to 2.5 times by 2047 to meet rising developmental priorities. India’s energy demand was 1074 Mtoe in 2023 and is expected to rise to 1921 Mtoe by 2040.¹⁵ Achieving Net Zero by 2070 requires an orderly transition with a greater share of non-fossil fuels and increased energy efficiency.¹⁶ India’s advancing energy transition is reflected in solar capacity reaching 90.76 GW, while wind energy capacity stood at 47.36 GW. Table 1 shows that India crossed the 250 GW milestone in non-fossil power installed capacity in August 2025, the highest-ever renewable energy capacity added in a single year. This indicates that India’s low-carbon future, strong policies, innovation, and immediate action will be key to South Asia’s energy transition.

3.1 Net Zero 2070

India’s long-term energy security goal aligns with its net-zero target. At COP26 in November 2021, India announced its target to achieve net-zero by 2070. In line with Paragraph 19 of Article 4 of the Paris Agreement, India’s long-term low-carbon development strategy has been submitted

Table 1. Cumulative non-fossil installed (in GW) (as on 30 November 2025)

Energy Segment	Operational Capacity	Capacity Under Implementation	Capacity Tendered	Projected Total Capacity
Solar Power	132.85	69.12	35.46	237.43
Wind Power	53.99	30.11	1.8	85.9
Bio Energy	11.61	—	—	11.61
Small Hydro	5.16	0.44	—	5.6
Hybrid RE Systems	—	59.24	11.48	70.72
Renewable Energy Sub-Total	203.61	158.91	48.74	411.26
Large Hydro	50.35	25.33	—	75.68
Total Renewable Energy Capacity	253.96	184.24	48.74	486.94
Nuclear Power	8.78	6.6	7	22.38
Grand Total: Non-Fossil Fuel Capacity	262.74	190.84	55.74	509.32

Source: PIB (Dec. 29, 2025). “Marks Highest-Ever Renewable Energy Expansion in India’s Energy Transition Journey,” Ministry of New and Renewable Energy, Government of India.

to the UNFCCC, reaffirming its goal of achieving net-zero by 2070.¹⁷ India’s long-term low-carbon development strategy is based on the principles of equity and climate justice, as well as the principle of Common but Differentiated Responsibilities and Respective Capabilities.

Several initiatives have been taken to reach this goal. “The Ministry of Environment, Forest and Climate Change launched the National Clean Air Programme (NCAP) in January 2019 to improve air quality in 131 cities across 24 States/

UTs by engaging all stakeholders”.¹⁸ By 2025-26, the programme had successfully reduced Particulate Matter 10 (PM 10) concentrations by up to 40 per cent or achieved the National Ambient Air Quality Standards for PM 10. Several monitoring portals are in place, and measures have been taken to improve data quality. For example, PRANA is used to monitor the implementation of NCAP, and under Swachh Vayu Survekshan 2022, the self-assessment reports of NCAP cities are evaluated. “Sustainable Alternative Towards

Affordable Transportation” (SATAT) is another notable initiative to set up a Compressed Bio-Gas production plant and make it available in the market for use as automotive fuel.

3.2 Clean Energy Pathways

India intends to strengthen its energy system through policy reforms, infrastructure expansion, and a range of cleaner energy pathways. This includes clean policies such as the National Green Hydrogen Mission, the PM Surya Ghar, Muft Bijli Yojana rooftop solar scheme, and the Carbon Credit Certificate Regulations, which aim to attract investment, shorten project timelines, and ensure a reliable energy supply. The clean energy transition and low-carbon pathways are therefore central to balancing energy security, economic growth, and climate objectives.¹⁹ Coal remains a primary energy source worldwide, and India is the second-largest consumer.

Chaturvedi²⁰ adds that coal-based power generation must peak by 2040 and then decline by 99 per cent between 2040 and 2060. The “*India’s Energy Transition*” report shows that the higher cost of coal power makes renewable energy more competitive.²¹ Since people’s livelihoods and revenue depend on coal mining in states like Jharkhand, Chhattisgarh, and Odisha, the government should support workers’ retraining for alternative industries to ensure a fair transition.

3.3 Hydropower Trade

Hydropower in South Asia plays a crucial role in meeting the region’s growing energy demand. This region is characterised by a diverse river landscape, and harnessing hydropower

development potential can help meet its increasing energy needs and reduce reliance on fossil fuels. Earlier energy trade in South Asia was limited to India and Bhutan, India and Nepal, or India and Bangladesh. In the early 1960s or 1970s, hydropower accounted for a relatively high share of total electricity demand in South Asia.²² In 1980, India’s share was 30 per cent, falling to 13 per cent by 1990. In Nepal, hydropower has been a primary source of electricity generation since 1990.²³ Timilsina²⁴ asserts that hydropower has an absolute advantage, with a comparative advantage arising from countries’ monthly or seasonal load profiles. For example, electricity demand is higher during June-October in Bangladesh and August-October in India. From April to July, India’s load curve shows declining electricity demand, while Bangladesh’s demand is increasing, suggesting India could supply electricity to Bangladesh during this period.

Recently, the first trilateral power transition from Nepal to Bangladesh via the Indian Grid was inaugurated on 15 November 2024, demonstrating the potential for regional electricity sharing.²⁵ Since 15 June 2025, Nepal has begun exporting 40 megawatts (MW) of electricity to Bangladesh via India’s transmission network, marking a shift beyond bilateral electricity trade. This cross-border electricity trade has been a historic development that not only positions India as an epicentre but also as a medium or transit for regional development.

3.4 Green Bonds

Climate finance is equally important for a smooth transition to energy security. Green bonds are debt securities issued for climate-compatible

projects and are regulated by the Green Bond Principles (GBP). The GBP was established in 2014 under the guidance of the International Capital Market Association.²⁶ The Paris Agreement recognised the role of private capital in the transition towards sustainability and supported the development of green bond markets. According to World Bank data from Bloomberg, “USD 21 billion in green bonds were issued in India, of which the private sector accounted for 84 per cent” .²⁷

In 2022, “Greenko, one of the largest private sector issuers of green bonds in India, raised USD 750 million through international green bond issuance” .²⁸ These bonds were deployed in public sector projects that help reduce the economy’s carbon intensity through renewable energy, energy efficiency, and clean transport. Since April 2024, India has permitted eligible foreign investors in the International Financial Services Centre to invest in the Sovereign Green Bonds. To do so, foreign investors must be registered with the Securities and Exchange Board of India, thereby further enhancing international participation in India’s climate finance.

3.5 EVs Facilitator

In South Asia, India is often seen as the region’s epicentre. This is due to its geographic position and cultural connections with larger nations, linking both land and sea states. However, India is also a transit point, a destination, and a source for many in the South Asian market, including for jobs and education. India’s connectivity with South Asian nations will enable the region to serve as a facilitator. For example, owing to net-zero targets, the transportation industry is gradually entering a

new era of electric vehicle (EV) manufacturing. According to the World Economic Forum²⁹, EVs are set to change everything about how energy is consumed and supplied. By 2040, more than half of the new cars sold worldwide will be EVs.

The National Electric Mobility Mission Plan (NEMMP) 2020 was introduced by the Government of India to promote and produce EVs for a cleaner, greener transport future. Previously, the FAME India Scheme (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) was implemented from 2015 to 2019, encouraging the adoption of electric and hybrid vehicles.³⁰ Now, the PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM-E DRIVE), approved in September 2024 and implemented until March 2028, focuses on curbing emissions and tackling urban air quality. Apart from two- and three-wheelers, e-trucks, and e-ambulances, the schemes have supported 14,028 electric buses as of July 2025.³¹

A scenario in which India becomes a global hub for EV manufacturing could meet the entire demand of the South Asian market.³² Bhutan’s move towards green transport, together with Nepal’s connectivity to India, and the inclusion of Bangladesh, could rejuvenate the aspirations of the sub-regional The BBIN (Bangladesh, Bhutan, India and Nepal) group now has only three partners (Bangladesh, India and Nepal). This market extends further into Southeast Asia through BIMSTEC (Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation), where India’s energy transition in the product-based market can serve as a model for the region. India’s connectivity projects, such as the Trilateral

Highways, need environmental guarantees to ensure the use of sustainable energy and environmentally friendly infrastructure and transport, thereby supporting the SDGs. The World Economic Forum³³ asserts that a sustainable transport system offers greater diversity in the fuel portfolio, reduces dependence on fossil-based sources, lowers the cost of ownership, and increases price stability, thereby fostering national security, energy independence, and a healthier environment.

3.6 International Solar Alliance

Technically, Indian foreign policy is set in a more partnership-based framework, but the International Solar Alliance (ISA) is the only platform where India calls for joining an ‘alliance.’ ISA’s founding vision, “One World, One Sun, One Grid,” was advanced by PM Modi and announced at COP21 in Paris. ISA has launched several platforms to work with beyond the South Asian region. It was first designed to serve 121 countries lying in the sun between the Tropics of Cancer and Capricorn. The ISA flagship goal is to attract USD 1 trillion in investment and add 1000 GW of additional solar capacity across member states by 2030.³⁴

The SUNRISE (Solar Upcycling Network for Recycling, Innovation & Stakeholder Engagement) connects government, industry and innovators to work in the fields of solar waste, green employment and sustainable resource management.³⁵ Other initiatives, such as the “One Sun One World Grid programme,” seek regional solar interconnections along vertical lines linking East Asia-South Asia, South Asia-Middle East, Middle East-Europe and Europe-Africa.³⁶ Notably, ministers and heads of

delegation from Small Island Developing States (SIDS) signed a Memorandum of Understanding (MoU) for procurement under the SIDS platform. This was jointly developed by the ISA and the World Bank Group to advance energy deployment through coordinated procurement, digital integration and capacity building to enhance energy resilience.³⁷

4. Conclusion

India continues to play a leadership role in the energy transition by improving energy security while aligning with its climate governance and development agendas. Energy is inherently linked to geopolitics and climate change, as it aligns with geopolitical agendas and development goals. India is a major player in both, linking its geography to proactive governance.

India’s neighbourhood-first agenda, the Act East connectivity policy, its Sagarmala ports, etc., all play a crucial role in geopolitics, defining partnerships, corridors, and connectivity for energy sharing and governance. India sets its clean energy targets by focusing on non-fossil-fuel electricity generation capacity. The major focus is on reducing emissions intensity and achieving net-zero by 2070.

The major push is a transition involving the expansion of solar and wind power, EV adoption in transport, and improvements in energy efficiency across geographies. At the same time, India’s energy transition seeks to balance climate goals with development needs. Here, coal remains pivotal in meeting the country’s growing electricity demand, especially amid urbanisation, but it is expected to be gradually phased out in the long run. Lastly, India’s policy implementation,

supported by continued international partnerships, climate finance, and technological innovation, becomes essential to its futuristic energy transition goals.

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India's Nuclear Moment: Leveraging Thorium and Global Uranium Ties Under a New Legal Framework

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A New Dawn

In a landmark achievement for India's nuclear energy programme, the 500 MWe Prototype Fast Breeder Reactor (PFBR) achieved criticality on 6th April 2026 at 08:25 PM. This marked a quantum leap in the use of nuclear energy for power generation. With this milestone, India advanced to the second stage of its three-stage nuclear programme, as enunciated by Dr Homi Jehangir Bhabha in 1954, using indigenous nuclear technology. It is a matter of satisfaction that it met all the stipulations of the Atomic Energy Regulatory Board (AERB), which had issued clearance after a rigorous review of the safety of the plant systems. Fast Breeder Reactor (FBR) technology serves as a vital bridge between the current fleet of pressurised heavy water reactors (PHWRs) and the future deployment of thorium-based reactors, leveraging the country's abundant thorium resources for long-term clean energy generation. In terms of plant details, the technology development and design of PFBR were carried out indigenously by the Indira Gandhi Centre for Atomic Research (IGCAR), an R&D Centre of the Department of Atomic Energy (DAE), and it was built and commissioned by Bharatiya Nabhikiya Vidyut Nigam Ltd (BHAVINI), a PSU under the DAE.

FBRs are a cornerstone of India's long-term nuclear strategy. In these reactors, Uranium-Plutonium Mixed Oxide (MOX) serves as fuel. The PFBR core is surrounded by a blanket of Uranium-238. Fast neutrons convert fertile Uranium-238 into fissile Plutonium-239, enabling the reactor to produce more fuel than it consumes. The reactor is designed to eventually use Thorium-232 in the blanket. Through transmutation, Thorium-232 will be converted into Uranium-233, which will fuel the third stage of India's nuclear power programme.

This unique capability significantly improves the utilisation of nuclear fuel resources and enables the country to extract far more energy from its limited uranium reserves while preparing for large-scale thorium use in the future. Beyond energy generation, the FBR programme strengthens strategic capabilities in nuclear fuel-cycle technologies, advanced materials, reactor physics, and large-scale engineering. The knowledge and infrastructure developed through this programme will support future reactor designs and next-generation nuclear technologies. As India continues to expand its clean energy portfolio, fast breeder reactors will play a crucial role in delivering reliable, low-carbon, base-load power with higher thermal efficiency. Achieving first criticality thus represents

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not only a technological milestone but also a major step towards a sustainable and self-reliant energy future for Viksit Bharat.

The reactor incorporates advanced safety systems, high-temperature liquid-sodium coolant technology, and a closed fuel cycle that enables the recycling of nuclear materials, thereby improving sustainability and reducing waste.

Introduction

Energy is the driver of a society's growth, and energy security means the uninterrupted availability of energy at an affordable cost. India suffers from what can be referred to as TQQ syndrome.¹ The energy needs of Indian industry are met by oil and gas and are increasingly shifting toward renewables, primarily solar. The current crisis of logistics chain disruption from the Middle East (M-E) has affected India because, firstly, the rates of crude and gas in the international market have gone through the roof², and secondly, India is the world's third-largest importer of crude oil, the fourth-largest consumer of LNG, and the second-largest consumer of LPG. Approximately 45% of India's crude oil, 60% of its natural gas, and over 90% of its LPG imports originate from the M-E. India also depends substantially on imports for solar cells, though India has built a solar module manufacturing capacity of nearly 200 GW annually. However, its solar cell manufacturing capacity is only around 30 GW³.

The rising import bill has prompted India to pursue electric vehicles, but lithium is central to India's energy transition, as it powers lithium-ion batteries used in electric vehicles, grid-scale storage systems and renewable energy integration.

However, India is entirely import-dependent for lithium, with supplies concentrated among a limited set of countries and subject to price volatility and global market shifts⁴. This excessive dependence on energy imports has weakened the INR and led to India being overtaken by Britain and Japan in terms of GDP. Thus, there is a need to leverage indigenous resources through indigenous technologies and innovative systems, which can help India achieve not only 'Energy Security' but also 'Energy Independence'.

The advantages of nuclear energy lie in the fact that, first, India's nuclear energy programme is substantially indigenous, especially in the first stage of the three-stage programme, and second, the conversion of nuclear energy is environmentally pollution-free⁵. There are challenges in terms of the capital cost of construction, its gestation period, the availability of fuel, which is captive to nuclear supplier group countries⁶, and restrictions imposed by the provisions of the Non-Proliferation Treaty-1968 on a country like India, which has not signed the treaty⁷.

However, over time, India has resolved issues with technology and fuel supply. Following India's first nuclear test in 1974, Western countries that had been the source of technology for India denied it, as part of a coercive policy to force India to sign the NPT. India did not succumb to their pressure and, over time, developed its own PHWR technology to exploit indigenous low-grade uranium to produce energy in a limited manner⁸ and to protect the availability of indigenous uranium. After the signing of the 123 agreement in 2008, the nuclear fuel supply finally normalised⁹. Today, NPCIL is operating 24 commercial nuclear power

reactors with an installed capacity of 8780 MW.

The reactor fleet comprises two Boiling Water Reactors (BWRs), 20 Pressurised Heavy Water Reactors (PHWRs) (excluding RAPS-1), and two VVER (light-water) reactors, each with a capacity of 1000 MW. NPCIL has 7 more reactors under construction, with a total capacity of 6800 MW¹⁰. With the vision of producing about 100 GW of power using nuclear energy by 2047, the requirement for uranium is likely to rise manyfold. India currently consumes about 1,500–2,000 tonnes of uranium each year. In 2025, the country's requirement was about 1,884 tonnes. With the expansion of nuclear

power, annual uranium demand is likely to rise to about 5,400 tonnes. However, India imports about 70% of its uranium requirements, mainly from Canada, Kazakhstan, Uzbekistan and Russia, because Indian uranium is of low-grade, with concentrations ranging from 0.02% to 0.45%, compared with the global average of 1–2%.

Because of the poor ore quality, extracting uranium in India is more expensive than importing it¹¹. However, indigenous uranium remains relevant, as it is used for India's nuclear weapons programme, which is not under IAEA safeguards. Major deposits in India are located in Jharkhand

Table-1

Ser No	Place	Type	Capacity	Remark
Under Construction				
a.	Kudankulam, Tamil Nadu (KKNPP Unit:3-6),	Light Water Reactor	4X1000 MW	i. In collaboration with Russia. ii. Overall, India is collaborating with 18 countries
b.	Rawatbhata Rajasthan (RAPS 7&8)	PHWR	2X700 MW	
c.	Gorakhpur Haryana (GHAVP Unit 1-2)	-do-	2X700 MW = 1400 MW	
d.	Total:		6800 MW	
Sanctioned and Under Planning				
	10 Plants of 700 MW Capacity at Gorakhpur, Kaiga, Chutka and Mahi Banswara	-do-	7000MW	Planned date of completion - 2032

(26%), Andhra Pradesh and Telangana (49%), and Meghalaya (9%), with the remainder in other states. The total uranium ore in India is estimated at 4.3 lakh tons. In view of the limited availability and lower quality of indigenous uranium, India is likely to remain vulnerable to geopolitical pressures, as is being experienced now in the case of oil and gas, and will continue to face such pressures in the future. Therefore, India needs to look beyond uranium in the nuclear energy route to strengthen the country's energy security. This makes graduation to 'Stage-2' of the 'Three Stage Nuclear Programme' at the earliest.

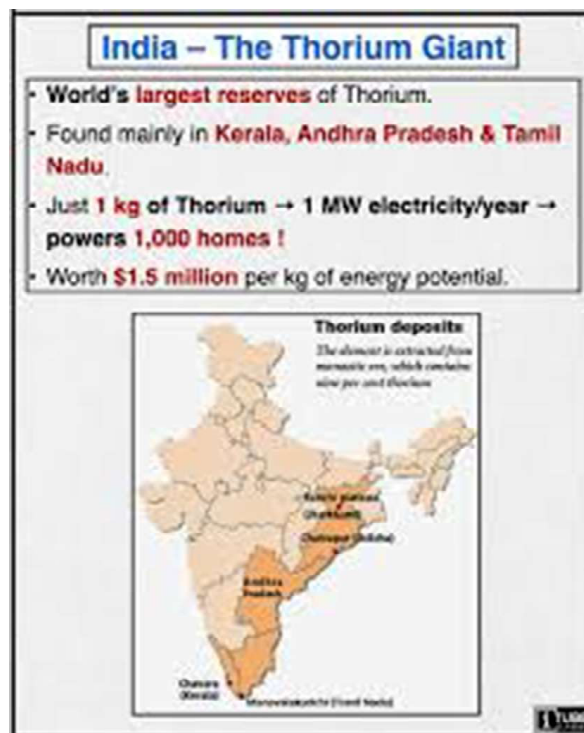
Efforts Being Taken for Nuclear Energy Conversion

A number of steps are being taken to optimise resources and effort to enhance the contribution of nuclear energy to India's energy basket. Important steps are as follows:

1. Establishment of New Nuclear Power Plants. These are based on uranium technology and include those under construction or in planning¹².

2. Exploitation of Indigenous Resources. India holds approximately 25% of the world's thorium. The country's total in-situ resources are estimated at 11.93 million tonnes of monazite, which contains roughly 1.07 million tonnes of thorium. The geographical breakdown of this resource is as follows: Andhra Pradesh (31%), Tamil Nadu (20%), Odisha (20%), Kerala (16%), and West Bengal & Jharkhand (smaller inland placer deposits). The beach sands of Kerala and Odisha contain monazite sand with 8-10% thorium¹³. However, using thorium as a fuel is

Map-1: Thorium Availability in India



more difficult than using uranium because it requires breeding,¹⁴ which is not cost-effective, whereas global uranium prices remain constant. However, thorium's material sovereignty tilts the balance in its favour.

3. Fast Breeder Test Reactor (FBTR). India's endeavour to develop a breeder reactor began in 1969, when the DAE entered into a collaboration with the French Atomic Energy Commission to obtain the design of the RAPSODIE test reactor and the steam-generator-based design of the PHENIX reactor, which was under construction at that time. The reactor designs were significantly modified by Indian engineers for the construction of the FBTR, designed to produce 40 MW of thermal power and 13.2 MW of electrical power. Also, BARC and IGCAR developed an

alternative mixed-carbide fuel that provided even better breeding and thermal properties¹⁵. Finally, the FBTR attained first criticality in October 1985¹⁶. It was an indigenously manufactured reactor¹⁷. With this reactor achieving criticality, India joined the USA, the UK, France, Germany, and the former Soviet Union as one of the few nations to build and operate a breeder reactor.

4. Kalpakkam Mini Reactor (KAMINI).

Jointly designed and built by BARC and IGCAR, this 30 MW research reactor achieved first criticality in 1996 and was named KAMINI¹⁸. It holds the distinction of being the world's first and the only reactor designed specifically to use Uranium-233 fuel, making it a pioneering facility in thorium-based fuel-cycle research¹⁹.

5. PFBR. Experience from FBTR operations fed directly into the design of a commercial-scale fast-breeding reactor, known as the PFBR, with a capacity of 500 MWe. In 2003, a separate public-sector utility, BHAVINI, was established to build and operate PFBR and future fast-breeder power reactors, though responsibility for design, R&D, and technical support remained with IGCAR²⁰. Construction of the PFBR began in 2004. By 2010, IGCAR had added new experimental and pilot-scale facilities covering the entire fast-reactor fuel cycle. By 2024, a Compact Reprocessing Facility (CORAL) and a demonstration fast-reactor fuel reprocessing plant had been developed to handle high-burn-up FBTR fuel²¹. In 2025, the United States lifted its decades-old restrictions on IGCAR, facilitating energy cooperation between the two nations²². Finally, PFBR attained criticality on 06 Apr 2026. It is an opportunity to review the direction that India's nuclear energy programme needs to

take. Should India remain committed to graduating to Stage-II, or should it pursue a more practical and economical approach based on traditional uranium-based technologies? In the short run, the ease of availability suggests that India needs to adopt a less expensive route for the exploitation of nuclear energy. However, keeping in view the experience of current geopolitical developments, it would be prudent to identify an optimal path, which entails continuing to invest in PHWRs/LWRs as a short- to medium-term goal and continuing to work on the closed fuel cycle to enhance its efficiency and effectiveness, with a view to aligning its growth with the Nation's mission to achieve 'Net Zero' emissions by 2070 as a long-term goal²³.

6. Small Modular Reactors (SMRs). As defined by the IAEA,²⁴ SMRs are advanced nuclear reactors with a power capacity of up to 300 MW(e) per unit, which is about one-third of the generating capacity of traditional nuclear power reactors. These reactors produce a large amount of low-carbon electricity. They differ in that they are only a fraction of the size of a conventional nuclear power reactor; their parts are modular, so their systems and components can be factory-assembled and transported as a unit for installation; and they use nuclear fission to generate heat and produce energy. Given their smaller footprint, SMRs can be sited in locations not suitable for larger nuclear power plants. Prefabricated SMR units can be manufactured, shipped, and installed on site, making them more affordable to build than large power reactors, which are often custom-designed for a particular location and can lead to construction delays. SMRs offer cost savings and

shorter construction times, and they can be deployed incrementally to meet increasing energy demand. Micro reactors (producing up to 10 MWe) have smaller footprints than other SMRs and will be better suited for regions that lack access to clean, reliable, and affordable energy (in the Indian context, they will be highly suitable for our border areas). The safety concept for SMRs often relies more on passive systems and the reactor's inherent safety characteristics, such as low power and operating pressure. SMRs have reduced fuel requirements. They may require less frequent refuelling, every 3 to 7 years, compared with 1 to 2 years for conventional plants. Some SMRs are designed to operate for up to 30 years without refuelling. As of date, more than 80 commercial SMR designs are being developed worldwide, targeting various outputs and applications, such as electricity, hybrid energy systems, heating, water desalination, and steam for industrial applications. Though SMRs have lower upfront capital costs per unit, their economic competitiveness remains to be proven in practice once they are deployed.

7. Indigenous SMRs²⁵. The concept design of the Bharat Small Modular Reactor (BSMR)-200MWe is an indigenously developed SMR, the result of a collaborative effort between BARC and NPCIL. It is based on Pressurised Water Reactor (PWR) technology and incorporates passive and engineered safety features²⁶. The BSMR model is slated to utilise Slightly Enriched Uranium (SEU) as fuel. Detailed engineering for BSMR is underway, with the demonstration unit expected to be erected and started up within six years of financial approval, followed by commissioning and regular operation in the seventh year, at an

estimated cost of Rs 5,700 crores²⁷. It is an example of indigenous development, with private nuclear vendors delivering various equipment and components. The SMR-55MWe is also modelled on PWR technology, featuring a block-type, highly modular design. The lead twin reactor units are planned for installation at the DAE site by 2033. The objective of the SMR-55MWe, once developed, is to deploy it in remote locations. Plans are in place to involve the Indian industry so that the required equipment for the SMR-55MWe will be produced domestically. Further, the DAE site plans to build a demonstration plant for a 5 MWth High-Temperature Gas-Cooled Reactor (HTGCR) for hydrogen production. This reactor will be coupled with suitable copper-chlorine (Cu-Cl) and iodine-sulphur (I-S) processes to generate hydrogen at 650°C, a clean fuel²⁸. These two thermochemical processes have been developed and demonstrated at BARC. Apart from these models, the government is likely to deploy 220 MW Bharat Small Reactors (BSR). India has achieved commercial maturity in indigenous Pressurised Heavy Water Reactor (PHWR) technology, which will serve as a strong foundation for advancing the country's goals of developing and deploying small reactors.

Legal Framework for Involvement of Civilian Industry in India²⁹

On 15 December 2025, the Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Bill, 2025, was introduced in Parliament, signalling a decisive shift in India's nuclear energy governance framework. With the President's assent on 20 December 2025,

the SHANTI Bill became an Act of Parliament. It substitutes the Atomic Energy Act (AEA), 1962 and the Civil Liability for Nuclear Damage Act (CLNDA), 2010.

The Act broadens the category of entities eligible to apply for a nuclear licence to ‘build, own, operate and decommission nuclear power plants or reactors’, without diluting the Central Government’s control over all strategically sensitive domains, including fissile material accounting, enrichment, isotopic separation and retaining control over sensitive activities such as spent fuel reprocessing and strategic waste management³⁰. The involvement of private firms will help mobilise large-scale financial resources, reducing the burden on public finances while accelerating project execution through greater efficiency. It may also contribute to technological innovation by leveraging global partnerships.

The international nuclear liability law³¹ establishes a two-tier compensation mechanism. First, liability is strictly and exclusively channelled to the nuclear operator³². Second, if national compensation is insufficient to satisfy all claims for nuclear damage, supplementary compensation is provided through an international fund, with contributions from contracting parties in accordance with a fixed formula. The CLNDA 2010 had departed from international norms by introducing an expansive right of recourse against suppliers. These provisions created legal uncertainty and discouraged foreign suppliers. The SHANTI Act has aligned India’s nuclear liability regime with established international CSC practice while preserving robust victim compensation through a government-backed mechanism.

Long-Term Mission for Exploitation of Nuclear Energy³³

The Nuclear Energy Mission (NEM), mentioned in the Union Budget of 2025–26, set the objective of 100 GW of nuclear power generation capacity by 2047. The mission also supports India’s broader goal of achieving net zero carbon emissions by 2070.

The following measures have been put in place to drive this vision:-

- Financial Commitment: The NEM allocates Rs 20,000 crore towards the design, development, and deployment of SMRs, signalling a serious long-term investment in indigenous nuclear technology.
- SMRs: Operationalisation of at least five indigenously designed SMRs by 2033.
- BARC Initiatives: Development of next-generation reactor designs, including the 200 MWe Bharat Small Modular Reactor (BSMR-200), the 55 MWe SMR-55, and a High-Temperature Gas-Cooled Reactor of up to 5 MWth (Megawatt thermal) designed for hydrogen generation.
- SHANTI Act, 2025: Already enacted.

Conclusion

The NEM is pursuing a vision of an energy-secure India, in which nuclear energy plays an important part in ultimately achieving energy sovereignty. The attainment of PFBR criticality is a positive step, but much more is needed in policy formulation, adequate funding, and institutional and industrial support for research, development, and manufacturing to achieve the avowed goal of a self-reliant and energy-independent India.

Endnotes:

- 1 *TQQ Syndrome refers to a Technology, Quality and Quantity problem. The resources which India has are either qualitatively poor, like coal, or quantitatively scarce, like petroleum and uranium. Where India is still short of technology, such as Thorium, solar panel and wafer technology, we have plenty of resources. We have end-to-end technology for the exploitation of petroleum products and uranium, but we are short of resources.*
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- 8 *Ibid.*
- 9 Rakesh Sood, “India and the NSG: Unfinished Business,” Observer Research Foundation, 25 July 2016, <https://www.orfonline.org/research/india-and-the-nsg-unfinished-business>.
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- 14 *Breeding is done in a reactor which is fuelled with uranium 238 and Thorium-232. After reaction extra neutrons are produced which are absorbed by the fertile material to transmute into fissile material which can undergo fission reaction.*
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- 16 “IGC Newsletter,” vol. 62 (October 2004), Indira Gandhi Centre for Atomic Research, <https://web.archive.org/web/20150924033217/http://www.igcar.ernet.in/lis/nl62/igc62.pdf>.
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 - 26 “Lok Sabha Unstarred Question No. 2264,” Department of Atomic Energy, Government of India, 12 March 2025, https://sansad.in/getFile/loksabhaquestions/annex/184/AU2264_DSSTVN.pdf.
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 - 29 Niranjana Chandrashekhara Oak, “SHANTI Act and India’s Nuclear Energy Governance Framework,” *MP-IDSAs*, 17 February 2026, <https://idsa.in/publisher/issuebrief/shanti-act-and-indias-nuclear-energy-governance-framework>.
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Beyond Oil, Gas, and the Sun: Thermoelectrics and the Strategic Contours of India's Energy Security

Subash Chandra Bose Rapaka*

Introduction: The Missing Pillar

Three storylines animate contemporary energy security discourse in India. The geopolitics of oil and gas imports. Chokepoint risk to maritime supply lines (the Strait of Hormuz and the Strait of Malacca). And the rapid but import-intensive deployment of solar photovoltaics (PVs). Each of these three vectors has attracted considerable commentary, dedicated policy instruments and years of institutional capacity building. Curiously, missing from this strategic vocabulary is a resource that is local, distributed and technology-intensive: thermoelectric (TE) energy conversion and the critical minerals that enable it.

TE technology converts heat directly into electricity using solid-state semiconductor materials. Because such a device has no moving parts, it can produce electricity silently, with zero emissions and low maintenance (Figure 1). The opportunity here is not one of replacement but of monetisation. India's energy-intensive industries - steel, cement, glass, chemicals, refining - account for roughly 40% of the nation's total primary energy consumption and forfeit a significant share of that energy as waste heat.¹ Estimates place the recoverable waste heat from Indian industry at 50–83 million tonnes of oil equivalent (Mtoe) per year by 2030, with associated CO reductions of 50–100 million tonnes.² To put that in perspective,

India produced approximately 34 million tonnes of crude oil in financial year (FY) 2018–19. In other words, the waste heat India currently squanders rivals the scale of its entire domestic crude output, yet this resource appears nowhere in any national energy security strategy.

This article makes the case that thermoelectrics should have a place at India's energy security table. To that end, we establish three pillars to support that claim: 1) Industrial waste heat recovery from local sources can position thermoelectrics as a resource to reduce import dependence. 2) The critical mineral supply chain needs for TE materials (tellurium, bismuth, tin, selenium, germanium, indium, and gallium) align strongly with both India's import vulnerabilities and the National Critical Mineral Mission (NCMM). 3) Defence and aerospace applications allow TE systems to enable national-security goals directly. Taken together, these pillars provide thermoelectrics with a collective strategic justification for inclusion in India's energy security considerations.

The Waste-Heat Imperative: India's Unmapped Domestic Energy Resource

Energy security has mostly been conceptualised as an issue of external supply lines: oil from the Gulf, LNG from Qatar and Australia,

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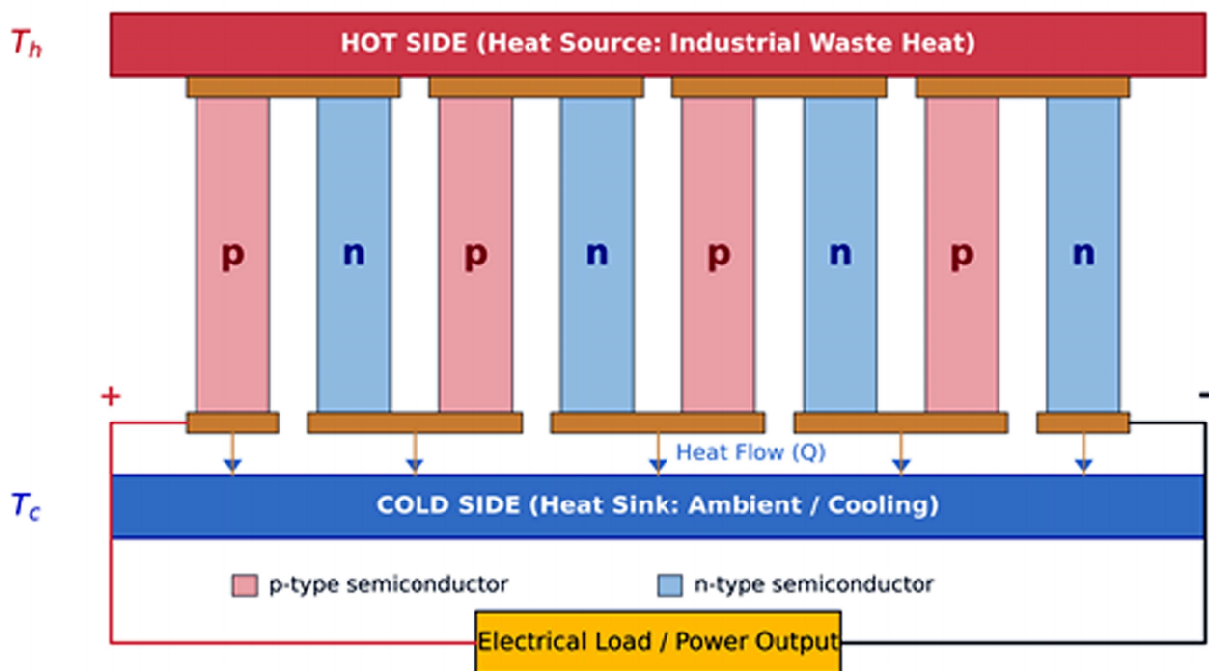


Figure 1. A TE module: a solid-state semiconductor device that converts heat directly into electricity, with no moving parts, noise, or emissions. Modules range from rigid industrial units to flexible film-based generators for wearable applications.

coal from Indonesia. Much less attention has been given to the energy we already produce and then waste at home. India’s industrial sector uses close to 40% of the country’s Gross Primary Energy Demand (GPED) and accounts for about 55% of final energy consumption.² A large proportion of that energy never reaches a productive end use – it leaks away as waste heat across a broad range of temperature grades: low-grade heat (below 200 °C) in food processing and textiles, medium-grade heat in chemical plants and refineries, and high-grade heat (above 500 °C) in cement kilns and steel blast furnaces.

Each kilowatt of waste heat we recover and convert to electricity is one less kilowatt India has to generate from imported coal or gas. One less kilowatt that has to traverse vulnerable sea lanes.

One less kilowatt of carbon we emit into the atmosphere. Converted waste heat is domestic. It’s zero imports. Waste-heat recovery essentially turns a factory-floor liability into a strategic asset. But India has no National Waste-Heat Atlas. No sector-by-geography assessment of this grand opportunity. And no policy mechanisms that treat waste heat as an energy resource equal to barrels of petroleum reserves or gigawatts of installed solar capacity.

One technology with particular ability to access this vast resource is the thermoelectric generator (TEG). Traditional waste-heat recovery options such as Organic Rankine Cycle (ORC) configurations or waste-heat boilers – while capable – require significant upfront investment, are mechanically complex, and are not easily

retrofitted into existing sites. TEGs offer a modular, scalable solution that operates quietly, requires minimal installation effort (they can be bolted to existing sites with minimal plant modifications), and can operate across large temperature gradients. Rated for service lives of decades and with no moving parts, TEGs require minimal maintenance, making them ideal for large-scale deployment across India's wide-ranging industrial landscape, including in small and medium enterprises that lack the capital required to justify a large ORC setup.³

However, the policy framework needed to drive this technology to market is not yet in place. In India, the Bureau of Energy Efficiency (BEE) runs the Perform, Achieve and Trade (PAT) scheme for energy-intensive industries. However, TE waste-heat recovery is not categorised as a distinct efficiency metric under PAT.⁴ Linking TE-based recovery to PAT credits and mandating it as part of environmental clearance for new industrial facilities would provide the policy push needed for widespread adoption.

Critical Minerals: The Supply-Chain Sovereignty Challenge

If Pillar 1 makes the demand-side case for thermoelectrics within India's energy security framework, Pillar 2 reveals the vulnerability of the supply side and, more importantly, the opportunity therein. Today's commercial TEGs are fabricated from a family of semiconductor materials based on elemental compositions most cited by geopolitical experts for supply-chain vulnerabilities: tellurium, bismuth, antimony, selenium, germanium, indium, and gallium. All seven of these elements are found on the Government of India's recent list

of 30 critical minerals published in 2023.⁵ That is no coincidence — it's because they are critical to a technology India has not yet positioned itself around, and their global supply chains are controlled by a single producing country.

The China Factor

China's dominance over key minerals needed for TE technology is almost as pronounced as its control over solar PV raw materials — remember how we said that exact vulnerability would sound familiar from our solar sovereignty discussion? India's import reliance on China for bismuth and tellurium was measured at 85.6% and 48.8%, respectively, by Takshashila Institution's 2024 report; both have been highlighted as strategic vulnerabilities in their critical minerals index.⁶ In fact, China produced 75% of the world's refined tellurium in 2024, all by itself.⁷ See Table 1 for TE-critical minerals cross-indexed with India's import reliance ratios and Chinese export control policies.

One need look no further than the evolution of those restrictions for proof. Initially targeting the gallium, germanium, and antimony supply chains in 2023-2024, Beijing's Ministry of Commerce went on to place export restrictions on tellurium, bismuth, indium, molybdenum, and tungsten on February 4, 2025 — the most aggressive mineral restrictions yet, as tensions over increased tariffs with the U.S. were flaring.⁸ The policy was further expanded twice since then, in April and October of last year, to include additional critical rare-earth elements, as well as precursor materials for lithium battery production and refining and processing methods.⁹

The IEA's Global Critical Minerals Outlook 2025 report notes that China has a structural

Table 1. India’s import dependence on China for TE-critical minerals. All seven elements appear on the Government of India’s 2023 list of 30 critical minerals. Sources: Takshashila Institution⁶, United States Geological Survey (USGS)⁷, International Energy Agency (IEA)⁸.

Mineral	Dependence on China	Role in Thermoelectrics	China Export Controls (2025)
Bismuth	85.6%	Primary TE material (Bi ₂ Te ₃ based)	Yes – Feb 2025
Tellurium	48.8%	Primary TE material (Bi ₂ Te ₃ , CdTe solar)	Yes – Feb 2025
Antimony	High	<i>p</i> -type TE alloys (Sb ₂ Te ₃)	Yes – Aug 2024
Gallium	High	Advanced TE compounds	Yes – Jul 2023
Germanium	High	High-temp SiGe systems	Yes – Jul 2023
Indium	High	Emerging TE research	Yes – Feb 2025
Selenium	Moderate	<i>n</i> -type BiTeSe	Not yet

Note: Exact import dependency percentages for Sb, Ga, Ge, and In fluctuate but are structurally classified as high vulnerability due to highly concentrated global refining capacity.

advantage over this dependence: Beijing has refining capacity for 19 of the 20 minerals assessed, with an average market share of just under 70%, and it also imposes export restrictions on more than 50% of energy-related minerals.¹⁰ The message for India, therefore, should be crystal clear: any domestic TE policy without mineral autonomy at the upstream end is not even worth considering.

Indigenous Recovery Pathways

India does, however, have options. Three domestic recovery pathways already exist at pilot

scale; all they lack is a concerted and coordinated policy push to bring them to commercial viability. The first option is copper electrorefining anode slimes. The largest share of tellurium is, in fact, recovered as a secondary by-product of copper refining operations, where it concentrates in the anode slime during electrolytic processing.⁷ In India, Hindustan Copper Limited already has refining capacity. Researchers have also successfully demonstrated the technical feasibility of recovering high-purity tellurium from Indian copper anode slime through hydrometallurgical processing.¹¹

Industrial-scale feasibility of ion-exchange technologies using Amino-Phosphonic Ion Exchange (AMPIX) resins for the selective recovery of bismuth and antimony ions from arsenic-bearing copper electrorefining wastes has also been reported.¹²

The second option is lead-refining slag. India's largest lead-zinc smelting complex, Hindustan Zinc Limited, produces a substantial volume of bismuth-bearing lead-refining slag, providing an entirely independent domestic recovery pathway.

The third is unconventional feedstocks. India's burgeoning e-waste sector will also have to be addressed at some point, with higher-tech options tailored to spent Bi_2Te_3 TE alloys, such as hydrothermal leaching or selective sulphidation.¹³ Other less conventional bismuth sources also warrant investigation: bismuth subsalicylate, a common treatment for gastrointestinal ailments, contains bismuth at 57% of the chemical's overall molecular weight.^{14,15} Leveraging this ultra-high-grade material through India's already-established biomedical waste treatment infrastructure is one of the most promising near-term circular-economy pathways; however, it remains largely unexplored.

Alignment with Existing Policies

The institutional scaffolding for these pathways already exists in part. Ownership of TE mineral policy would naturally fall to the Ministry of Mines, via its NCMM. Approved by the Union Cabinet in January 2025 with an 34,300 crore budget — 16,300 crore in corpus and 18,000 crore as projected public sector undertaking (PSU) investment — the Mission aims to scale critical mineral production by unlocking India's mining

potential across six metal categories and is slated to run through 2030–31.¹⁶ Further, its three stated verticals — domestic mining; bilateral cooperation; and urban mining — align closely with the recovery streams enumerated above. Recent policy momentum is also reflected in an announcement in the 2025–26 Union Budget of an upcoming tailings policy, which will provide a framework for mining critical minerals from mine tailings and dumps.¹⁷

All that remains is the translation of the final order — incorporating targeted production of TE-grade tellurium and bismuth into the NCMM work plan and tasking the relevant centres — Centre for Materials for Electronics Technology (C-MET), Council of Scientific and Industrial Research–National Metallurgical Laboratory (CSIR-NML), CSIR–Institute of Minerals and Materials Technology (CSIR-IMMT), among others already working with these metals at scale — with converting small-batch recovery into repeatable, scalable metallurgical processes.

Strategic and Defence Applications

Pillar 3 transitions the case for thermoelectrics from industry to national security. As noted above, those same attributes that make thermoelectrics attractive for waste-heat recovery applications — no moving parts, zero acoustic signature, zero fuel burn, low infrared signature, decades-long service lives, scalability from milliwatts to kilowatts — map cleanly onto specialised yet strategically valuable use cases peppered throughout India's defence and aerospace industries. The physics doesn't change, just the arena in which they're deployed.

Near the tactical edge, TEGs can replace batteries in remote-sensing outposts, unattended

ground sensors along the Line of Actual Control (LAC), or individual soldier electronics during deployments in Ladakh or Siachen. Indian researchers have already demonstrated flexible Bi₂Te₃-based generators suitable for wearable and on-body energy harvesting, with power densities sufficient to power a non-trivial fraction of the batteries used by foot patrols today.¹⁸ Paper-based disposable TEGs have also been prototyped, enabling lightweight energy harvesting in scenarios where fuel-burning generators are not feasible.¹⁹

At the platform level, the value proposition shifts from soldier power to machine power. Exhaust heat from tanks, naval engines, or idling diesel generators at remote outposts can be recovered and converted into electricity for communications, sensors, heating/cooling, or other loads – sparing logistics planners from having to ship and stockpile additional fuel along long supply lines, where fuel convoys are themselves a force-protection liability. Further up the technology ladder, TEGs can provide precise thermal management for satellite subsystems, sensor packages, and high-energy lasers aboard spacecraft. For deep-space missions where sunlight is too weak to power solar panels, ISRO has already identified radioisotope thermoelectric generators (RTGs) as a must-use technology.²⁰ India is far from square one here either: textured Bi-Sb-Te nanomaterials have been synthesised domestically, higher-efficiency extrinsic Bi-Te modules are technically feasible with today's tooling, and an Indian method for preparing TE nanomaterials has already been patented domestically.²¹

Institutions ready to realise these capabilities already exist at the confluence of three agencies.

MeitY for integrated semiconductor fab set-up and standards; DRDO for defence use cases and testing protocols; and ISRO for space systems and mission demand. A joint push across these three would give thermoelectrics the institutional momentum required to graduate from scientific proofs of concept to mission-deployed technologies. Defence procurement under the Defence Acquisition Procedure (DAP) 2020 in India, with its emphasis on indigenous sources, provides the policy groundwork for such a programme.²² Furthermore, by design, this would also create an at-home market for recovered tellurium and bismuth, aligning with Pillar 2's supply-chain sovereignty efforts and ensuring the recovery methodologies it describes have dedicated demand on the back end.

A Three-Pillar Policy Framework

One point that emerges from the three sections above is that TE power generation and the associated critical minerals are an underappreciated yet strategically important aspect of India's energy security, and that a coordinated policy framework is required to leverage them. Figure 2 shows such a framework, built around three pillars. Each pillar has its own policy objectives, tools, and coordinating agency, but they support each other.

Pillar 1: Industrial Waste-Heat Deployment

The objective is to position waste heat as an eligible domestic energy source and to build the policy and incentive infrastructure for TE recovery at commercial scale. This entails three prerequisites. Firstly, thermoelectric-based waste-

Three-Pillar Thermoelectric Energy Security Framework

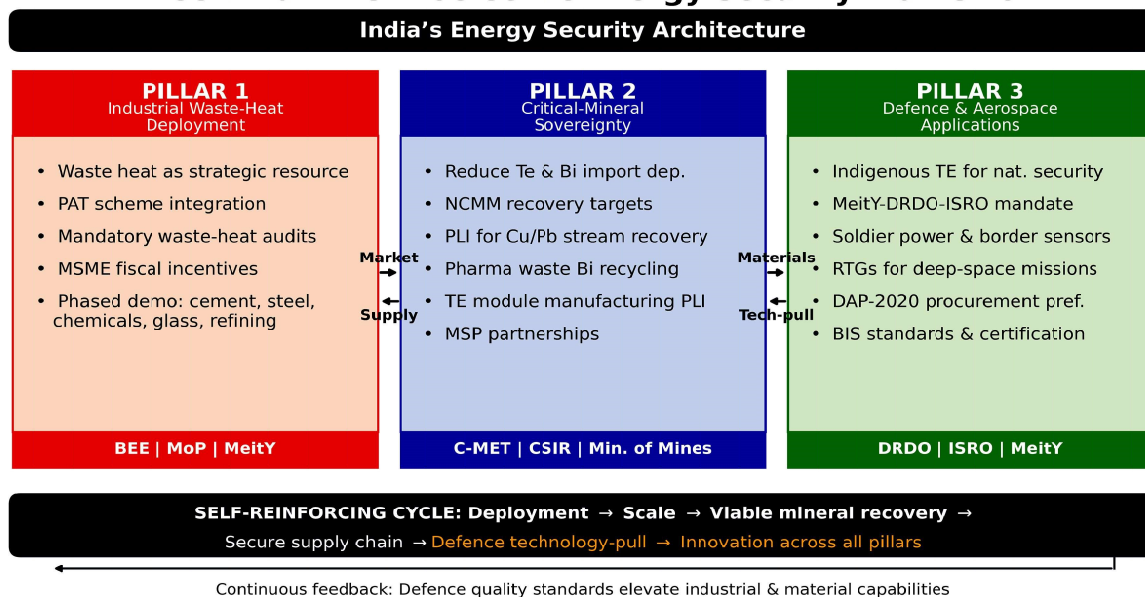


Figure 2. The three-pillar TE energy security framework: policy objectives, instruments, lead institutions, and cross-pillar synergies.

heat recovery must be subsumed within the PAT framework as an endorsed energy conservation technology, under which plants are awarded tradable credits for their TE production. Secondly, waste-heat analysis and recovery target setting must be mandated within Environmental Impact Statements (EISs) for energy-intensive industries. Thirdly, tax incentives – capital subsidies, accelerated tax depreciation, and qualification for green bonds – should be available for TEG deployment, with specific programmes focusing on Micro, Small and Medium Enterprises (MSMEs) unable to afford legacy ORC plants. Capitalising on this framework, a deadline-driven pilot programme should first be rolled out within the cement and steel industries before pursuing the chemicals, glass, refining, and food processing sectors.^{3,4}

Pillar 2: Indigenous Critical-Mineral Capability

India should aim to reduce its dependence on imported TE-critical minerals such as tellurium and bismuth by boosting domestic recovery and recycling rates and securing reliable foreign sources through partnerships. Initiatives should include setting specific targets for TE-grade tellurium and bismuth recovery within NCMM's mandate document. The expansion of the Production-Linked Incentive (PLI) scheme to include tellurium recovery from copper anode slime (produced at Hindustan Copper) and bismuth recovery from lead smelting dross (produced at Hindustan Zinc) should also be considered. Complementary investments in Research and Development (R&D) should be made to explore alternative recovery routes, such as extracting

bismuth from pharmaceutical waste streams at institutions like C-MET, CSIR-NML, and CSIR-IMMT. An individual domestic PLI scheme for TEG manufacturing can help India develop a supply chain for finished devices, which is currently absent. India should expedite its membership of the Minerals Security Partnership (MSP) on the global stage to widen access to overseas sources of critical minerals if any supply bottlenecks arise.^{12,16}

Pillar 3: Strategic Defence and Aerospace Applications

The aim is to establish domestic TE fabrication capacity in line with requirement trajectories from defence and aerospace programmes, as part of a joint mandate across multiple agencies. The lead execution vehicle is a MeitY–DRDO–ISRO Thermoelectrics Strategic Steering Committee, led by the Secretary, MeitY, which will devise a jointly owned technology roadmap. This roadmap will identify timelines (e.g. Bi₂Te₃-based low-temperature systems by 2028, PbTe-based mid-temperature systems by 2032) that are commensurate with defence domestic private sector participation (DSP) requirements from DAP 2020.²²

Interconnections and Strategic Value Multiplication

These three pillars are not independent, parallel efforts. They form an ecosystem in which each pillar creates the conditions the others need to succeed. The enormous latent value of the 83 Mtoe of recoverable industrial waste heat identified under Pillar 1 provides the market pull needed to justify building, domestically, the complex mining,

beneficiation, and refining capabilities required to produce TE-critical minerals at scale (Pillar 2). That domestic mineral capacity, in turn, insulates India's waste-heat recovery industry from the weaponised supply chains described in Section 3 — ensuring that Pillar 1's deployment ambitions are not held hostage by Chinese export controls. The strongest of these reinforcements come from Pillar 3. Defence and aerospace cannot compromise on cost or manufacturing shortcuts for the TE systems they require. Take, for example, the customised precision thermal-management modules ISRO designs for satellite subsystems. These must not only survive launch vibration, hard vacuum, and 15 years of zero-touch operation — they must do so at the smallest possible size and weight. Such stringent quality requirements drive the creation of durable, high-efficiency TEGs that — once qualified for military platforms — can then be commercialised to performance standards that help elevate the baseline for India's entire domestic manufacturing supply chain.

Overcoming Technological and Institutional Bottlenecks

The three-pillar TE vision makes sense on paper, but its execution will necessitate overcoming technical, economic, and organisational hurdles; hurdles that can each derail the effort entirely if not solved first. The technical hurdle is the most obvious. Overall system efficiency is the bottleneck to TEG deployment. Today's commercial Bi₂Te₃ TEGs convert heat to electricity with only 3–8% system-level efficiency; some jet demonstrator TEGs have performed significantly worse. These figures aren't embarrassing—they're perfectly

acceptable for low-temperature waste-heat recovery, where the alternative is none at all—but they do set qualifying criteria for any deployed R&D funding. Long-term efforts should be conditioned on meeting regular milestones in conversion efficiency. We should expect to see 5% system-level efficiency from domestically produced industrial TEGs by FY 2028. In the meantime, TEGs utilising higher-manganese silicides should be seriously considered for early disruptive deployment—if they receive equal support.

Cost issues are another hurdle. Investing in waste-heat recovery systems for existing industrial plants also carries a cost—one many facilities—especially those in the MSME range—are unwilling or unable to pay if the return on that investment takes five to seven years. That Return on Investment (ROI) could be achieved through subsidies, tax incentives such as accelerated depreciation, or soft loans, but many smaller businesses cannot afford these upgrades without such support. Not to mention the impact of imported critical minerals costs throughout the value chain, which is another reason why Pillar 2 supports sourcing minerals domestically where possible.

One of the most important hurdles may be neither technological nor economic but bureaucratic. India's road to critical-mineral self-sufficiency has been hindered by a lack of stewardship and chronic information asymmetry. The Geological Survey of India, for example, categorises mineral deposits using thresholds that are not conducive to recognising bankable reserves—marginal deposits fall under study categories that

signal low to no commercial potential. More fundamentally, ownership of the TE value chain end-to-end is split across ministries. MeitY has responsibility for electronic materials and semiconductor manufacturing; the Ministry of Mines controls the NCMM; BEE and the Ministry of Power (MoP) are responsible for industrial energy efficiency; DRDO and ISRO have the defence and aerospace mandates, respectively. All have legitimate claims on the TE agenda. But none has been given the mandate or the incentive to own it in its entirety. Absent a formal inter-ministerial coordination mechanism, such as the Thermoelectrics Strategic Steering Committee we propose under Pillar 3, agencies will continue to regard thermoelectrics as well outside their primary purview.

India has faced this type of institutional fragmentation in the past. The National Solar Mission and the Semiconductor Mission both required robust cross-ministerial architectures to cut through red tape and channel resources towards a unified vision. Thermoelectrics faces an identical structural challenge and warrants identical treatment.

Conclusion: From Laboratory to Strategy

Energy security has never been India's strong suit. Headline-grabbing debates about energy security have tended to focus on visceral, dramatic, easily visualised images: menacing oil tankers navigating the Strait of Hormuz; liquefied natural gas terminals speckling our western coastline; giant solar farms in Rajasthan. Thermoelectrics is none of these things. It is small. It is quiet. It works

behind the scenes. It will not dominate the headlines. It will not feature prominently in ministerial press briefings. But India needs thermoelectrics — badly.

At the beginning of 2023, most policymakers did not regard minerals and metals as a serious geostrategic issue. In recent months, China has upended that narrative through its careful and consistent weaponisation of critical-mineral supply chains. It began with gallium and germanium — two key minerals required for semiconductor fabrication — and has since extended to antimony, tellurium, bismuth, and rare-earth elements.²³ None of this should have come as a surprise to India: we import 85.6% of our bismuth and 48.8% of our tellurium from China.⁶ In light of China's actions, those numbers are no longer just rows in a spreadsheet. They are soft targets that India will be held hostage to in the event of a future China-India conflict.

Through industrial waste-heat harvesting, domestic critical-mineral sourcing, and targeted deployment in defence and aerospace applications,

thermoelectrics offers a path to blunt those needles while unlocking value from an otherwise stranded domestic energy source.

The policy frameworks already exist: PAT credits, the NCMM, PLI, DAP 2020. The foundational institutions already exist: C-MET, CSIR, DRDO, ISRO, BEE. Hell, the researchers already exist: Indian researchers are building flexible TEGs right now; printing fully paper-based TEGs; and patenting novel synthesis routes for next-generation TE nanomaterials.

What India lacks is awareness. Thermoelectrics needs to be recognised as an integral part of the energy security discussion in policy circles. It needs to be considered alongside oil, natural gas, and renewables — not as a substitute for any of them, but as the critical missing link in India's domestic energy stack that ties together waste-heat recovery, critical-mineral self-sufficiency, and strategic autonomy. If we do not start paying attention now, China's supremacy over these emerging supply chains will only continue to grow. There is no time like the present.

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From Volume to Value: Transforming India's Coal Endowment into Strategic Energy Security

Saptarshi Basu, Bhaskar Bhandarkar, Manish Sahu, Gopal Singh*

India is at a crucial point in its energy journey. With about 389.42 billion tonnes of coal resources, including 47.3 billion tonnes of lignite, the country ranks fifth in the world for coal reserves. It set a record by producing 1.047 billion tonnes in FY 2024-25. However, this wealth has a major weakness: India imports 85-89% of its crude oil. This dependence leaves the economy vulnerable to geopolitical events, results in annual foreign exchange outflows exceeding USD 100 billion, and creates problems for transport and petrochemical supply chains.

Sustainable coal use in India must move beyond the unrestrained growth of conventional combustion. It requires a deliberate shift towards processes such as beneficiation and washing, mine-mouth power generation, and industrial heating. Other key methods include entrained-flow gasification, Indirect Coal Liquefaction (ICL) with Fischer-Tropsch synthesis, and Coal-to-Chemicals (CTC) co-production of methanol, ammonia, urea, and DME. We also need to focus on Carbon Capture, Utilisation, and Storage (CCUS) clusters and on circular fuel substitution using alternatives such as RDF, biomass, industrial waste, and plastic thermolysis. This approach will help free up high-value coal for strategic conversion.

Key Findings from Techno-Economic and Global Analysis

The Ten-Point Problem Statement (synthesised from the prompt and validated against technical annexes):

1. **Low Coal Quality and Non-Coking Dominance:** The vast majority of reserves are thermal (non-coking) grades, unsuitable for metallurgy without blending; high moisture and variable GCV (2,500–6,500 kcal/kg) reduce combustion efficiency.
2. **High Ash and Contaminants (25–45% Ash Typical):** Renders direct combustion inefficient and polluting; increases handling, boiler maintenance, and ash disposal burdens; yet this very characteristic favours entrained-flow gasification with slagging systems, where impurities can be managed pre-combustion.
3. **Regional Underdevelopment in Coal Belts:** Jharkhand (26.4% reserves, ~83 Bt), Odisha (~25%, ~79 Bt), and Chhattisgarh (~18%, ~57 Bt) together dominate, yet these states exhibit lower HDI, higher multidimensional poverty, a history of insurgency (e.g., Left-Wing Extremism corridors), and weaker institutional capacity—creating risks of leakage, illegal mining, and social instability.

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4. **Freight Congestion and Long-Haul Inefficiency:** The majority of coal mined in the east and central belts is transported 1,000–2,000+ km to western, northern, and southern demand centres; this ties up dedicated rail capacity, inflates logistics costs, and generates dust and spillage externalities.
 5. **Petroleum Import Vulnerability:** 85–89% dependence on crude imports creates exposure to price volatility (e.g., the 2022 spikes), supplier concentration risks, and strategic chokepoints; synthetic fuels from domestic coal offer a partial but meaningful hedge.
 6. **Leakage-Prone Logistics and Governance Gaps:** Pilferage, theft, grade manipulation, and illegal extraction are estimated to account for several per cent of production; weak digital traceability and enforcement in remote mining areas.
 7. **Climate Pressure and Decarbonisation Commitments:** Coal remains indispensable in the medium term, yet India's Net Zero 2070 pledge, updated NDCs, and international scrutiny (G7, COP processes) demand measurable reductions in emission intensity; unabated CTL would be incompatible without CCUS.
 8. **Governance Fragmentation:** The coal value chain spans the Ministry of Coal (mining), Power (generation), Petroleum & Natural Gas (fuels/fertilisers), Steel (metallurgical), Chemicals & Fertilisers, Railways (logistics), Environment (clearances/CCUS), and Finance (fiscal instruments)—no single coordinating mechanism exists for integrated conversion pathways.
 9. **Underused Waste-to-Energy and Circular Substitution:** Industrial by-products (oil sludge, PET waste, paper rejects, rubber dust, biomass) offer 100–200 Mt of coal-equivalent displacement potential annually; the cement sector's Thermal Substitution Rate (TSR) averages only 5–7% (top plants 25–30%), compared with EU benchmarks of >50–100% in leading facilities; CPCB guidelines (2016/2023) exist, but enforcement and scale-up lag.
 10. **Need for Mine-Mouth Integrated Thermal and Gasification Development:** The current paradigm of raw-coal evacuation to distant end-users is economically and strategically suboptimal; pithead power, gasification, ICL, ammonia-urea, methanol, and materials clusters co-located with mines can convert low-grade coal into transportable, higher-value products while generating local employment and reducing rail burden.

These ten issues are not merely technical; they are structural and institutional. Addressing them requires a paradigm shift from volume maximisation (more tonnes mined and transported) to value maximisation (the highest strategic use of each tonne: coking for steel, washed thermal for efficient power, low-grade/high-ash for gasification/CTL/CCUS, and substitutes for substitutable industrial heat). ICL is preferred over Direct Coal Liquefaction (DCL) in India because it offers greater flexibility for handling high-ash domestic feedstock. It allows easier removal of impurities, including sulphur, mercury, and particulates. Additionally, it integrates well with pre-combustion CCUS and enables the co-production of high-value chemicals and fertilisers. Energy

efficiency ranges from 45 to 55 per cent, with a liquid yield of 1.1 to 1.3 barrels of synfuel per tonne of coal.

Regarding economies of scale, the optimal plant size ranges from 50,000 to 100,000 barrels per day (bpd). The estimated capital expenditure is between USD 6 and 9 billion, including CCUS. The breakeven oil price is between USD 70 and 100 per barrel and depends on co-product credits and carbon pricing. With CCUS, lifecycle emissions decrease from around 900 kg CO per barrel to between 250 and 350 kg CO per barrel, representing a reduction of 60 to 90 per cent. Water is a significant constraint.

The process uses 8 to 12 barrels of water for each barrel of synfuel, necessitating zero-liquid discharge (ZLD), mine-water utilisation, and closed-loop recycling as essential practices. There is considerable potential for import substitution. Large-scale deployment of ICL/CTC in the eastern and central coal belts could replace 10 to 15 per cent of oil imports by 2035, equivalent to about 35 to 50 million tonnes of crude equivalent annually. This shift can also help create strategic synthetic fuel reserves for defence, aviation, and crisis resilience.

The 2026 Fertiliser Crisis: A Frozen Price and an Exploding Bill

In April–May 2026, as the Strait of Hormuz effectively closed amid geopolitical tensions, Indian Potash Limited secured the largest urea tender in the country's history, at nearly double the price of two months earlier. Diammonium phosphate (DAP) tenders followed at record landed costs. Yet in a Vidarbha fertiliser shop, the 45-kg bag of

urea continued to sell for 242 — the same price it has been at since 1 April 2018.

India pays roughly 3,600 to land that bag at the port. The farmer pays 242. The 3,358 gap, scaled across ~35 million tonnes of annual urea consumption, is the central operating principle of Indian fertiliser policy. The result: a projected FY27 subsidy bill exceeding 2 lakh crore — the highest peacetime outgo in the instrument's history — even before the full impact of disrupted imports and domestic gas curtailments (a 25% drop in March 2026) is felt. This is not merely a fiscal problem. It is a structural vulnerability: heavy dependence on imported urea, ammonia, and natural gas feedstock, exposed to every chokepoint from Hormuz to Red Sea disruptions. The policy of absorbing every global price spike on the exchequer to protect the farmer has worked — but at mounting and ultimately unsustainable cost.

The Coal Opportunity: From Volume to Value

India holds 389 billion tonnes of coal resources, including vast high-ash thermal grades (25–45% ash) that are suboptimal for long-haul power generation but ideally suited for modern entrained-flow gasification. The May 2026 policy research paper, Sustainable Coal Application for Energy Security and Petroleum Import Substitution (Basu, Bhandarkar & Sahu), provides a rigorous techno-economic and governance framework to convert this endowment into a strategic asset — specifically for the fertiliser sector.

The core mechanism is straightforward and already proven at pilot scale in India: Coal (high-ash, mine-mouth) ! Gasification (oxygen/steam !

syngas: CO + H₂) ! Ammonia synthesis ! Urea production. This is not speculative. The Talcher Fertiliser Ltd project in Odisha (coal/petcoke gasification to urea, methanol, and SNG) is under construction and represents India's flagship demonstration. Scaling this model across mine-mouth clusters in Talcher-Ib Valley, Korba-Raigarh, and Jharia-Bokaro directly attacks the import dependence and price volatility that define the current crisis.

How Gasification Directly Solves the Four Core Problems of the 2026 Crisis

1. Import Dependence & Forex Outflow.

India's fertiliser vulnerability is largely an ammonia and urea import problem, compounded by natural gas feedstock risk. Coal gasification produces syngas domestically, enabling on-site or nearby ammonia-urea production. The coal paper quantifies that scaled ICL/CTC deployment (with co-production of ammonia/urea) can deliver meaningful substitution — reducing the need for imported merchant ammonia and finished urea. Every tonne of coal converted to urea at the mine-mouth displaces a tonne of imported urea or ammonia, directly easing the current account and insulating against Hormuz-style shocks.

2. Domestic Production Resilience. The March 2026 gas curtailment, which cut domestic urea output by 25%, would have been far less damaging if a meaningful share of ammonia synthesis had shifted to coal-derived syngas. Mine-mouth plants are not hostage to pipeline gas allocation priorities. They create a parallel, coal-based production backbone that complements gas-based plants and, over time, reduces pressure on them.

3. Long-Term Subsidy Trajectory. The current system is a ratchet: global prices rise ! subsidy bill explodes ! MRP stays frozen. Coal-based urea has a different cost structure. While initial capex for gasification and ammonia-urea complexes is high (USD 6–9+ billion for large integrated plants), marginal costs are tied to domestic coal (stable, allocated under policy) rather than to volatile imported spot urea or LNG. Over time, as more supply shifts to this controlled-cost base, the average subsidy per bag declines — even if the printed MRP remains politically frozen. The coal paper's emphasis on co-production (urea + methanol + power + chemicals) further improves project economics and reduces the net fiscal burden per unit of fertiliser output.

4. Regional Development & Political Sustainability. The fertiliser subsidy is politically untouchable because it protects 14 crore landholdings. But the coal paper adds a powerful pro-coal constituency: the coal-bearing districts of eastern and central India (Jharkhand, Odisha, Chhattisgarh). Mine-mouth clusters create formal, skilled jobs in gasification, ammonia synthesis, CCUS operations, and ancillary industries — precisely in regions with histories of underdevelopment and insurgency. A credible just-transition framework (community equity, skilling, local content) turns potential opposition into stakeholder support, making the overall policy coalition more durable than one based solely on subsidy absorption.

Policy Architecture Proposed

- Establish a National Sustainable Coal and Carbon Conversion Mission under the Cabinet

Secretariat/PMO, coordinating the Ministries of Coal, Petroleum & Natural Gas, Power, Steel, Chemicals & Fertilisers, Railways, Environment, Forest & Climate Change, and Finance.

- Create a Technical Standards Council (BHEL, CIL, GAIL, NTPC, SAIL, IOC, CIMFR, academic labs) to standardise gasifier/CTL modules, adapt to high-ash coal, and develop CCUS protocols.
- Designate integrated coal-conversion industrial regions (Talcher-Ib Valley, Korba-Raigarh, Jharia-Bokaro corridors) with fast-track clearances tied to strict environmental performance bonds.
- Deploy policy instruments: Viability Gap Funding (VGF) and concessional sovereign debt for first-of-a-kind ICL+CCUS plants; revenue-share rebates and feedstock allocation priority for gasification/CTL coal; carbon contracts for difference (CCfD) or equivalent for CCUS outperformers; mandatory ZLD, methane monitoring, and digital traceability; and freight pricing reform reflecting the full system costs of long-haul raw coal.

Phased Roadmap

Phase I (2026–2030). Establish 3 to 5 major mining clusters at the mines. These clusters will ensure that the minerals are properly processed and digitally tracked. Also, use waste materials and biomass in cement and heat production, aiming for 15 to 20% of energy to come from these sources. A technical council and a special mission will also be launched.

Phase II (2030 to 2040). Focus on establishing

carbon capture and utilisation projects across regions. This involves transporting and storing CO₂, using it for coal-bed methane recovery, storing it in saline aquifers, and converting it into minerals. Also, build networks to transport methanol, syngas and synthetic fuels. The use of these products in key sectors such as defence, railways and fertilisers could be supported by the government.

Phase III (2040 to 2050). Set carbon limits for the entire production lifecycle (less than 200 kg of CO₂ per barrel equivalent) and ensure that biomass is co-fed and that renewable hydrogen is used in production. Integrate the above with the National Hydrogen Mission and review progress going forward.

Projected Outcomes by 2035 (under supportive policy)

10–15% oil import substitution; 50–80 Mt coal redirected to high-value gasification/CTL; 200,000+ skilled jobs in coal districts; 60–90% emission intensity reduction in conversion pathways; strengthened energy sovereignty and balance-of-payments resilience.

This paper provides the evidence base, international comparative analysis, and actionable ministry-level implementation framework to transform India's coal endowment from a source of vulnerability into a strategic asset for energy security, industrial competitiveness, and an orderly transition to Net Zero 2070.

Global Benchmarks and Lessons from Leading CTL and Clean Coal Nations

India is not operating in isolation. Global experience provides both proof of concept and

cautionary lessons for CTL/CCUS deployment at scale.

China

The Shenhua Ningxia CTL Complex, the world's largest integrated facility, is located at the Ningdong Energy and Chemical Industry Base in Yinchuan, Ningxia Hui Autonomous Region (arid northwest; water-stressed context analogous to parts of India's coal belts). The scale and investment are as follows:

- Total complex: ~235,000 bpd liquid fuels (Phase I DCL ~24,000 bpd; Phases II/III ICL ~210,000 bpd).
- Coal input: >20 Mt/year. - Investment: ~USD 7.9 billion (state-backed). - Products: 2.7 Mt diesel, 0.98 Mt naphtha, 0.34 Mt LPG + by-products (sulfur, ammonium sulfate, mixed alcohols). - Efficiency: ~42% coal-to-liquids conversion.

Technology & Environmental Controls:

- Hybrid: Initial DCL (Shenhua proprietary, iron-based catalyst, 460°C/190 bar) + massive ICL (Siemens/MAN syngas coolers + Chinese HTFT).
- Zero Liquid Discharge (ZLD): Aquatech system recycles >55 million litres/day; critical for arid locations.
- CCUS Demonstration: Captures portion of concentrated process CO for EOR in nearby fields; full-scale pilots advancing. Lifecycle CO ~7.95 t/t product (base)! ~4.5 t/t (with CCS).
- Emission controls: Advanced particulate, SO_x, NO_x; vitrified slag utilised in construction.

- Economics: Breakeven USD 60–80/bbl (lower than generic estimates due to vertical integration—owns mines—economies of scale, and by-product revenue). State strategic priority overrides pure merchant economics.

Lessons for India: Scale matters: 100k+ bpd plants achieve competitive unit costs. - ICL route dominates expansion (feedstock flexibility for high-ash Chinese coals mirrors India). ZLD and CCUS are non-negotiable for social license and policy support in water-stressed, climate-conscious jurisdictions. The national energy security imperative (China imports ~70%+ of its crude) justifies sovereign financing and fast-track approvals. India's Talcher and similar projects can replicate Ningxia's integrated model (gasification + urea/methanol + future ICL liquids + CCUS).

South Africa

- Sasol Secunda is the longest-operating commercial CTL. Details are as follows:
- Capacity: ~160,000 bpd primary (gasoline, light olefins) + chemicals; multiple trains since 1977/1983.
- Technology: ICL with HTFT (high-temperature Fischer-Tropsch); iron catalysts.
- Resilience: Operated through sanctions, oil shocks, and post-apartheid transition; demonstrates 40+ year asset life with continuous optimisation.

Lessons: Co-production of chemicals/fertilisers improves economics and strategic value; catalyst and reactor R&D critical for local coal adaptation; long-term offtake agreements (synthetic fuels into transport) anchor viability.

United States and Australia: Demonstration and Niche Deployment

- US: Multiple DOE-funded pilots (H-Coal, SRC, Exxon Donor Solvent, etc.) in the 1970s–80s; recent interest in CBTL (coal-biomass-to-liquids) and CCUS integration (e.g., FutureGen, Illinois Clean Fuels). No commercial-scale CTL due to abundant domestic shale oil/gas and environmental opposition.
- Australia: Arckaringa and other proposals are being considered. These proposals focus on export-oriented projects or on mining-related projects in specific areas. There are regulations in place for water and biodiversity. Here, export-oriented projects are being prioritised, mining projects in

specific areas are being considered, and stringent regulations are in place to protect water. Biodiversity is also being protected with regulations.

- Lesson: In liberalized markets with cheap alternatives, CTL requires strong policy push (energy security premiums, carbon pricing exemptions, or defence mandates). India’s context (high import dependence, coal abundance, developmental-state capacity) is more analogous to China/South Africa’s than to the US/Australia.

International Comparative Matrix: Clean Coal Technology Adoption (2025)

India lags in scaling commercial CTL/CCUS but has policy momentum (National Coal Gasification Mission targeting 100 Mt of

Technology	India	China	USA	Australia	South Africa
Coal Washing/Beneficiation	Moderate	Extensive	Mature	Mature	Moderate
Supercritical/USC Boilers	Growing (new)	Advanced	Established	Advanced	Growing
IGCC / Gasification	Early/Pilot	Large-scale	Mature (demo)	Pilot	Commercial
CTL Implementation	Pilot/Under Construction	Commercial (235k bpd Ningxia)	Demonstration /Limited	Limited	Commercial (160k bpd Sasol)
CCUS Integration	Emerging (pilots)	Operational (EOR)	Widespread (demo)	Early stage	Emerging
ZLD/Water Management	Policy push	Advanced (Ningxia)	Strict	Strict	Moderate

gasification by 2030; 8,500 crore in incentives; Atmanirbhar Coal Mission; coal block auctions) and a technical foundation (BHEL gasifier development, CIMFR/CSIR catalyst R&D, Talcher Fertiliser project) to accelerate rapidly if governance and financing align.

Key International Takeaway: Successful large-scale CTL requires (a) sovereign or quasi-sovereign financing for first-of-a-kind plants, (b) integration with chemical/fertiliser co-production for revenue diversification, (c) mandatory CCUS/ZLD from design stage, and (d) alignment with national energy security and industrial policy—not pure market signals.

Risks, Realism, and the Path Forward

This is not a silver bullet. Large-scale coal gasification + ammonia complexes entail high upfront capital costs, high water intensity (mitigated by ZLD and mine-water use), and require rigorous CCUS to be compatible with Net Zero 2070. The coal policy should be explicit: no project receives sovereign support without carbon capture readiness, ZLD, >95% slag valorisation, and just-transition commitments. It treats coal conversion as a transitional bridge (2026–2045/50), not a permanent lock-in, with periodic reviews and sunset provisions for non-performing assets.

Yet the alternative — indefinite absorption of every global spike while domestic production remains gas-dependent and import-exposed — is the higher-risk path. The 2026 crisis has shown the limits of that approach. Coal gasification, executed intelligently at mine-mouth scale with CCUS, offers a credible route to gradually broaden the domestic production base, dampen the

transmission of price volatility, create jobs where they are most needed, and reduce the long-term fiscal load-bearing wall of the 242 bag.

Synthesising the Ten Strategic Issues into Actionable Policy Challenges

The ten issues interact across five structural domains. Policy must address them holistically rather than in silos.

1 Resource Quality and Conversion Constraint. High-ash coal, with 25 to 45 per cent ash content, does not burn well. It contains many impurities, such as sulphur, mercury, and arsenic, which make combustion inefficient. A key point to consider is that coal should be classified and allocated based on its value. The best coals, such as Steel Grade I and II and Washery I to IV coals, which are suitable for making coke, should be reserved for steelmaking. Coals such as G1 to G6, which have been washed and are suitable for electricity generation, should be used in high-efficiency power plants. Other coals, such as G7 to G17 and those with ash content, should be used to make gas or for other special processes, such as Integrated Gasification Combined Cycle (IGCC), Circulating Fluidized Bed Technology (CFBC), and Coal to Chemical (CTC), and for power generation right at the mine, with advanced systems to control emissions. Beneficiation (washing) mandates apply to all coal above G8 or allocated to distant power plants. This hierarchy is already implicit in grading systems but requires statutory enforcement and allocation linkage.

2 Geography, Poverty, Governance Deficit, and Regional Development. The coal areas in Jharkhand, Odisha, Chhattisgarh, and parts of West

Bengal and Madhya Pradesh face many problems. These coal districts experience multiple forms of poverty; the systems in place are weak, and there has been significant conflict in the past. When coal is extracted and shipped away, conditions worsen. This is what people call the “resource curse”. It means that the people in these coal districts do not receive the money they should from the coal. Instead, the money goes elsewhere. The coal districts do not get to use the coal to make things and create jobs for the people. Mine-mouth clusters (pithead power + gasification + ICL/CTC + slag valorization + shared utilities) convert extraction sites into industrial growth poles, formalising employment, improving HDI, and reducing incentives for insurgency through economic inclusion. Just-transition funds and community equity stakes (5–10% of project SPV) should be mandatory for new clusters.

3 Transport, Supply-Chain Inefficiency, and Leakage. We should generate power and heat at the coal-extraction site and use them for industry, sending any surplus power to other locations via the grid. Coal should be converted into products that can be transported through pipes, such as gas, methanol, ammonia, synthetic crude and DME, at the mine site. A group like the Coal Logistics Rationalisation Board could be established to regulate prices, so that it costs more to send coal more than 500 kilometres unless it has been upgraded and can be tracked. We should use tags and a special kind of computer system called blockchain to track the coal from the mine to where it is used, and have special paths for trains that can carry containers and tankers rather than just open cars.

4 Import Vulnerability and Strategic Exposure. 85–89% dependence on oil imports is very risky, as crises such as supply disruptions, price spikes and currency depreciation can occur. For India, dependence on oil imports will continue to be a challenge. CTL/CTC can deliver 10–15% substitution by 2035 under an aggressive but feasible rollout (3–5 large clusters + supporting gasification). This is partial but strategically significant—equivalent to 35–50 Mt crude/year, reducing current account pressure and building sovereign synthetic fuel reserves (defence, aviation, strategic petroleum reserves integration). Producing fertilisers such as ammonia and urea, along with petrochemical feedstocks such as methanol and naphtha, helps reduce the need to import them. This is beneficial for agriculture and for making plastics. By producing these things ourselves, we are less dependent on other countries for fertilisers such as ammonia and urea and for petrochemical feedstocks such as methanol and naphtha.

5 Climate Pressure, Policy Fragmentation, and the Sustainability Test. The government has a problem with fragmentation. This means that no single ministry is in charge of the project from start to finish. This causes delays in projects that need to be done. That is why we need a National Mission for the following:

- The ability to use carbon capture and storage, which is also called CCUS readiness.
- The ability to use biomass as a fuel, also called biomass-feeding pathways.
- Regular project reviews every five years. Future plans for hydrogen and renewable energy beyond 2040 and 2050.

-
- Have stringent rules to ensure pollution control, responsible water use, land restoration after the project is over, and support for the community around the project.

Conclusion

The 2026 fertiliser crisis is a symptom of a deeper design flaw: a system that treats fertiliser security as a pure consumption subsidy rather than a production and conversion challenge. The sustainable coal policy framework reframes the problem. By prioritising high-ash domestic coal for gasification and for the co-production of ammonia and urea in integrated mine-mouth clusters, India can simultaneously address energy security, petroleum import substitution, regional development, and — over time — the fiscal sustainability of the fertiliser promise itself.

India's coal debate is not about mining tonnage or power megawatts alone. It is about national resilience, industrial geography, strategic imports, environmental stewardship, state capability, and social justice. The ten-point analysis in the prompt paper, validated and expanded by the attached technical resources and international benchmarks, shows that India has both the resource scale (389.42 Bt) and the technological pathways (ICL + CCUS + co-production) to convert a portion of this endowment into synthetic fuels, chemicals, and energy-security assets—but only if policy shifts decisively from maximising raw-coal volume to sustainable value-chain transformation.

We have the opportunity to act now and make a difference. The evidence is clear. The policy architecture is ready. What remains is decisive implementation at the ministry level.



Energy Security in a World in Flux: India's Search for Strategic Redundancy

Maitri Sisodia*

प्रजासुखे सुखम् राज्ञः प्रजानां च हिते हितम्
“In the happiness of the subjects lies the ruler's
happiness; in their welfare, his welfare.”¹

Kautilya's old test of statecraft is crisp and unsentimental. It treats welfare not as benevolence but as the state's practical capacity to maintain order, livelihoods, and security when pressures mount. For twenty-first-century Bharat, energy sits at the centre of that compact. A spike in crude prices, a sanctioned payment channel, a tanker delayed by conflict, an LNG cargo diverted, or a mineral supply chain squeezed does not remain confined to ministries and markets. It enters freight rates, fertiliser costs, aviation margins, factory output, household cooking bills, and the everyday confidence of citizens. Energy insecurity, in that sense, is never only about fuel. It is about the state's ability to protect national life from external volatility.

India's energy question has therefore moved squarely into the realm of strategic autonomy. India is still building and expanding at continental scale: roads, homes, ports, industrial corridors, data centres, transport networks and manufacturing clusters. As India works towards becoming a leading global power, it must ensure an uninterrupted, sustained supply of energy. The challenge is not only to secure that energy, but also to do so without allowing every external shock to narrow national policy space. The old oil-security instinct was to diversify suppliers. That remains

necessary, but the present disorder demands a thicker cushion. Sanctions, shipping insurance, payment systems, maritime chokepoints, LNG contracts, refinery flexibility, solar equipment and critical minerals now sit within the same security conversation.

Former President A.P.J. Abdul Kalam recognised the stakes in development when he called energy independence India's "first and highest priority."² For India, energy independence cannot mean autarky in every molecule, machine and mineral. That would be economically unrealistic and strategically limiting. The more serious aim is energy autonomy through managed interdependence: using global markets where they serve India, building domestic capacity where dependence poses a strategic risk, and ensuring that no single pressure point can narrow India's strategic choices.

The evolution of the International Energy Agency reflects this widening. Founded in 1974 to ensure the security of oil supplies, the IEA's work now extends beyond oil to natural gas, electricity systems and clean-energy supply chains.³ For India, this widening is not an abstract shift in energy vocabulary. Its challenge is no longer simply to buy enough oil at a tolerable price, but to keep

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growth steady when risk can arise from crude and LNG cargoes, maritime chokepoints, refinery flexibility, power grids, solar modules, batteries and minerals. Strategic redundancy is India's answer to this condition. The goal is not to withdraw from interdependence, but to build sufficient depth across suppliers, routes, reserves, technologies and domestic capabilities so that dependence remains manageable and never hardens into vulnerability.

From Diversification to Strategic Redundancy

Daniel Yergin's warning remains relevant: "The definition of energy security needs to be expanded" to meet the pressures of a globalised world.⁴ For India, that expansion now means strategic redundancy. Diversification remains necessary because no large importer can afford excessive dependence on a single supplier, route or political region. But diversification alone is no longer sufficient when disruption can spread through sanctions, insurance, shipping routes, refinery compatibility, LNG contracts, cyber risks, grids, solar factories and mineral processing. India's task, therefore, is not merely to multiply sources of supply, but to build depth across the energy system so that a shock in one part does not become a national vulnerability.

The older idea of energy security assumed that the main danger lay at the point of supply: an embargo, a war in an oil-producing region, a cartel decision, or a sudden price spike. Countries responded by diversifying their sources of supply. That remains necessary, but it no longer captures the full nature of risk. A cargo may be available yet difficult to insure; a supplier may be willing,

but payments may be constrained; a route may remain open, yet freight costs may surge; a clean-energy target may be sound, yet modules, batteries or minerals may be concentrated elsewhere. The vulnerability, in other words, is no longer confined to the energy source. It can sit anywhere along the chain that connects energy to national life.

Strategic redundancy is the discipline that addresses this condition. It is not duplication for its own sake, nor a retreat into autarky. It is the creation of cushions across the system: alternative suppliers when a market tightens, alternative routes when a chokepoint comes under stress, reserves that buy time, flexible refineries and contracts that preserve choice, domestic capacities that reduce exposure, and institutions that can coordinate quickly when pressure builds. In ordinary commerce, redundancy may appear inefficient. In national strategy, it is what prevents dependence from becoming coercion.

Oil Diplomacy in a Sanctions-Heavy Order

Oil remains the first test of this approach because India's development story is still tied to imported hydrocarbons. PPAC data show the scale of the system that India must manage: crude oil imports stood at 245.769 million tonnes in the latest reported annual cycle.⁵ This is not a vulnerability confined to the petroleum sector. It touches freight, food inflation, aviation, fertilisers, the current account and household budgets.

The war in Ukraine gave India's oil diplomacy a sharper edge. India's purchase of discounted Russian crude was often interpreted abroad as an alignment. For New Delhi, it was also a matter of

economic responsibility. A developing economy cannot treat affordable energy as a diplomatic luxury. Its first obligation is to keep prices, mobility and industrial activity stable for its citizens. Strategic autonomy, in this context, is not a posture but the freedom to make energy choices according to national need.

However, discounted crude is not a doctrine. Replacing one dependence with another would merely shift vulnerability from one point to another. The real strength lies in optionality. India has continued to engage its traditional Gulf partners, bought from Russia when commercial and strategic conditions allowed, and broadened sourcing from other geographies. The Ministry of Petroleum and Natural Gas has noted that India now imports crude from around 40 countries, with about 70 per cent of crude imports coming through routes outside the Strait of Hormuz, compared with about 55 per cent earlier.⁶ That is strategic redundancy in practice.

This matters because oil diplomacy today is not merely a buyer-seller relationship. It encompasses crude grades, refinery configuration, freight, insurance, payment channels and domestic price management. India's refining system, with its ability to process a range of crude grades, gives the country room to respond to shifting discounts and availability. But refining capacity must be supported by maritime access and financial flexibility. In a sanctions-heavy world, crude availability is only one part of security; the real test is whether shipping, insurance, payments, refining and domestic distribution can continue without interruption.

West Asia will remain central to this equation. India's ties with Saudi Arabia, the UAE, Iraq,

Qatar and other regional partners span energy, diaspora, remittances, investment, logistics and strategic consultation. The evolving Iran-Israel-US crisis has only underlined this logic. India has kept diplomatic channels open across the region, called for de-escalation and dialogue, and remained attentive to the security of key shipping routes.⁷ The right direction is already clear: continuity with old partners, expansion of new options, and sufficient route diversity to ensure that no single region becomes a point of compulsion.

Gas and LNG: Transition Fuel Under Geopolitical Conditions

Natural gas is often described as a transition fuel. It is cleaner than coal in many applications and is important for fertilisers, city gas, industry, transport and power balancing. India has set a target to raise the share of natural gas in its energy mix from 6.7 per cent to 15 per cent by 2030.⁸ That ambition is sensible, but gas will serve India's transition only if its price, supply and infrastructure risks are carefully managed. Recent years have shown how quickly gas markets can turn unforgiving. Europe's search for alternatives to Russian pipeline gas tightened global LNG markets and affected Asian buyers. For India, which has price-sensitive consumers and industries, excessive exposure to spot LNG can be costly. Long-term contracts offer stability, but they must retain flexibility. The 20-year LNG agreement between Petronet LNG and QatarEnergy for 7.5 million tonnes per annum, beginning in 2028, reflects this search for dependable supply.⁹ Yet even long-term supply is only one part of security. India also needs sufficient terminal capacity, pipeline connectivity,

city gas expansion and pricing arrangements that allow gas to reach consumers without becoming a shock transmitter.

The movement towards a national gas grid, expanded LNG terminals, city gas distribution and policy reforms for a gas-based economy shows that India is not treating gas merely as an imported commodity.¹⁰ It is being integrated into the country's wider development system. A molecule of LNG matters only when it can be received, re-gasified, transported, priced and used in fertilisers, industry, transport or households. Gas carries its own maritime exposure. LNG may enter India through terminals on its coast, but its reliability is shaped long before it reaches them — in Gulf stability, shipping lanes, freight costs and contract terms. A disruption in West Asia can therefore affect not only crude oil but also LNG flows. Gas may be a transition fuel, but for India it is also a strategic fuel: useful only if it strengthens the energy transition without introducing a new layer of price and route vulnerability.

The Ocean as Energy Infrastructure

The Ocean is integral to India's energy infrastructure. Tankers and LNG carriers link Indian refineries, fertiliser plants, power systems and households to some of the world's most politically sensitive passages. Hormuz, Malacca, Bab el-Mandeb, Suez and the Red Sea are not merely map points. They are corridors through which energy, inflation and strategic risk travel. The Strait of Hormuz remains the most visible pressure point. EIA data show that flows through Hormuz in 2024 and the first quarter of 2025 accounted for more than one-quarter of global

seaborne oil trade and about one-fifth of global oil and petroleum-product consumption. Around one-fifth of global LNG trade also passed through Hormuz in 2024, primarily from Qatar.¹¹ The Red Sea system carries a similar warning. In the first half of 2023, the Suez Canal, SUMED pipeline and Bab el-Mandeb handled about 12 per cent of seaborne oil trade and 8 per cent of global LNG trade.¹²

These numbers matter because disruption at sea rarely stays at sea. A vessel forced to reroute incurs additional time, insurance, fuel costs and uncertainty. A delayed LNG cargo can disrupt power, fertiliser and industrial calculations. Higher freight costs can feed into domestic prices long before citizens know which passage was under stress. UNCTAD's Review of Maritime Transport 2024 notes that over 80 per cent of world trade by volume moves by sea, with chokepoints increasingly exposed to geopolitical tension, conflict and climate stress.¹³

India's response is already moving beyond the narrow idea of naval presence. Naval capacity is indispensable, but energy security at sea also rests on port resilience, maritime domain awareness, logistics partnerships, white-shipping agreements, island-state cooperation and crisis coordination. The SAGAR vision — Security and Growth for All in the Region — has given India a language for this wider role in the Indian Ocean.¹⁴ It is increasingly part of India's energy-security vocabulary.

India's interest is straightforward: sea lanes must remain open, secure and predictable. Chokepoints must not be allowed to become instruments of coercion. For India, keeping the

ocean stable is not only a maritime objective; it is also tied to development, inflation management, industrial continuity and the everyday security of households.

Strategic Reserves and Domestic Buffers

Strategic Petroleum Reserves are not merely storage facilities. They are time-buying instruments. In an energy crisis, time is strategic capital: it allows the government to arrange alternative cargoes, calm markets, support refiners, protect essential sectors and prevent uncertainty from turning into panic. India's Strategic Petroleum Reserve capacity totals 5.33 million tonnes at Visakhapatnam, Mangaluru and Padur. The government has also approved two additional commercial-cum-strategic reserves of 6.5 MMT at Chandikhol and Padur under a public-private partnership model.¹⁵ Such reserves are not intended to carry the economy through an indefinite disruption. Their value lies in the first days of pressure, when they can steady markets, protect essential sectors and give the state time to arrange alternatives.

The value of a reserve lies not only in the volume of crude it holds, but also in how well it is integrated with the wider energy system. Commercial inventories, refinery stocks, port logistics, crude grades, release protocols and demand management all matter. An emergency release is not a mechanical act; it requires judgement on timing, location, refinery compatibility and market signalling. India's move towards expanding strategic storage and adopting commercial-cum-strategic models reflects a

practical understanding of this balance: reserves must remain financially viable, but their purpose is national continuity.

Domestic buffers add a second layer of protection. India advanced its E20 target from 2030 to 2025, and the government has reported 20 per cent ethanol blending for the current Ethanol Supply Year.¹⁶ This marginally reduces exposure to petrol imports, supports rural value chains, and links farmers to the fuel economy. It is not a complete answer to energy dependence, nor should it be treated as one. Feedstock, water use and vehicle compatibility require careful management. But as part of a wider buffer, ethanol has clear strategic value.

Green hydrogen belongs to a different horizon. The National Green Hydrogen Mission, with an outlay of 19,744 crore, targets 5 million tonnes of annual green hydrogen production by 2030.¹⁷ Its promise lies in sectors that are hard to electrify directly — refining, fertilisers, steel, shipping and heavy industry. Here again, the point is not a single substitute but system depth. Efficiency is the least dramatic but most durable buffer. Better appliances, industrial energy management, building codes, public transport and logistics planning reduce import pressure without spectacle. In a turbulent world, the energy that is not wasted is ultimately the energy that doesn't have to be imported.

Solar, ISA and Clean-energy Sovereignty

India's renewable expansion is now central to its energy future. MNRE reported an installed renewable energy capacity of 220.10 GW as of 31 March 2025, within India's broader 500 GW non-fossil capacity target by 2030.¹⁸ But capacity

addition, by itself, does not settle the sovereignty question. Clean energy reduces dependence on fuel imports, but it can create new dependencies if the equipment, storage and minerals underpinning it remain concentrated elsewhere. Solar power is the clearest case. The IEA notes that China's share across all major stages of solar-panel manufacturing — polysilicon, ingots, wafers, cells and modules — exceeds 80 per cent.¹⁹ That concentration has helped reduce global costs, but it also carries strategic risk. A country that replaces imported crude with imported clean-energy hardware reduces one vulnerability while creating another.

India's response has been to deploy at scale while deepening domestic manufacturing. The Production Linked Incentive scheme for high-efficiency solar PV modules aims to create nearly 48 GW of domestic module manufacturing capacity.²⁰ The emphasis on integrated capacity matters because module assembly alone cannot secure India if cells, wafers, polysilicon and equipment remain externally dependent.

The International Solar Alliance provides India with a broader platform. Its "Towards 1000" strategy aims to mobilise USD 1 trillion in solar investment by 2030, provide energy access to 1 billion people, and install 1,000 GW of solar capacity.²¹ ISA is an instrument of development diplomacy and of Global South institution-building. The same sovereignty question now arises in critical minerals. Lithium, cobalt, nickel, graphite, copper and rare earths are central to batteries, storage, EVs, grids, wind turbines, electronics and defence

technologies. Vulnerability often lies not only in mining but also in processing and refining. A country can possess reserves and still remain dependent if it lacks the ability to process them.

The IEA's Global Critical Minerals Outlook 2025 shows the pace of change: lithium demand rose by nearly 30 per cent in 2024, while demand for nickel, cobalt, graphite and rare earths rose by 6–8 per cent.²² India's National Critical Mineral Mission, approved with an outlay of 34,300 crore over seven years, covers exploration, mining, beneficiation, processing and recovery from end-of-life products; GSI has been tasked with 1,200 exploration projects from 2024–25 to 2030–31.²³ This is precisely the whole-chain thinking the transition requires. The transition must therefore reduce old dependencies without creating new ones. For India, clean energy will become truly strategic only when deployment is matched by manufacturing depth, mineral security and control over the technologies that carry the transition.

Institutions and the Larger Doctrine

Strategic redundancy must move from phrase to practice. India's energy governance is necessarily spread across petroleum, power, renewable energy, mines, shipping, external affairs, commerce, finance, heavy industries, the environment, regulators, public-sector enterprises and state governments. Each handles part of the system; the strength lies in ensuring risk is not viewed in fragments. India's current policy direction already contains the building blocks of this approach: crude-source diversification, routes

outside Hormuz, SPR expansion, ethanol blending, green hydrogen, solar manufacturing, critical-mineral exploration, maritime cooperation and renewable deployment. These are not scattered initiatives. They show a state steadily building energy depth across fuels, technologies, routes and institutions.

The need for coordination becomes clearest during a disruption. A shipping shock can involve petroleum, shipping, finance, external affairs and ports. A critical-mineral restriction can affect mines, heavy industry, power, commerce and technology. A delay in solar equipment can disrupt renewable targets, grid planning and industrial policy. A cyberattack on port-energy logistics can quickly escalate from a technical incident to an economic concern. The point is simple: energy risk does not respect departmental boundaries. This is why risk assessment, scenario planning and stress-testing matter. Temporary pressure in Hormuz, Red Sea rerouting, LNG price spikes, refinery outages, payment-channel stress or mineral-processing restrictions are not remote possibilities for a large importing economy. Route-risk mapping, supplier concentration assessments, critical-mineral tracking, SPR release protocols and clear public communication during shocks would strengthen the direction India has already begun to pursue.

Industry and states are central to this effort. Refiners, ports, shipping firms, insurers, power producers, miners and manufacturers carry much of the operational burden. States handle land, transmission, industrial clusters, distribution-company health, mining clearances, port capacity

and local acceptance. The Union government sets the strategic direction, but energy security becomes real only when that direction moves through markets, ministries and states into everyday execution.

Conclusion: From Scale to Strategic Weight

India's rise will require more energy, even as the economy becomes more efficient. A country of India's size and ambition cannot build prosperity on fragile supply lines. It needs oil and gas for the transition period, reliable electricity for industry, clean power for climate credibility, minerals for manufacturing, and institutions that can withstand a hostile external environment. The temptation in energy debates is to seek certainty in one direction. Some speak as if hydrocarbons will remain dominant indefinitely. Others speak as if renewables will dissolve dependence by themselves. India cannot afford either simplification. It must secure oil and gas without allowing them to delay cleaner systems. It must expand renewables without creating new supply-chain captivity. It must use global markets without allowing them to become instruments of coercion.

Strategic redundancy offers a practical way through this tension. It involves building sufficient depth - in suppliers, routes, reserves, contracts, domestic capacity, transition fuels, clean technologies, minerals and institutions - to preserve national choice. As India navigates the demands of growth and the pressures of a fragmented world, energy security will be central to its journey from large economy to a leading power.

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Atmanirbhar Energy: Critical Minerals and Next-Gen Carriers in India's Transition

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Introduction

As the world accelerates the deployment of renewable energy sources and green technologies, a new form of dependency is emerging in efforts to meet net-zero goals. Critical minerals needed for green technologies and renewable energy are increasingly used as a geopolitical lever amid tensions, leading to supply chain and price disruptions. Currently, China has dominance in critical minerals, especially in processing and refining.¹ The Belt and Road Initiative (BRI) has been instrumental in helping China establish economic and diplomatic ties with mineral-rich countries, thereby enabling it to achieve dominance in processing and refining.² Chinese financial institutions have also played a key role in establishing China's dominance, particularly in processing and refining. China's ability to finance high-risk, long-term projects has evolved since the BRI, with these projects now bankrolled by state-led banks, giving China influence in resource-rich countries.³ For India, which is highly import-dependent for most critical minerals needed for its net-zero ambitions,⁴ it is essential to become atmanirbhar, i.e., self-reliant, to achieve its goal of 500 GW of clean energy by 2030 and net-zero by 2070.

Domestic Policies of India

India today stands at a critical juncture, where the energy transition needed to reduce its hydrocarbon bill risks deepening its dependence on mineral imports, as critical minerals have become the new frontiers of geopolitics. The Govt. of India launched the National Critical Mineral Mission (NCMM) in 2025 for a period of seven years, from 2024-2025 to 2030-2031, with a proposed expenditure of Rs. 16300 crore and an expected expenditure of Rs. 18000 crore by Public Sector Undertakings (PSUs) and other stakeholders⁵. There is no universal definition of what constitutes critical minerals. Countries identify critical minerals based on their importance to energy, the economy, and national security, as well as their susceptibility to supply chain disruptions and price shocks. Based on this assessment, the Govt. of India currently lists 31 minerals as critical minerals⁶.

To boost investment in the critical minerals sector, the Union Government has amended the Mines and Minerals (Development and Regulation) Act, 1957⁷ to liberalise the mining sector. The reforms simplified and expanded mineral access by allowing leaseholders to add critical minerals to existing leases at no extra cost and by removing

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sale restrictions on captive mines. This amendment aims to consolidate India's mining framework flexibly to enhance critical mineral extraction. India is also the third-largest e-waste generator,⁸ and to turn this waste into a reliable source for the critical mineral supply chain, the Government of India has enacted a Rs 1500 incentive scheme for critical mineral recycling to develop recycling capacity for the separation and production of critical minerals from secondary sources.⁹

The Government of India has also developed a policy to extract critical minerals from mine waste¹⁰ and, in principle, has approved a National Critical Mineral Stockpile, under which India will maintain a two-month stockpile of critical minerals, with private-sector involvement, to safeguard itself against supply-chain disruptions. In this year's Union Budget, the Government of India has also proposed a dedicated rare-earth corridor in Odisha, Tamil Nadu and Kerala to develop a domestic ecosystem of mining, refining and manufacturing, thereby reducing import dependence and enhancing domestic capabilities in strategic sectors. The measures taken by the government underscore the importance of critical minerals to India's development across sectors and the urgency of becoming self-reliant in this sector. However, more needs to be done for India to become self-reliant in the critical minerals needed for its energy needs.

What India Should Do

India needs to boost its exploration efforts. Although India is blessed with abundant resources, only about 20% of its geological resources have been explored¹¹. Therefore, it is essential to ramp up India's exploration capability, with significant

investments in advanced geological surveys, deep-seated mineral prospecting, and data-driven resource mapping. Mining is associated with a long gestation period, especially in metal mining, which deters investors. Research has also shown that mines take an average of 16.3 years from discovery to production, with 12.3 years of those 16.3 years spent on discovery and exploration studies.¹² Therefore, it is imperative to leverage artificial intelligence (AI), machine learning, remote sensing and geospatial technologies for exploration as well as for recovering critical minerals. Leveraging these technologies can not only help identify deposits but also analyse geospatial datasets, reduce the risk associated with early-stage exploration and ramp up the recovery process for critical minerals. These technologies also improve the lifespan of critical machinery and have played a major role in operations and management¹³. Therefore, it is imperative to adopt these technologies to deliver faster results, thereby helping attract private-sector investment.

India has engaged with both the Global North and the Global South to secure access to critical minerals. To complement domestic efforts, India has created KABIL, a joint venture (JV) between three PSUs, National Aluminium Company Ltd. (NALCO), Hindustan Copper Limited (HCL) and Mineral Exploration & Consultancy Ltd. (MECL), in the ratio of 40:30:30 for overseas mineral acquisition¹⁴. It has multiple bilateral agreements and participates in several initiatives to diversify the critical mineral sector. However, there is a need to ramp up diplomacy to secure technology transfer agreements. While access to critical minerals is important, technology transfer is equally important,

as India lags significantly in processing and refining¹⁵.

These partnerships should focus on rare earth separation technologies, battery-grade material processing, and recycling technologies. The government should allow foreign companies to set up processing and refining facilities in the country, either through joint ventures (JVs) with domestic companies or through other incentives. Special economic zones (SEZs) for critical mineral processing and refining can be leveraged to attract investment and enable technology transfer to Indian industries. There is also a need for collaboration between PSUs, private-sector companies, research institutions, and international partners to accelerate the development of the domestic mining value chain. The government has added 9 research institutions as Centres of Excellence (CoEs) to strengthen the mining value chain¹⁶. Each CoE must bring in at least two industry partners and two research and development (R&D)/academic partners¹⁷.

The Government of India recognises that developing the mining chain requires an integrated approach rather than relying solely on mining. Therefore, all stakeholders with diverse expertise must collaborate to build an integrated domestic critical mineral supply chain to achieve self-reliance and move towards net-zero by 2070. India also needs to reform its regulatory clearance processes. Clearances remain the most critical bottleneck in developing India's mineral value chain. However, under the MMDR, Part D designates critical, strategic and atomic minerals as exempt from public consultations¹⁸. However, clearances under the Environment Protection Act and the Forest Protection Act remain a hurdle, as they are

unpredictable, time-consuming and multi-layered, further extending the already long time periods associated with mining. India must develop a single-window, time-bound clearance mechanism, especially for critical mineral projects, to fast-track them. The fast-track mechanism should include environmental, tribal, water and forest clearances without adversely affecting the project, communities and the ecology.

India is currently evaluating a mix of tax support and fiscal incentives through outcome-linked programs to localise components needed for battery manufacturing for electric vehicles (EVs).¹⁹ The Ministry of Heavy Industries is running a Production Linked Incentive (PLI) scheme, namely "National Programme on Advanced Chemistry Cell (ACC) Battery Storage," with a total outlay of 18,100 crore to establish 50 GWh of domestic Advanced Chemistry Cell manufacturing capacity²⁰. However, India should also prioritise developing a battery recycling ecosystem. Battery recycling remains the quickest and one of the most cost-effective ways to reduce India's import dependence.

As India aims to have 30% of its fleets as EVs²¹, the volume of end-of-life batteries will grow; therefore, there is a need to develop a secondary supply of cobalt, nickel and lithium, which, if systematically recovered, can help in reducing import dependence, as India imports all of these critical minerals in near totality. This technology would also help insulate India from price shocks and supply chain vulnerabilities, as China currently dominates the global battery trade.²² The prioritisation of battery recycling will also help India develop capabilities in technologies such as

hydrometallurgical and recycling technologies, which will enable India to develop midstream processing, a process in which raw mineral concentrates or ores are transformed into refined or chemically enhanced products suitable for downstream manufacturing processes²³.

India lags significantly in midstream capability, and developing battery recycling would help India not only build midstream capacity but also support the adoption of circular economy principles. Despite being the third-largest producer of e-waste, India's waste sector is largely informal, leading to poor metal recovery and harming the environment, public health, and the workforce.²⁴ It is estimated that India generated around 6.2 million tonnes of e-waste; however, only 2 million tonnes is formally recycled.²⁵ For e-waste to function as a genuine source of critical minerals, it is imperative that Extended Producer Responsibility (EPR) be strengthened. Under the Circular Economy Framework, multiple waste management rules were notified, including an EPR framework related to recycling and reuse.²⁶ However, enforceability has been an issue in India because the EPR portal lacks a wide array of critical minerals needed for the energy transition.²⁷ To strengthen the EPR framework for critical mineral recovery, it is essential that the EPR portal include all 31 critical minerals. It is also important to set mineral recovery targets and provide incentives for formal recycling. These reforms and incentives can help strengthen the EPR framework and, subsequently, critical mineral recovery.

There is also a need for a dedicated financing mechanism to support early-stage, high-risk critical mineral projects, as these projects have long

gestation periods and uncertain returns. India can adopt the model of Japan, where the Japan Organization for Metals and Energy Security (JOGMEC), a Japanese government body, is tasked with collaborating with both government agencies and the private sector to secure a stable supply of mineral resources needed by Japanese industry. JOGMEC also assists Japanese companies with exploration and development by providing private equity capital and liability guarantees, supports the technical stage of early metal resource development, and carries out technological development.²⁸

India can also adopt a tax credit for mining exploration, in the lines of Canada's, under which a 15% tax credit is given to investors in junior mining and exploration²⁹ companies, making it easier for these companies to raise capital for early-stage exploration. While both models differ in their approach to government involvement, they converge on the principle that some form of state intervention in these projects is necessary, either directly or through policies. India can establish a fund that addresses the full spectrum of financial incentives needed to enhance the critical mineral value chain. There is also a need to develop ports and logistics infrastructure. Ports and logistics infrastructure are prerequisites for enabling the critical mineral value chain; however, they are underappreciated. India's port investments have been tilted towards green hydrogen and ammonia handling, with Kandla, Paradip and Tuticorin designated hubs under the National Green Hydrogen Mission (NGHM)³⁰.

No designated ports exist under NCMM. China recognised early on the importance of ports

and logistics infrastructure. Through the BRI, China has systematically invested in infrastructure linking mineral-rich regions to shipping routes, giving it easy access to minerals in Africa and Latin America. This ensures that China controls the most cost-effective routes³¹ for critical mineral supply chains, including mines, infrastructure, and finance. This, combined with China's dominance in processing and refining, gives China leverage over the global mining supply chain. Therefore, it is essential to identify ports and analyse the need for logistical infrastructure, both domestically and overseas, in the regions where India is acquiring mineral assets, so as to become self-reliant in critical minerals.

To develop an integrated critical minerals value chain, human capital is a fundamental component. India has to invest significantly in its human capital to become self-reliant in the critical minerals value chain. India has to build capacity in underground mining, ore handling, equipment operations and safety protocols. The Ministry of Mines, in coordination with the Skill Council of the Mining Sector, launched an initiative to train 5.7 million workers in mining-related activities by 2030, and the NCMM also has skill development as a component, aiming to train 10,000 workers.³² However, the skills component has to prioritise vocational training alongside technical training to develop a capable workforce in the critical mineral sector.

Developing Next-Gen Energy Carrier for Atmanirbhar Bharat and Energy Security

It is imperative for India to develop the critical mineral value chain as India aims to meet its net-zero goals, because the question is not merely about

deploying resources, but about how they are stored, transported and converted across the value chain. Therefore, it is imperative to build a model where extraction is combined with recovery, production is combined with recycling, and import substitution is coupled with the circular economy. Each of the technologies needed to meet net-zero goals has varied mineral requirements, and each of those mineral requirements will have some or other supply chain vulnerabilities. Therefore, it is important to build an effective foundation for a critical mineral supply chain. In India's context, *atmanirbharta* in critical minerals must be achieved through intelligent extraction, recycling and recovery.

India's pathway to net-zero depends on technologies such as green hydrogen, green ammonia, and advanced battery chemistries. These technologies have distinct needs, so it is essential to ensure a reliable critical mineral supply chain. For instance, green hydrogen production via electrolysis requires platinum-group metals for proton exchange membrane electrolyzers, and green ammonia synthesis at scale requires a reliable nitrogen infrastructure and energy storage capacity, which depend on lithium, cobalt, and nickel. Solid-state batteries, another crucial green technology for energy storage in both grid-scale applications and electric mobility, require lithium, manganese, and rare earth elements in volumes that India cannot produce domestically.

To develop these energy technologies at scale, India has to ensure that its critical minerals strategy and energy transition plans are not operating in silos. All the schemes, such as NCMM, NGHM and ACC PLI, must be brought under a single

coordinating framework that aligns mineral availability projections with technology deployment. Without integrating critical mineral availability and technology deployment, India risks investing heavily in manufacturing capacity that will remain constrained by critical mineral bottlenecks.

India also has to invest in indigenous R&D for next-generation battery chemistries- particularly

sodium-ion and solid-state architectures – to reduce dependence on the most geopolitically vulnerable minerals. CoEs under NCMMs have to work on alternative material pathways. Atmanirbharata in critical minerals is not a standalone objective; rather, it is the enabling condition for every net-zero ambition India has set for itself.

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Maritime Security, SLOC Vulnerabilities And India’s Maritime Goodwill Curve

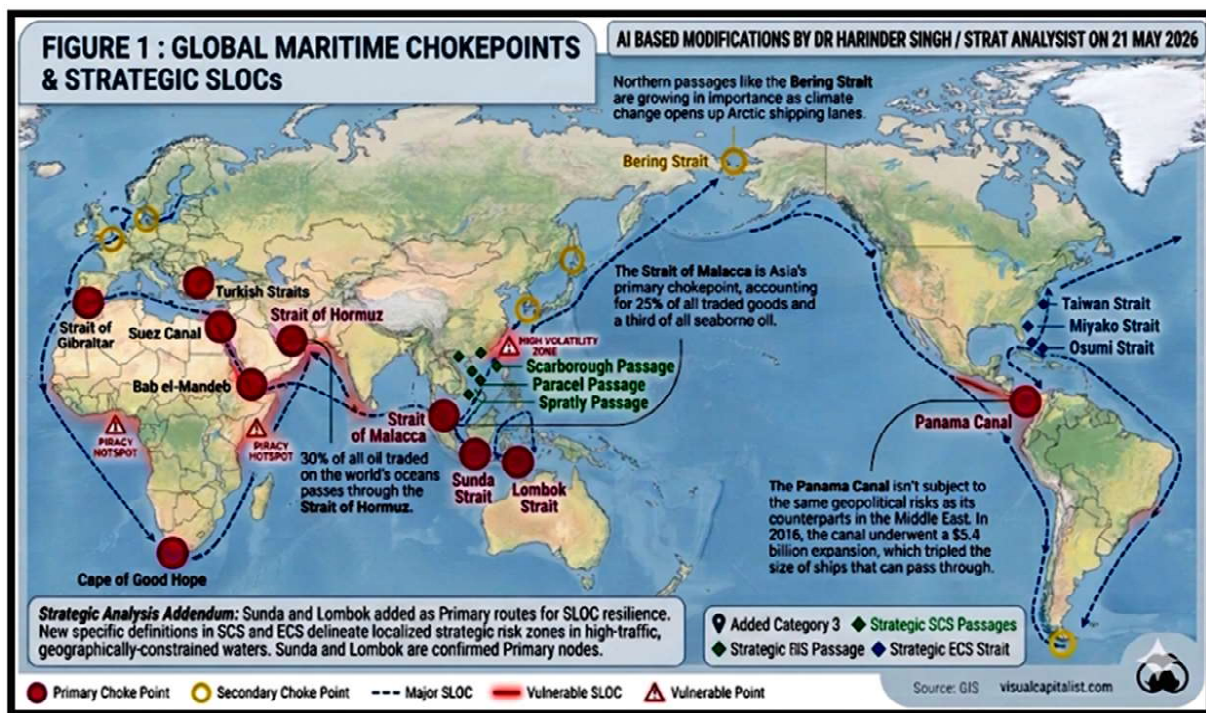
Harinder Singh*

Introduction: Chokepoint Paradox and multiplex Geopolitics

Strategic debates in India view national sovereignty in terms of territorial boundaries and continental security concerns. Yet, recent crisis around the Strait of Hormuz demonstrates that ‘India’s economic stability is equally dependent upon secure maritime trade corridors and resilient diplomatic partnerships requiring continuous regional cooperation.’¹

As the world’s third-largest energy consumer, India’s economic growth remains heavily dependent on vulnerable maritime trade routes, creating what may be termed the “*Chokepoint Paradox*.” Historically, as Angus Maddison (2006) observed, India and China dominated global wealth through expansive trade networks².

Modern supply chains operate through dispersed production hubs and maritime transit networks. Under the present ‘*Multiplex World*



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*Order*³, sea lane stability is no longer guaranteed by a single naval power. As Kishore Mahbubani's "*Great Convergence*"⁴ suggest maritime stability increasingly depends upon cooperative management of shared space.

Yet contemporary policy remains hindered by 'sea blindness', prioritising land borders while underestimating the maritime foundations of national security.⁵ Major chokepoints such as the Strait of Hormuz, the Strait of Malacca, and the Bab el-Mandeb remain vital corridors of global energy trade. They remain vulnerable to *weaponised interdependence*⁶ of global economic and supply networks. Any constriction here rapidly affects freight costs, energy prices, industrial supply chains and the uninterrupted flow of hydrocarbons.

For too long, India's 'Maritime Strategy' has emphasised naval force projection and the use of naval capability to secure uninterrupted energy flows. This approach is insufficient under present maritime conditions. India must move beyond a purely military understanding of sea control⁷ to a broader maritime security, energy-resilient, and regional cooperation framework – namely "*Multidimensional Energy Sovereignty (MES) framework*". By combining strategic planning with diplomacy, the framework operationalises *India's Maritime Goodwill Curve (IMGCC)*⁸ and will help our nation transition from a '*reactive security provider*' to a '*proactive role*' in shaping regional maritime stability.

Strategic Fragility: Limitations of Conventional Maritime Security

The present-day 'maritime threat environment'

extends beyond the reach of traditional naval responses. It has evolved significantly from the period dominated by Somali piracy, a comparatively limited maritime threat, to a more complex phase of '*Hybrid Maritime Conflict*'. Current threats increasingly include low-cost loitering munitions, Unmanned Underwater Vehicles (UUVs), and autonomous drone swarms. 'Grey-zone tactics exploit the ambiguous space between peacetime commerce and open conflict.'⁹

Vulnerabilities of Hub-and-Spoke Supply Model.

Modern maritime logistics primarily relies on the Hub-and-Spoke (H&S) model, in which multiple regional sourcing locations (spokes) feed into centralised transit hubs before passing through critical maritime passages.¹⁰ Although efficient under stable commercial conditions, it creates major concentration risks when these primary hubs or chokepoints are contested. During periods of asymmetric conflict, the high volume in these corridors makes them a high-value strategic target.

Carrier Battle Group (CBG) vs. 300% Insurance Premium

A Carrier Battle Group (CBG) alone cannot resolve prolonged maritime instability. Although it provides substantial deterrent capability, it also heightens concerns about regional escalation.¹¹ Transit premiums for vessels navigating contested chokepoints rise significantly during periods of instability, thereby substantially increasing commercial shipping costs. Analysis indicates that insurance premiums increased from the standard 0.07% of hull value to over 1.0%, resulting in a

300% to 500% increase in insurance costs.¹² Figure 3, 'War Risk Surcharge Volatility' diagram, placed here for the period 2023-2026, highlights the massive cost liabilities.

3. Signal of Conflict. The arrival of a heavy naval task force acts as a force multiplier for market panic. It signals imminent kinetic escalation to reinsurance markets, permanently embedding



CBG or Naval deployments alone cannot fully resolve this insurance crisis due to three structural asymmetries:

1. Cost-Exchange Asymmetry. We all understand that intercepting a '\$20,000 Shahed-type drone with a \$2.1 million SM-2 or \$4.3 million SM-6 missile'¹³ is operationally effective but financially unsustainable. Similarly, the insurance markets recognise the financial limits of such defensive responses during a prolonged crisis.

2. Defensive Bubble vs. Dispersed Fleet. A CBG requires a substantial internal defensive screen to protect itself. It cannot provide point defence for individual merchant tankers scattered across a 500-mile transit corridor. Mandating convoys introduces 'time-on-risk' delays, increasing the actuarial probability of a mass-casualty event.

"War Risk" clauses in maritime contracts.

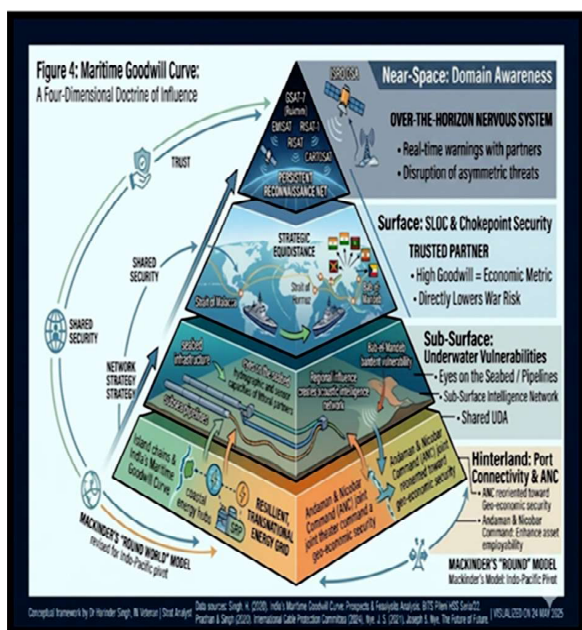
Achilles' Heel of Air-Sea Integration: Tanker Vulnerability & Incomplete AAR

The tactical limitations of carrier air elements are compounded by an operational bottleneck: India's incomplete Air-to-Air Refuelling (AAR) capability and the fragility of support tankers in contested airspace.¹⁴ Without persistent, long-range combat air patrols (CAP) over distant SLOCs, merchant vessels remain vulnerable to ballistic missiles and loitering munitions. Extending these air arcs requires a continuous AAR pipeline. However, the recent asymmetric downing of two large, non-stealthy refuellers highlights the catastrophic vulnerability of force-multiplier fleets.¹⁵

These lumbering, high-signature targets face immediate neutralisation. Their loss causes

immediate fuel starvation for the forward-deployed fighter fleet, collapsing defensive air cover and leaving the naval task force and shipping exposed to saturation strikes. India's current inventory of heavy refuellers (Il-78 MKI) is structurally limited in both volume and availability.¹⁶ Attempting to patrol the Western Indian Ocean or the Bab-el-Mandeb with an incomplete, vulnerable AAR capability would invite operational paralysis. A Navy cannot command the surface if its aerial logistical spine can be severed by a single, low-cost munition. To secure sea lanes, India requires deep strategic goodwill in the littorals rather than mere naval firepower.

Maritime Goodwill Curve: Four-Dimensional Doctrine of Influence



To move beyond purely military responses, India needs to address the persistent trust deficit in key littoral regions bordering critical chokepoints. Classical geopolitical thinking, particularly Mackinder's Heartland framework, "The Round

World model", revisited for the Indo-Pacific, reveals that controlling global sea lanes and island chains is an important geopolitical factor in the Indo-Pacific.¹⁷

To win and preserve regional peace, India's Maritime Goodwill Curve (IMGC) framework offers a practical and more cooperative strategic approach.¹⁸ It posits that energy transit security increasingly depends on the level of strategic trust with the littoral state.¹⁹ Goodwill here is not merely symbolic diplomacy. It's a measurable strategic asset. As Joseph Nye states, it's a highly 'Quantifiable Smart Power Asset' with layered strategic advantage. Let us expand this doctrine within a four-dimensional operational framework to establish broader maritime resilience.

Near-Space: Space-Based Domain Awareness.

Modern maritime security is increasingly linked to space-based infrastructure. To deter asymmetric threats before they reach maritime chokepoints, we need to improve coordination between space and maritime surveillance systems. By integrating the capabilities of the Defence Space Agency (DSA) and ISRO, India can maintain continuous satellite-based maritime monitoring. This can be achieved by leveraging the CARTO, RISAT, and GSAT-7 (Rukmini) satellite series, along with the EMISAT electronic intelligence constellation. This space-to-sea linkage shall form an integrated early-warning network to support IMGC operations. By sharing satellite-derived, real-time early warnings with friendly regional partners, India can identify drone activity and piracy threats before they directly affect shipping lanes.

Sub-Surface: Underwater Vulnerabilities.

Subsea pipelines and communication cables form a critical part of global infrastructure. They are among the most vulnerable components of energy sovereignty. The surface fleet has limited ability to monitor sub-surface sabotage. This vulnerability of undersea communications cables was evident in Bab-el-Mandeb.²⁰ Rather than relying on continuous physical monitoring of the seabed, IMGC must operationalise shared Underwater Domain Awareness (UDA). By investing in the hydrographic and sensor capabilities of littoral partners, India can improve underwater monitoring capabilities while building a collaborative, regional, real-time underwater surveillance network.

Surface: SLOC & Chokepoint Security

This domain yields the most immediate ‘Goodwill Dividend’. At the surface tier, maritime sovereignty is maintained through Strategic Equidistance – using diplomatic agility to navigate a heavily sanctioned world as a trusted partner rather than a hegemonic threat. Regionally, high goodwill serves as an economic metric that directly lowers war-risk surcharges. When littoral states perceive India as a collaborative, non-threatening partner, operational friction and security premiums for Indian-flagged energy hulls decrease sharply.

Hinterland Tier: Port-to-Pillar Connectivity and ANC.

The maritime security continuum must extend inland to include critical infrastructure that receives, stores, and distributes imported energy. In the

context of the Andaman & Nicobar Command (ANC), India’s island chains remain a paramount national asset.

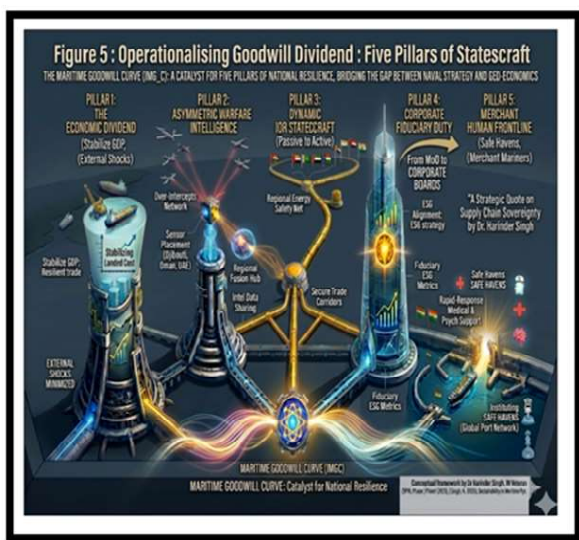
As late as early 2015, the Cabinet Committee on Infrastructure Enhancement & Security in GoI was considering ways to enhance the employability of infrastructure and strategic assets in the A&N islands.²¹ With the 2019 institutionalisation of the Chief of Defence Staff and our joint theatre command still *in fieri*, it’s time to reorient the latter towards India’s geo-economic security. This can be achieved by tethering our coastal energy hubs and Strategic Petroleum Reserves (SPR) to regional littoral networks. We can transform these domestic stockpiles into vital nodes within a resilient, transnational energy grid.

Operationalising Goodwill Dividend: Five Pillars of Statecraft

Maritime goodwill curve acts as a catalyst for five substantive pillars of national resilience, bridging the vital gap between naval strategy and geo-economics:-

Pillar 1: The Economic Dividend (Stabilising the Landed Cost). In the context of modern chokepoint volatility, the primary threat to India’s sovereignty is *inflationary contagion* from imported energy. When the Strait of Hormuz became contested, economic friction was evident in dramatically higher P&I insurance premiums. Unlike kinetic defence, which invites reciprocal aggression, the Goodwill Curve signals regional stability. By maintaining high-trust partnerships (through HADR, joint patrols, and capacity building), India actively reduces underwriters’ perceived risk, thereby protecting India’s GDP

from external geopolitical shocks. This synergy between international diplomacy and maritime operations is critical to stabilising the maritime supply chain.²²



Pillar 2: Asymmetric Counter-Warfare (Intelligence over Intercepts). Rather than attempting to ‘out-missile drone swarms’, the Goodwill Curve operationalises **Regional Intelligence Fusion**. High levels of strategic trust enable the forward placement of sensors and the seamless sharing of real-time intelligence with littoral partners (e.g., Oman, UAE, Djibouti). An early-warning data point shared by a friendly littoral neighbour is infinitely more valuable than a multi-million-dollar interceptor launched in isolation.

Pillar 3: Dynamic SPR Leadership (Regional Energy Safety Net). While India’s Phase II SPR expansion (adding a planned 4.0 Million Metric Tons (MMT) at Chandikhol and 2.5 MMT at Padur II under a commercial-cum-strategic Public-Private Partnership (PPP) model) is a critical domestic imperative,²³ the Goodwill Curve enables the Strategic Petroleum Reserves

(SPR) to serve as a regional diplomatic asset. By positioning India as a regional energy guarantor, domestic stockpiles act as a stabilising force across the entire IOR. This transforms the SPR from a passive stockpile into an active tool of energy statescraft, ensuring our littoral partners are deeply invested in the safety of the sea lanes that supply our tanks.²⁴

Pillar 4: Boardroom ESG Governance (Fiduciary Sovereignty). The mandate for national security must move swiftly from the Ministry of Defence (MoD) to the corporate boardrooms of India’s energy giants. We must reclassify maritime security as a core tenet of Environmental, Social, and Governance (ESG) strategy.²⁵

“When the security of national supply chains is treated merely as an external logistics cost rather than an internal fiduciary duty, we surrender our industrial sovereignty to market volatility.” – Dr Harinder Singh.

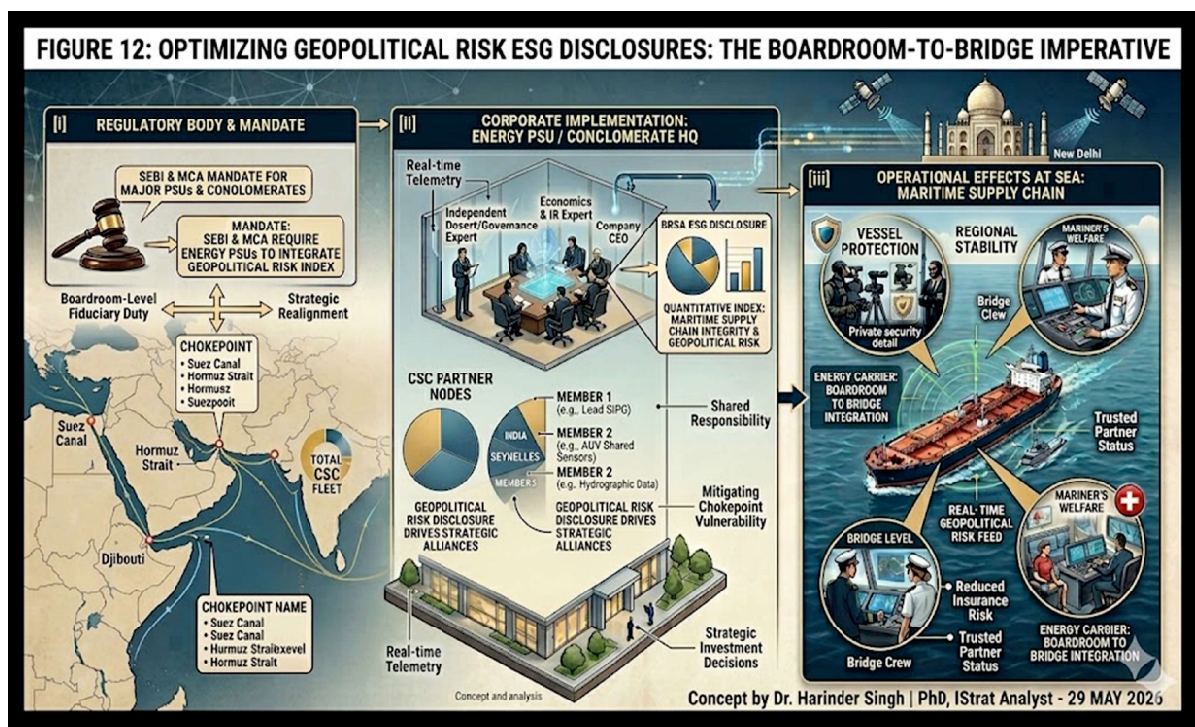
For India’s energy PSUs, supply chain integrity is a primary fiduciary duty to the nation. Integrating environmental sustainability and developmental economics into maritime operations ensures that both private and public corporate capital support strategic national objectives.²⁶

Pillar 5: The Human Frontline (The Merchant Mariner’s Resilience). The disruptions in the Strait of Hormuz and Bab el-Mandeb have taken an agonising psychological toll on merchant mariners, the unheralded frontline workers of global energy transit. True sovereignty is maintained by those who man the hull. The Goodwill Curve mandates establishing regional *“Safe Havens”* and rapid-response medical infrastructure for mariners in trusted littoral states.

alternatives. This fund will finance non-predatory maritime infrastructure, such as solar-powered coastal ports, ecological conservation zones, and sustainable fisheries, across key island chains and critical littoral nodes. Unlike competitors' debt traps, this developmental model preserves the host nations' sovereignty, earning India immense diplomatic capital that translates directly into long-term transit safety for its energy fleets.

6. Corporate Fiduciary Mandate “Boardroom to Bridge” ESG Disclosures.

Corporate Affairs (MCA) mandate major energy PSUs and private conglomerates to incorporate a quantitative “*Maritime Supply Chain Integrity & Geopolitical Risk Index*” into their annual *Business Responsibility and Sustainability Reporting* (BRSR) under the *Environment, Security and Governance* (ESG) framework. Recognising these geopolitical risks in ESG reporting can encourage corporate investment in regional stability initiatives, vessel protection measures, and mariners' welfare.



Energy security is a shared responsibility. To bridge the gap between military commands and corporate headquarters, energy security must be treated as a boardroom-level fiduciary duty rather than an external logistics externality. It is recommended that the Securities and Exchange Board of India (SEBI) and the Ministry of

Conclusion: Beyond the Gauntlet

India's long-term maritime security cannot rely solely on Carrier Battle Groups (CBGs) or air power supported by AAR. The evolving Indo-Pacific environment demands a broader framework that integrates maritime resilience, energy security, regional trust, and cooperative

statecraft. India's Maritime Goodwill Curve (IMGC) links regional cooperation to operational stability across critical maritime corridors. In an era shaped by hybrid threats, vulnerable SLOCs and chokepoints, disrupted supply chains, and weaponised interdependence, goodwill must be understood not merely as symbolic diplomacy but as a practical strategic asset.

For India, functioning solely as a "Net Security Provider" is no longer sufficient. The changing maritime environment requires sustained regional influence, trust, and cooperative engagement. India must increasingly become a "Net Influence Generator" capable of shaping

long-term maritime stability across the Indo-Pacific. From satellite-enabled maritime awareness and seabed infrastructure security to petroleum reserves and regional partnerships, sovereignty in the twenty-first century has become multidimensional. Maritime influence today depends not only on deterrent capability but also on resilience, connectivity, credibility, and sustained engagement.

Strategy must therefore move beyond reactive security responses toward a maritime order founded upon credible partnerships, economic resilience, and cooperative regional frameworks.

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From Vulnerability to Resilience: Redefining India's National Maritime Energy Security Doctrine

Sanjay Kamra*

The Indian Ocean Region (IOR) remains of immense importance to India, as it carries 40% of global commercial trade traffic and almost 70% of the world's energy trade. India has a significant presence in the region, given its peninsular geography, which extends deep into the Indian Ocean, with the Arabian Sea and Bay of Bengal on its western and eastern sides, respectively. India, with its fast-growing economy and efforts to become a global manufacturing hub, will need to secure the maritime routes available to it for commercial trade.

Consequently, securing maritime security in the area is urgent, as these Sea Lines of Communication (SLOCs) are the main arteries for sustaining and advancing its national growth plans, securing National Security, and maintaining its influence in the region. The target of becoming a developed nation by 2047 under the 'Viksit Bharat' can only be achieved by adopting a multipronged strategy that ensures the continued availability of maritime routes and a credible naval presence along them, thereby mitigating any potential threat to our national interests. It is important to recognise that 95% of India's trade and more than 90% of India's energy imports depend on this maritime connectivity.

For decades, a global consensus held that vital maritime trade routes would not be disrupted given the catastrophic economic shocks such an action would trigger. That assumption was shattered in February 2026. The outbreak of the Israel-US conflict with Iran led to the complete closure of the Strait of Hormuz to international shipping, sending shockwaves through global energy security—with India particularly vulnerable. Consequently, global crude prices surged from a pre-war benchmark of USD 65 per barrel to a staggering USD 115 per barrel.

This has had a far-reaching impact on India and driven home a harsh lesson: India's energy security can no longer be managed through long-term contracts. Instead, India needs a multi-pronged strategy to mitigate risks by immediately expanding strategic reserves, addressing critical chokepoint vulnerabilities through an effective countermeasure policy, and mitigating navigational challenges, including GPS disruptions and AIS spoofing for shipping vessels. India must have its own infrastructure to capture maritime awareness, strategic bilateral and multilateral partnerships with friendly energy-sourcing countries, and formidable naval influence covering this most important sea line of communications.

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The Operational Layer: Anatomy of Chokepoints and SLOCs

There are four maritime routes or corridors that affect India's energy security. Each presents both common and distinct physical, geopolitical and operational challenges. Of these, the Strait of Hormuz is the most critical chokepoint for India's energy imports, as historically nearly 80% of Indian crude oil imports and nearly 60% of LPG needs have used this route. It is an exceptionally narrow sea route, only about 3 km wide, that is navigable by crude oil tankers and LPG vessels. The route is said to have a capacity to handle 20 million barrels per day. About 130-140 ships used to cross this narrow sea lane in the pre-war period, which has reduced to a single-digit figure post 28 Feb 2026 war. This has severely affected the movement of India-bound tankers and vessels. The effect has led India to seek alternative sources of crude oil beyond the Middle East, resulting in critical delays, increased freight rates, and higher insurance premiums. All this has resulted in a substantial increase in Indian bucket prices, which reached a peak of USD 140 per barrel, according to some reliable sources. Any prolonged escalation of these geopolitical situations will put immense pressure on India, seriously affecting its GDP growth. India has now increased the number of countries it sources crude oil from 27 to 47 and has also raised domestic LPG production by more than 40%.

The Strait of Malacca is India's eastern vulnerability. It handles 16 million barrels of crude oil per day and is the only maritime route connecting to energy sources in the Pacific Ocean. Nearly 60% of India's commercial trade uses this

route, and 100% of non-Gulf LNG trade passes through this vital chokepoint. Any disruption of this route will severely jeopardise India's interests; if there is any simultaneous blockage of the western Hormuz route and the Strait of Malacca, it will be catastrophic for India. Effective maritime security is an urgent requirement for India to maintain continuity of trade via the Pacific Ocean LNG route and other commercial trade with East Asian countries.

The Bab el-Mandeb Strait and the Suez Canal collectively serve as the gateway to Europe and North Africa. Any disruption on this route, whether through drone attacks, missile batteries, or high-speed armed boats originating from coastal belt areas in this region, will seriously disrupt vessel traffic. If such asymmetrical warfare methods are used, they will force traffic to be rerouted around the African continent via the Cape of Good Hope. This will add 3,500 nautical miles, cause a 10-14-day delay, and incur exorbitant freight and insurance premiums, which will be highly detrimental to trade and the broader economic context of our country.

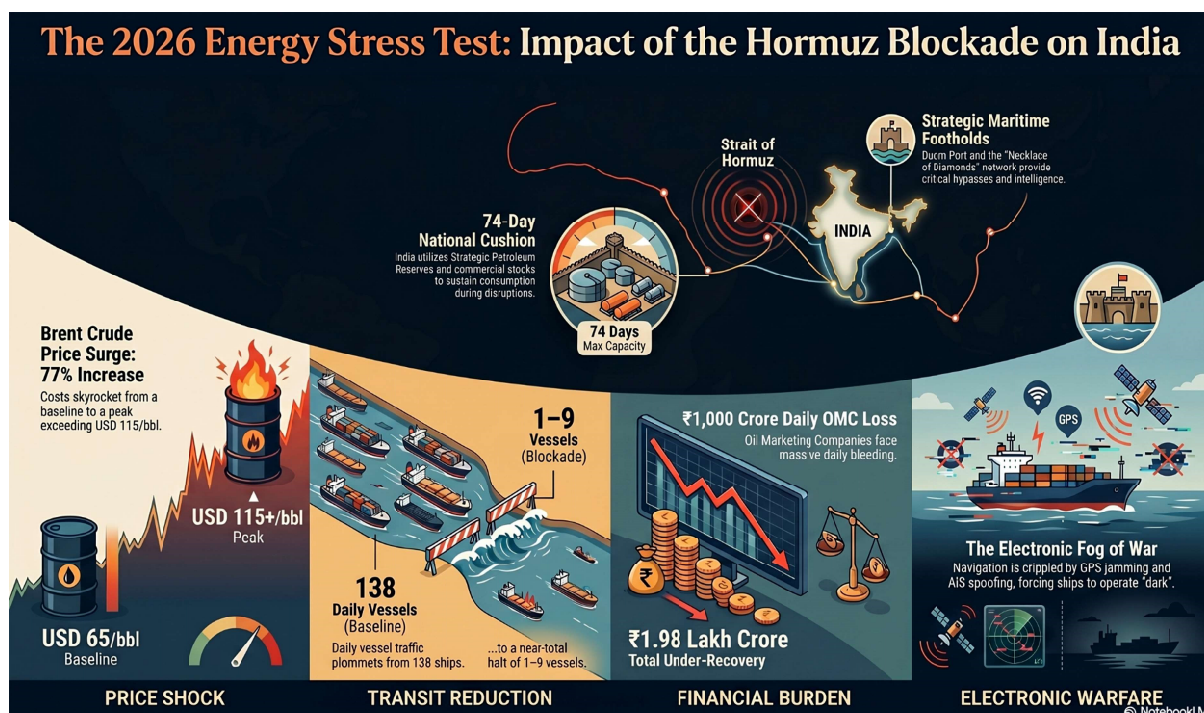
Tactical disruptions via GPS denial and electronic warfare severely impair the efficient navigation of ships along routes in this area. There have been reports of heavy GPS jamming and AIS spoofing in the Arabian Sea, the Gulf of Oman, and the high seas adjoining Fujairah. These tactical disruptions have led to errors in the navigation system and corrupted navigation. This is a serious issue that increases the risk of collisions and accidents involving shipping vessels. Another threat is the potential exposure of exact positions to asymmetric warfare by terrorists and rogue sea elements, which has often forced civilian ships to

switch off their AIS transponders to avoid potential attacks. Therefore, for India, it has become an unavoidable requirement to preserve navigational integrity and maritime awareness by deploying its own infrastructure, including the ISRO-developed NavIC satellite navigation system, and by equipping its naval and commercial ships with these technologies. The absence of these measures will surely render our military and commercial assets in navigational darkness.

The February 2026 crisis emerging from the Israel-America-Iran war has further exposed vulnerabilities stemming from digital platforms' weaknesses against cyberattacks, space-based weapons, and unmanned platforms powered by Artificial Intelligence (AI). This war has demonstrated how these technologies were extensively employed by America and Israel to

completely destroy or deny Iranian naval resources the ability to even respond to their first attack. All the air defence infrastructure, be it on the ground or on board Iranian naval platforms, was rendered useless or completely destroyed by combining conventional airpower and naval platforms with these third-dimensional force multipliers.

These vulnerabilities are strategically significant because nearly 95% of global digital communications traffic is transmitted through submarine cable networks, many of which traverse the Indian Ocean Region. Simultaneously, the proliferation of autonomous drones, loitering munitions and low-cost precision-strike systems has reduced the barriers to asymmetric maritime disruption, enabling even non-state actors to threaten offshore energy infrastructure and commercial shipping lanes. This evolving



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operational environment requires us to move beyond conventional naval preparedness toward integrated maritime-electromagnetic resilience. Energy security in the coming decades will depend not only upon naval presence but also upon digital survivability, cyber resilience and uninterrupted access to secure maritime data networks. Accordingly, India's future maritime-security architecture must incorporate anti-jamming navigation capability, indigenous satellite redundancy, AI-enabled maritime-domain awareness, cyber-secure port infrastructure and integrated civil-military digital coordination mechanisms.

The Economic Buffer: India's Strategic Reserves

In response to the severe operational and economic disruptions triggered by the 2026 crisis, India was forced to adopt major changes to its energy-security strategy. The shift reflected a broader strategic realisation that energy security depends not on procurement contracts but on effective control over logistics infrastructure, storage capacity, maritime access to routes, and supply-chain continuity. This change led to the event that during the Prime Minister's May 2026 visit to Abu Dhabi, a series of strategic agreements were envisioned between India and the UAE.

The Strategic Petroleum Reserve was conceptualised on 16 Jun 2004. It has remained the backbone since then, with implementation carried out in phases. A further development, the adoption of out-of-the-box solutions, has emerged recently, including bilateral and multilateral agreements with friendly sourcing countries. The

following are the main implementation frameworks that have emerged so far:

Phase-I Status

SPR Phase-I provides a storage capacity of 5.33 Million Metric Tonnes (MMT) which is equivalent to approximately 9.5 days of national consumption. The reserve infrastructure is distributed across three underground unlined rock cavern sites:

- **Visakhapatnam (AP): 1.33 MMT**
- **Mangaluru (Karnataka): 1.50 MMT**
- **Padur (Karnataka): 2.50 MMT**

In addition, India depends on the rolling inventories of the Oil Marketing Companies (OMCs) such as IOCL, BPCL, and HPCL, which include their own static storage and mobile transportation assets, amounting to 64.5 days' worth of consumption stock. Of this total, refineries hold half in crude oil and the other half in finished products such as petrol and diesel. The total aggregated storage in these ways amounts to 74 days' reserves. For LPG, India is completely dependent on OMC rolling inventory, amounting to 45 days of consumption and 60 days' worth of LNG.

Phase II Expansion

Phase II received 'in-principle' Cabinet approval in June 2018 and financial approval under the PPP model in July 2021. However, progress was delayed due to a scarcity of funds and issues with land acquisition for the project. It is reliably learnt that, in the aftermath of the ongoing geopolitical disruptions in the Middle East, the Government has now fast-tracked the project. The SPR Phase II expansion remains critical for long-term resilience. Once fully operational, India's

standalone strategic cover could expand to approximately 22 days. The approved expansion includes:

- **Chandikhol (Orissa) : 4.0 MMT**
- **Padur Expansion (Karnataka): 2.5 MMT**
- **India-UAE Strategic Reserve Framework.**

In a new development, a series of strategic agreements were envisioned between India and the UAE. This arrangement could significantly increase India’s capacity for autonomous energy security insulation. Under the proposed India-UAE strategic partnership framework, ADNOC could commit approximately USD 5 billion towards infrastructure, technology and strategic storage investments. India could secure the ability to store up to 30 million barrels of crude oil within Indian

reserve facilities. India could retain sovereign first-use rights during emergency conditions.

SPR Phase I Cover: 5.33 MMT (9.5 Days).

Total Integrated Cushion: 74 Days (SPR + OMC commercial stocks).

The UAE Boost: 30-million-barrel addition to meet the 90-day IEA international goal.

The Strategic Layer: “The String of Pearls” Vs “Necklace of Diamonds”

India’s maritime energy strategy cannot be understood in isolation from China’s expanding strategic footprint across the Indian Ocean Region (IOR). Over the past decades, China, with some seemingly not-so-good intentions, has developed a network of dual-use ports, logistics nodes and infrastructure partnerships popularly known as the ‘String of Pearls’. While officially presented as



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commercial infrastructure under the Belt and Road Initiative (BRI), several of these facilities possess military capabilities for supporting People's Liberation Army Navy (PLAN) operations across the Indian Ocean.

Chinese increased presence at Gwadar (Pakistan), Djibouti (Horn of Africa), Hambantota (Sri Lanka) and growing access in the Gulf region collectively create the possibility of maritime influence over the Sea Lines of Communication (SLOCs). This becomes particularly significant because India's energy security architecture remains heavily dependent upon uninterrupted access to the Gulf.

The challenge for India is not only a conventional Naval competition but the risk of an

asymmetry. China possesses the world's largest commercial shipbuilding ecosystem, extensive rare-earth processing capabilities, large strategic reserves, and a rapidly expanding naval reach. During periods of crisis, these advantages may translate into substantial maritime advantages, leading to influence over regional energy trade.

India's response, through its 'Necklace of Diamonds' strategy, aims to establish a distributed presence rather than pure militarisation. Unlike China's port acquisition model, India's approach emphasises logistics partnerships, bilateral and multilateral agreements, maritime awareness, and coalition-based security arrangements. The operational strengthening of the Andaman and Nicobar Command, together with the expansion



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of QUAD cooperation and Gulf partnerships, reflects India's recognition that maritime energy security will increasingly depend on regional presence, distributed logistics capabilities, and partnerships. The Andaman and Nicobar Command, located approximately 100 nautical miles from the western entrance to the Strait of Malacca, serves as a forward operating platform for maritime awareness, surveillance, logistics support, and sea-lane monitoring. INS Baaz and related infrastructure projects will significantly strengthen India's eastern maritime presence.

To counter China's strategic encirclement by securing access to countries surrounding India under the guise of economic and commercial partnerships, India is working to establish a counter-presence in friendly neighbouring countries to create ship repair facilities, logistics centres, and maritime awareness coalitions within a legitimate security framework. India has been developing maritime repair facilities at Vadinar in Gujarat. The facility is being developed in collaboration with Drydocks World, a DP World company, and Cochin Shipyard Limited, and in partnership with the Deen Dayal Port Authority, to create a large ship repair cluster that will also cater for repairs to naval vessels. This is in line with the Indian Government's Maritime India Vision 2030 and Maritime Amrit Kaal Vision 2047.

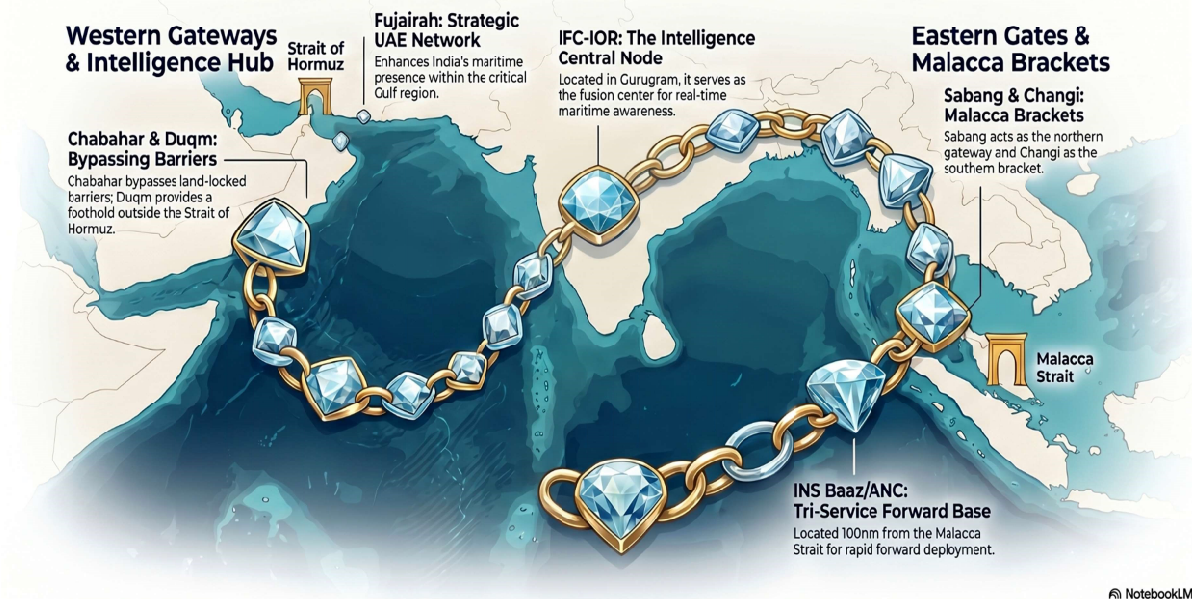
Apart from this, India is focused on getting access to the following strategic nodes outside the mainland:

- **Fujairah, UAE.** It is one of the most strategically located nodes in the Indo-Gulf region, which provides a bypass of the Strait of Hormuz. It also provides an alternative

overseas strategic storage capacity, largely immune to disruptions at the mouth of the Strait of Hormuz or in the Persian Sea.

- **Duqm Port, Oman.** Duqm, due to its location away from Hormuz, can again serve as a Naval refuelling hub and provide ship repair facilities.
- **Chabahar Port, Iran.** Despite Iran's instability, Chabahar remains a strategically critical Indian maritime asset, to which India has invested USD 120 million, fully paid in August 2025. The investment has been made to develop the Shahid Beheshti terminal. The port provides access to Central Asia, bypass capability around land barriers, geopolitical presence within Iran, and connectivity to INSTC corridors. The investment remains linked to the International North–South Transport Corridor (INSTC), with a 750 km Chabahar–Zahedan railway line linking the port directly to Central Asia and Russia, preserving the long-term commercial intent of India's trade bypass around Pakistan.
- **Sabang Port, Indonesia.** Sabang provides India with a forward eastern maritime presence near the Malacca Strait. The location strengthens bilateral patrol coordination, anti-piracy operations, and regional surveillance capability.
- **Changi Naval Base, Singapore.** India has inked logistics agreements with Singapore to facilitate the sustained operational presence of Indian naval assets near the southern end of the Strait of Malacca. This effectively extends India's operational reach into the Pacific.
Physical assets and maritime deployments alone cannot secure the interests of stakeholders

The Necklace of Diamonds: India's Strategic Maritime Network



Note: The above Infographic is original work generated using NotebookLM AI.

in the Indian Ocean. India's maritime doctrine has therefore evolved from SAGAR (Security and Growth for All in the Region), launched in 2015, to MAHASAGAR (Mutual and Holistic Advancement for Security Across the Region), launched in March 2025. Through this endeavour, India seeks to have the world recognise that it is now willing to contribute as a global maritime stakeholder, transitioning from a regional security provider to its friendly nations.

Conclusion and Strategic Recommendations

The 2026 maritime crucible (Middle East War) marks a major turning point for India and the broader Indo-Pacific stakeholders. The crisis that

erupted has shown that maritime chokepoints can severely disrupt both large and small nations without mercy. Weaker economies, or those that have not developed resilience in their energy security, can be severely damaged or even destroyed. Therefore, it is important to build and maintain strategic reserves of crude oil and LNG/LPG, ensure credible naval access to secure maritime routes, and deploy technological measures to counter cyber-attacks, GPS jamming, EW, and digital security threats. This is an urgent requirement to safeguard national interests, absorb such shocks, and protect the country's economic growth. It is equally important to pursue international collaborations to mitigate the risks of any misadventures along or in the maritime trade

routes. There is an immediate requirement for India to redefine its maritime security to ensure energy security and protect its broader macroeconomic interests.

Strategic Energy Resilience. India must accelerate the expansion of Strategic Petroleum Reserve (SPR) infrastructure by rapidly operationalising the Chandikhol site, the Padur expansion, and the Rajasthan salt-cavern ecosystems. Rapid-access storage architecture is most important during future maritime disruptions and energy shocks. Simultaneously, India requires dedicated underground LNG and LPG reserve systems capable of providing at least 30 days of independent strategic insulation. Gas security is now closely linked to fertilizer production and to energy availability for rural and urban consumption. It is also linked to transport networks and power generation.

Maritime and Digital Security Architecture. The crisis also demonstrated that navigational independence and maritime awareness are core national security requirements. India must therefore accelerate the deployment of NavIC-based maritime navigation systems, anti-jamming capabilities, AIS redundancy frameworks, and resilient maritime electromagnetic infrastructure. India's future maritime security must also prioritise indigenous Intelligence, Surveillance and Reconnaissance (ISR) capabilities, integrated with space-based systems. Undersea communication cables must likewise be recognised as critical infrastructure because of their role in global financial systems, digital commerce, and military communications.

Indo-Pacific Strategic Coordination. India's maritime security strategy must increasingly

operate through regional partnerships and distributed resilience frameworks. Institutions such as IORA, BIMSTEC and the QUAD provide the foundation for a coordinated Indo-Pacific maritime security architecture focused on SLOC continuity, crisis coordination, dark-target identification and chokepoint resilience. Strategic infrastructure partnerships with the UAE, Oman, Singapore, Indonesia and Iran should evolve into long-term maritime resilience ecosystems that support logistics continuity, operational persistence and emergency energy access during periods of regional instability. Simultaneously, the QUAD framework offers substantial potential for coordinated maritime domain awareness, logistics interoperability and Indo-Pacific energy security cooperation.

Towards a National Maritime Energy Security Doctrine. A formal National Maritime Energy Security Doctrine would help institutionalise inter-ministerial coordination and align long-term strategic planning across operational, economic and technological domains. Such a doctrine would provide the foundation for India to transition from a vulnerable maritime energy consumer to a resilient Indo-Pacific maritime power. The 2026 crisis demonstrated that India's future energy security can no longer be managed through fragmented institutional mechanisms operating independently across the defence, shipping, petroleum and digital infrastructure sectors. India presently lacks a unified doctrinal framework that integrates naval operations, strategic reserves, maritime infrastructure, cyber resilience, energy logistics and economic continuity planning.

For India, the future of energy security

increasingly depends on ownership of energy resources and the ability to secure maritime access to them across contested oceanic trade routes. India's energy security architecture needs to be shaped not only by procurement contracts but also by logistics resilience, chokepoint-bypass capability, maritime awareness, technological sovereignty, and strategic partnerships. The 2026 crisis demonstrated that maritime geography remains the ultimate determinant of energy continuity in an interconnected global economy. Future conflicts are likely to span physical, digital, electromagnetic and economic domains. This necessitates India developing integrated, dependable frameworks rather than conventional

models. India's evolving response is being shaped by strategic reserves, distributed maritime partnerships, digital platform maturity, naval modernisation and regional diplomacy. This marks a major transition from reactive dependence to a proactive approach. If India can sustain this through long-term institutional coordination and investment, this transformation could position India not merely as a major energy consumer but as a stabilising Indo-Pacific power. In the present and the future, energy security is no longer defined by possession of fuel reserves alone but by uninterrupted control over the maritime, digital and logistical systems that enable continuous energy availability.

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Anchoring the Indo-Pacific: Geopolitical Strategic Balancing and Supply Chain Resilience in India-Vietnam Ties

Sonu Trivedi*

Introduction

The India-Vietnam Enhanced Comprehensive Strategic Partnership (ECSP), upgraded in May 2026, is grounded in shared geopolitical concerns and economic complementarities. The upgrade significantly deepens cooperation across defence, supply chain diversification, critical minerals, and financial and digital connectivity. It also aligns India's "Act East Policy" and "Developed India @2047" with Vietnam's "Vision of a developed country by 2045".

Against this backdrop, the Paper argues that to understand why these two middle powers are deepening their alliances, it is important to study the geopolitical alignments, defence convergences, and economic complementarities between India and Vietnam. Given the changing power dynamics in the Indo-Pacific, the Paper also argues how Vietnam fits into this broader geopolitical balance.

To analyse the argument, the Paper draws on major international relations theories, including 'Neorealism', 'Liberal Institutionalism' and 'Constructivism', and reflects on why and how India and Vietnam are deepening their ties. It also examines the evolution of India-Vietnam relations and the recent upgrade to ECSP. Geopolitical balancing by both countries amid the shift in power in the Indo-Pacific is also highlighted. The Paper further explores key drivers of growth in sectors

such as manufacturing, supply chains, critical minerals, human resource mobility and EV manufacturing. Finally, the Paper focuses on the immense potential of tourism and people-to-people exchanges to foster a comprehensive political and economic relationship between the two countries.

Theoretical Framework

Analysing the India-Vietnam Enhanced Comprehensive Strategic Partnership (ECSP), which encompasses robust India-Vietnam relations and critical supply-chain frameworks, requires a multidimensional approach. The Paper uses an international relations theoretical framework to analyse this partnership. The evolution of these multifaceted relations can be evaluated through the lenses of three core international theories: Neorealism, Liberal Institutionalism and Constructivism.

Neorealism highlights the anarchic nature of the international system, in which states seek to maximise security by balancing against rising threats. The primary factors shaping states' behaviour are the distribution of power and the need to balance against potential hegemonies. From a Neorealist perspective, the India-Vietnam partnership exemplifies external balancing, particularly in response to China's territorial claims in the South China Sea and its growing assertiveness in the Indo-Pacific. Both countries

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are prioritising independent foreign policies while strengthening their defence capabilities. Vietnam seeks to enhance its strategic presence by diversifying its diplomatic options through partnerships with a rising Asian power, such as India. By contrast, India uses its deepening defence and maritime ties with Vietnam as a geostrategic lever to project power in response to the rise of an assertive China and the shifting balance of power in the Indo-Pacific.

Liberal Institutionalism holds that even in an anarchic system, absolute gains can be achieved by strengthening institutional engagement. According to this view, states cooperate out of mutual self-interest, facilitated by international regimes, institutions, and economic interdependence. The liberal institutional perspective views ECSP through the lens of institutional networks and economic interdependence. Both nations are concerned not only with security balancing but also with institutional integration and economic partnerships. Bilateral agreements to raise the trade target to USD 25 billion by 2030, digital payment linkages between their central banks, and cooperation on critical rare-earth minerals have highlighted their joint efforts to build resilient supply chains. Institutional collaborations through the Indo-Pacific Oceans Initiative (IPOI) emphasise a shared security architecture, 'freedom of navigation', and a 'rules-based order' in the South China Sea. These frameworks reduce transaction costs and build long-term trust, making both economies mutually resilient to external threats.

Constructivism emphasises the role of shared ideas, norms, identities, and socialisation in shaping state behaviour. It holds that national interests are

not fixed by material power alone but are socially constructed through interaction. According to Constructivism, shared history, civilisational linkages, and anti-colonial solidarity construct a powerful narrative of mutual trust and partnership. India's 'Act East' policy and Vietnam's integration into the IPOI provide the ideological and normative backbone of their alignment. Both nations share a post-colonial identity as rapidly growing, aspirational societies with complementary national visions - India's '*Viksit Bharat 2047*' and Vietnam's '2045 Development Vision'. Their shared commitment to strategic autonomy and to the United Nations Convention on the Law of the Sea (UNCLOS) provides a strong normative foundation for cooperation. Taken together, these factors turn a strategic and security pact, amid fluctuating geopolitical pressures, into a socially constructed partnership.

Evolution of India-Vietnam Relations

The historical connections between India and Vietnam have enriched our ancient literature and mythology. Originating in the 2nd century BCE, these linkages through trade and commerce can be traced back to the establishment of the Champa Kingdom, which flourished in what is now central and southern Vietnam. As a pivotal maritime centre, it has fundamentally shaped the region's geopolitical landscape in ancient times. Historically, it has played a significant role in shaping the culture, commerce and connectivity between India and Vietnam¹. It has served as a vital bridge for the transmission of Indian social, political and cultural traditions to Southeast Asia and for forging lasting links with the Indian subcontinent.

These centuries-old ties continue to shape contemporary bilateral relations, forming a civilisational foundation for the strategic partnership between India and Vietnam today. The Hindu Kingdom of Champa and Indian Buddhist philosophy and religion also blended seamlessly with Vietnam's indigenous belief system. India also provided "crucial moral and political support to Vietnam during its national liberation struggle against France and the United States".²

The foundation of the friendship was laid by India's first Prime Minister, Jawaharlal Nehru, and Vietnam's President Ho Chi Minh. As a visionary leader, Ho Chi Minh fought American troops with an unyielding spirit and became a household name in Kolkata, India, through the slogan "Mera Naam Tera Naam, Vietnam-Vietnam" ("My name and your name are the same as Vietnam"), which proclaimed solidarity with the people of Vietnam in their fight against American imperialism³.

The bilateral ties were upgraded to 'Strategic Partnership' in 2007 and to 'Comprehensive Strategic Partnership' (CSP) in 2016⁴. A decade of this CSP (2016-26) and 54 years of diplomatic ties (1972-2026) have resulted in the elevation of ties to the 'Enhanced Comprehensive Strategic Partnership' (ECSP) in 2026.

India and Vietnam have been reported as among the fastest-growing economies in the world. Both countries have achieved sustained economic growth and trade diversification over the past three decades. Vietnam's 'Doi Moi' reforms of the late 1980s and India's 'New Economic Policy' of 1991, both focused on liberalisation, privatisation and globalisation, mark parallel growth trajectories for

both countries. Together, the two countries have pursued market-led, export-oriented growth strategies and sought to deepen their integration into regional and global value chains. Given their political histories of reform and complementarities, they have emerged as globally integrated, dynamic economies in the region.

In foreign policy and diplomacy, both India and Vietnam have recast their strategies since the late twentieth century. Economic reforms have led to diversification and greater multilateral engagement in Vietnam. India's diplomacy in the post-Cold War era has evolved from classical non-alignment to multi-alignment, emphasising strategic autonomy within a rules-based order. Both countries have converged on a strategic outlook of multipolarity and diversified partnerships in a complex, interdependent world.

As two growing economies of the Global South, India and Vietnam have emphasised the importance of addressing shared challenges related to international law and of ensuring the voices and rights of developing countries. Leaders of both countries have also agreed to work closely on regional and international platforms to 'promote peace, stability, and development'.

During his recent visit, President To Lam called India a "centre of growth and innovation in the world" and discussed linking the "strategic visions and development strategies of both countries to better address the turmoil in the situation of the world today"⁵. As both countries move towards the goal of becoming 'developed countries' – Vietnam by 2045 and India by 2047 – they share a vision for growth and mutual prosperity. It is fitting to quote Prime Minister

Modi's words, "Together, we will walk, grow, and win", which reflect the foundational vision for collective development⁶.

Towards Enhanced Comprehensive Strategic Partnership

India and Vietnam officially elevated their bilateral relations to an 'Enhanced Comprehensive Strategic Partnership' (ECSP) during the State visit of the Vietnamese President, H. E. To Lam to India⁷. The upgrade marks the 10th anniversary of the 'Comprehensive Strategic Partnership' signed in 2016, deepening their bilateral cooperation. Both countries have institutionalised a multifaceted partnership in the region, anchored in defence and security cooperation, economic and green transformation, and strategic and regional alignment.

For India, Vietnam is an important factor in its 'Act-East Policy' and a significant partner in the 'Vision MAHASAGAR'. As part of ECSP, Vietnam has announced its intention to join India's 'Indo-Pacific Ocean Initiative' (IPOI). This integration of Vietnam into IPOI will be a strategic milestone for expanding India's footprint in the regional architecture and enabling Vietnam to pursue geopolitical balancing.

Altogether, India and Vietnam concluded thirteen agreements during the May 2026 visit to India by the President of Vietnam, H. E. To Lam. The agreements cover a wide range of issues, including defence and maritime security; culture and tourism; critical minerals and digital technology; health and pharmaceuticals; trade, commerce and investment; and urban management and development partnership⁸.

Both nations aim to reach USD 25 billion in bilateral trade by 2030, with two-way trade currently at around USD 16 billion⁹. While traditional items still dominate the trade basket between India and Vietnam, investments in new technology sectors, including the digital economy, technology and innovation, critical minerals, renewable and green energy, semiconductors, pharmaceuticals, healthcare, space technology, cybersecurity, the blue economy and marine technology, are increasingly significant drivers of bilateral trade growth between India and Vietnam.

Enhanced engagement in both "traditional and emerging areas of defence cooperation and defence systems procurement" between India and Vietnam has been the primary focus of the joint statement issued by the two leaders¹⁰. Collaboration in "oceanography, including areas such as ocean observing platforms, data management, ocean prediction and services, capacity building and maritime scientific research" has also been emphasised¹¹.

Digital technologies and critical emerging technologies have also been key themes in the joint statement between the two countries. It focuses on "facilitating greater collaboration and partnership in critical and emerging technology areas such as Digital Public Infrastructure, 6G, Artificial Intelligence, space and nuclear technology, marine sciences, biotechnology, pharmaceuticals, advanced materials and critical minerals. Cooperation will focus on practical initiatives such as joint research, R&D centres, and product development as mutually beneficial."¹² Under this initiative, "the Reserve Bank of India and State Bank of Vietnam" have agreed to

promote financial innovation and digital payments. They have decided to link their respective platforms via QR codes for retail payments to facilitate tourism and business on both sides.

India and Vietnam are deepening bilateral healthcare ties to modernise medical infrastructure. The cooperative framework between the two countries covers digital health transformation, the integration of Artificial Intelligence into medicine, and expanded research into traditional medicine. Both countries have signed a tourism cooperation memorandum and agreed to “promote sustainable two-way tourism, including cultural and heritage, medical and wellness tourism”.¹³ They have also committed to strengthening air connectivity and logistics cooperation by expanding direct flights.

To establish institutional linkages and a formal framework enabling India and Vietnam’s largest megacities to collaborate, “a memorandum for the establishment of friendship and cooperation between the Brihanmumbai Municipal Corporation (BMC) in Mumbai and the Ho Chi Minh City People’s Committee in Vietnam has been signed.”¹⁴ As a key pillar of bilateral cooperation and the deepening of people-to-people ties, the joint statement focuses on “greater student, faculty and research exchanges between universities and think tanks of the two countries”. The two countries have also signed a memorandum on “documentation, conservation, digitisation and online dissemination of Cham manuscripts of Indian origin currently preserved in Vietnam”.

India-Vietnam Strategic Balancing

India and Vietnam have officially elevated their bilateral ties to an ‘Enhanced Comprehensive

Strategic Partnership’ (ECSP). A core element of this upgraded framework is geostrategic balancing against China’s growing assertiveness in the South China Sea. This aligns with the combination of Vietnam’s maritime frontline position and India’s ‘Act East policy’ and broader Indo-Pacific ambitions.

Vietnam shares a sensitive land border with China and faces complex maritime disputes. It balances these pressures by cultivating deep defence and political ties with major powers. In this endeavour, India is a crucial partner for Vietnam in maintaining its strategic autonomy. For India, a strong Vietnam is a friendly partner in the Indo-Pacific, preventing unilateral domination in Southeast Asia and securing vital sea lanes of communication through which a significant share of India’s global trade flows.

Both nations advocate a ‘free, open, and rules-based’ Indo-Pacific, with strict adherence to the ‘United Nations Convention on the Law of the Sea’ (UNCLOS) and to freedom of navigation. Vietnam has joined India’s ‘Indo-Pacific Oceans Initiative’ (IPOI). This alignment reflects strategic convergence and enables close cooperation with India’s regional maritime architecture without directly forming a formal anti-China alliance.

Defence remains the cornerstone of the partnership between India and Vietnam. The two nations have established a new 2+2 Strategic Defence Dialogue and are focusing on naval interoperability, port calls, defence equipment procurement, capacity building and technology co-production. Both countries are working to enhance defence procurement. This includes advanced negotiations for Indian military exports to Vietnam,

such as the BrahMos supersonic cruise missile, which Vietnam seeks to strengthen its coastal defence posture in the South China Sea.

Amid reports that Vietnam is finalising a BrahMos deal with India, a significant shift is underway in the region's geopolitics. Although Vietnam maintains strong economic relations with China, it has increasingly sought to diversify its defence and strategic partnerships with India. Vietnam's defence preparedness reflects China's growing monopoly and hegemonic designs in the South China Sea and its maritime expansion, leading to a changing balance of power in the region. Furthermore, by expanding its BrahMos deal in Southeast Asia (Vietnam being the third country after the Philippines and Indonesia), India is increasing its influence and emerging as a 'net security provider', countering China's hegemony in the region.

Key Economic Drivers and Sector Goals

India and Vietnam are accelerating economic integration under their 'Enhanced Comprehensive Strategic Partnership', aiming to "expand the bilateral trade target to USD 25 billion by 2030". Beyond defence, the two nations aim to build resilient supply chains, enhance bilateral investment, and strengthen cooperation in the digital economy.

Manufacturing & Supply Chains: India and Vietnam are rapidly integrating their manufacturing and supply chains to form a powerful regional "China-Plus-One" alternative. The two manufacturing ecosystems are highly complementary rather than competitive. India,

supported by large government programmes such as the Production Linked Incentive (PLI) Scheme, is attracting significant global investment in electronics, pharmaceuticals, and automotive manufacturing. Vietnam is actively diversifying its manufacturing sources and increasing imports of industrial inputs (such as iron, steel, and auto parts) from India to support its export needs. India also hopes to benefit from Vietnam's highly efficient export processing zones to boost its own "Make in India" initiatives. Both nations are positioning themselves as complementary hubs for American and European businesses restructuring their global supply chains away from China.

Rare Earth and Critical Minerals: India and Vietnam are focusing on rare earths and critical minerals to secure supply chains and reduce reliance on monopolistic markets. This partnership combines Vietnam's vast rare earth reserves with India's surging demand and expanding processing capabilities. "Through new initiatives in critical minerals, rare earths, and energy cooperation, we will ensure the economic security and supply chain resilience of both sides."¹⁵

The Government of Vietnam has identified "the mining industry, including the rare earth minerals sector, as a priority for development, and has introduced measures to attract foreign investment, such as tax incentives, streamlined procedures for obtaining mining licences, and the establishment of industrial zones dedicated to mining and processing." The strategic partnership between India and Vietnam on rare-earth elements makes Vietnam a crucial partner for India's growing industrial and green technology needs. Rare-earth elements are also crucial for achieving "self-

reliance and long-term security of the country, as the manufacturing of products across industries such as defence, aerospace, electronics, electrical equipment, including renewable energy, is highly dependent on the rare earth elements.”¹⁶

Healthcare & Pharmaceuticals: The India-Vietnam healthcare and pharmaceutical partnership is rapidly expanding, driven by India’s position as a global supplier of generic medicines and Vietnam’s growing domestic pharma market. In light of this, Vietnam aims to increase its reliance on Indian companies for cost-effective medicines and drug procurement for its public hospitals. This reflects Vietnam’s commitment to move away from its historical reliance on a single source of supply, cementing India as its most trusted and cost-effective partner for pharmaceuticals and medical equipment. They are also collaborating on traditional medicine, digital healthcare transformation, and AI applications in the health sector.

Human Resource Mobility: India and Vietnam are rapidly deepening their bilateral relationship, with a major focus on human resource mobility and capacity building. As part of the ECSP, both countries view workforce development and human resource mobility as crucial to securing supply chains, driving economic growth, and achieving strategic autonomy in the region. India is one of the largest global exporters of healthcare professionals, including doctors and nurses, as well as highly skilled corporate employees, IT specialists, and technical advisors. Both countries have prioritised knowledge sharing and the integration of startup ecosystems by building corporate networks. In the evolving technology landscape, India’s experienced IT professionals are

migrating to and partnering with Vietnam, as the country develops its digital economy and semiconductor industries. We find Indian expatriates frequently working in Vietnam as managers, tech experts, and executives in sectors such as manufacturing, renewable energy, and software.

India’s Consumer Market & The EV Boom: India’s rapidly growing consumer market is highly attractive to Vietnamese companies, particularly in the electric vehicle (EV) sector. Vietnamese EV giant VinFast views India’s market as a major priority, given the local appetite for sustainable and affordable mobility. VinFast is investing USD 500 million to build a large, integrated EV manufacturing plant in Thoothukudi, Tamil Nadu. The facility, which can scale to 150,000 vehicles annually, will allow VinFast to leverage the government’s EV manufacturing ecosystem. It has been reported that “VinFast also plans to establish a nationwide dealer network to build the brand with the commitment of good cars, good prices and excellent after-sales services.”¹⁷ It is also launching a “green and eco-friendly” taxi service in the Delhi-NCR region and expanding its operations to Bengaluru and Hyderabad by the end of 2026¹⁸.

Strengthening People-to-People Exchanges

Cultural and people-to-people ties provide the foundation on which the political and economic partnership thrives. In this regard, India and Vietnam have focused on tourism as a vital pillar of economic growth and cultural integration. The ECSP has focused on cultural, medical and

wellness tourism, which will further sustainable tourism opportunities between the two countries.

The flourishing tourism sector has also acted as a catalyst for trade. Low-cost airlines such as Vietjet and IndiGo have rapidly expanded their networks, directly boosting air travel and accelerating investments in hospitality by Indian and Vietnamese conglomerates. Beyond holiday getaways, Vietnam has also emerged as a major hub for meetings, exhibitions and Indian destination weddings. This has led to an influx of Indian tourists, fostering social and cultural familiarity and adaptation. The hospitality sector in Vietnam, including hotels and local tour operators, has adapted by training staff in Indian cultural preferences and opening authentic Indian restaurants, thereby attempting to bridge the cultural gap.

Social media platforms and their feeds have amplified travellers' wish lists for destinations such as beaches in Da Nang and Phu Quoc, heritage cities like Hoi An and Hue, and the urban landscapes of Hanoi and Ho Chi Minh City. This has shifted Indians' perception of Vietnam from a historically war-torn country to a vibrant, culturally rich, and affordable luxury destination, an alternative to expensive European holiday destinations.

Given the deep civilisational linkages between India and Vietnam, the two countries have agreed to collaborate on digitising ancient Cham manuscripts and to promote research into their shared civilisational and Buddhist heritage. Committed to deepening academic ties and institutional research, both countries have agreed to enhance educational cooperation and academic

exchanges between their institutions. This expansion of people-to-people exchanges has been a major pillar of political cooperation between the two countries, leading to growing trust and a strong public mandate for enhanced diplomatic alignment.

Conclusion

The India-Vietnam 'Enhanced Comprehensive Strategic Partnership' is forward-looking. It is a highly ambitious framework rooted in civilisational ties and shared geopolitical interests. Bilateral relations are underpinned by mutual interdependence in a rapidly shifting geopolitical order. Both countries firmly support a 'free, open and rules-based' Indo-Pacific. They share security interests to counterbalance regional security concerns and oppose any coercion by any hegemonic power.

Vietnam remains a vital anchor of India's Act East policy. The partnership has been strengthened by Vietnam's accession to the IPOI, which aligns with Vietnam's regional perspective. Under ECSP, the institutionalisation of the 2+2 Defence Dialogue further reinforces the commitment to a 'rules-based' security architecture in the region. On the economic front, both countries have set a high bilateral trade target of USD 25 billion by 2030. They are also diversifying supply chains and strengthening digital ecosystems through strategic MOUs covering critical minerals, digital connectivity, urban governance, and fintech. Overall, this partnership serves as a model for Indo-Pacific stability, underpinned by mutual trust and confidence, ensuring economic resilience and security in the maritime domain.

To conclude, it is worth quoting from Prime

Minister Modi's speech, which draws on Lord Buddha's teaching, "If you light a lamp for someone else, it also illuminates your own path." Reinforcing

this principle, he adds, "By supporting each other's visions and goals, we will collectively realise our aspirations to become developed nations."

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