EXPLORING ENERGY SECURITY IN INDIA: A STRATEGIC MANAGEMENT PERSPECTIVE

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by

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DECLARATION

I Shashank Sharma hereby certify that the work which is being presented in the project report entitled “EXPLORING ENERGY SECURITY IN INDIA: A STRATEGIC MANAGEMENT PERSPECTIVE” in partial fulfilment of the requirements for the award of the degree of Masters of Business Administration (Executive) in Data Science and Analytics, submitted in the University School of Management & Entrepreneurship, Delhi Technological University is an authentic record of my own work carried out during the period from June’2026 to July’2026 under the supervision of Prof. Manoj Kumar Sharma. The matter presented in the project report has not been submitted by me for award of any other degree of this or any other institute.

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CERTIFICATE BY THE SUPERVISOR

Certified that Shashank Sharma (Roll No. 24/UEMBA/05) has carried out their capstone work presented in this project report titled "EXPLORING ENERGY SECURITY IN INDIA: A STRATEGIC MANAGEMENT PERSPECTIVE" for the award of Masters of Business Administration (Executive) Data Science and Analytics from University School of Management and Entrepreneurship, Delhi Technological University, under my supervision. The capstone embodies results of original work, and studies are carried out by the student himself and the contents of the project report do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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ABSTRACT

India's energy-security challenge is not a simple choice between coal and renewable energy. The country needs more energy for growth, but it must also limit exposure to imported fuels, volatile prices, infrastructure constraints and environmental damage. This capstone examines that tension through a strategic-management lens. It focuses on coal and petroleum among non-renewable fuels, and on solar and wind as the main renewable electricity options. State-level data from the NITI Aayog India Climate and Energy Dashboard were cleaned and combined to create national trends up to 2024-25.

Coal and lignite consumption rose from 421.24 million tonnes in 2005-06 to 1,069.91 million tonnes in 2024-25. Imports increased even faster, reaching 248.50 million tonnes and an import bill of roughly ₹262,230 crore. Petroleum-products consumption climbed from 141.79 million tonnes in 2010-11 to 227.66 million tonnes in 2024-25. Coal still supplied about 73.0% of electricity generation in the selected dataset, so a sudden withdrawal would create reliability concerns.

Renewable growth has also been substantial. Solar generation increased from 7.34 TWh in 2015-16 to 144.15 TWh in 2024-25, while wind reached 83.35 TWh. India's assessed potential is about 748 GW for solar and 1,163 GW for wind, but only a small share has been converted into installed capacity. Under the report's trend-based scenario, additional solar and wind output by 2030-31 could reduce the annual coal-import bill by about ₹16,369 crore before capital, grid, storage and balancing costs are considered.

The evidence supports a solar-led, wind-complemented and storage-backed pathway, with coal managed through a measured transition. Fuel choices are compared through Value proposition (QCDFIR)—Quality, Cost, Delivery, Flexibility, Import Resilience and Responsiveness. The four-stage strategic process converts the analysis into intent, formulation, implementation, and evaluation and control. Recommendations centre on integrated planning, grid and storage investment, efficient coal use, lower petroleum demand, stronger domestic manufacturing, healthier DISCOMs and clear accountability.

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LIST OF ABBREVIATIONS

Term	**Meaning**
BESS	Battery Energy Storage System
CEA	Central Electricity Authority
CUF	Capacity Utilisation Factor
DISCOM	Electricity Distribution Company
ESO	Energy Storage Obligation
FY	Financial Year
GW	Gigawatt
ICED	India Climate and Energy Dashboard
ISTS	Inter-State Transmission System
MNRE	Ministry of New and Renewable Energy
Mt	Million Tonnes
MU	Million Units of Electricity
NEP	National Electricity Plan
NITI	National Institution for Transforming India
OLS	Ordinary Least Squares
PLF	Plant Load Factor
PPAC	Petroleum Planning and Analysis Cell
RCO	Renewable Consumption Obligation
RPO	Renewable Purchase Obligation
TWh	Terawatt-hour
Value proposition (QCDFIR)	Quality, Cost, Delivery, Flexibility, Import Resilience and Responsiveness

CHAPTER 1: INTRODUCTION

1.1 Background and industry context

Energy security means having enough energy available at a cost that households and businesses can reasonably bear, without frequent disruption or excessive dependence on outside suppliers. Physical supply is only one part of the picture. Reliability, affordability, infrastructure, environmental impact, technology and the ability to absorb external shocks matter as well. Cherp and Jewell (2014) argue that the meaning of energy security depends on who or what is being protected, which functions are valued and which threats are most relevant. Ang, Choong and Ng (2015) reach a similar conclusion: countries usually need a combination of indicators rather than one universal measure. This multidimensional view is also supported by Kruyt et al. (2009), Chester (2010), Sovacool and Mukherjee (2011) and Winzer (2012).

India faces this issue on several fronts at the same time. Demand for electricity and mobility is rising with urbanisation, industrial growth and higher incomes. Coal still anchors power generation, while petroleum remains deeply embedded in transport and industry. At the same time, India has a large renewable resource base, but technical potential does not automatically become dependable electricity. It must be supported by transmission, storage, flexible demand, domestic manufacturing, land access and financially stable distribution companies. Studies of the Indian grid similarly show that renewable expansion must be accompanied by operational flexibility, stronger interconnections, forecasting and market reform (Palchak et al., 2017; Das et al., 2020). The practical question is not whether renewable energy should grow, but how the entire system must change so that this growth genuinely strengthens energy security.

NITI Aayog's India Climate and Energy Dashboard brings together regularly updated information on energy supply, demand, emissions and policy. The accompanying manual notes that the platform draws detailed records from states, power plants, distribution companies and other official sources. This makes it well suited to

a study that begins with state-level data and then develops national strategic insights (NITI Aayog, 2026a; NITI Aayog, 2026b).

1.2 Business problem

At the centre of this capstone is a clear policy and management problem: India needs more reliable and affordable energy, yet continued dependence on fossil fuels—particularly imported coal and petroleum—creates growing economic exposure. These fuels still support production, transport, logistics and power-system stability. Their rising use, however, also brings foreign-exchange outflows, price volatility, current-account pressure, imported inflation, transport bottlenecks, pollution, carbon risk and the possibility that some assets may become uneconomic. Research on India finds that oil-price shocks can transmit to exchange-rate volatility (Ghosh, 2011), while coal comparisons that include domestic environmental costs weaken the economic case for new coal capacity (Chakravarty & Somanathan, 2021). Renewable expansion has its own risks when grid, storage and institutional capacity do not keep pace, including curtailment, higher balancing costs and dependence on imported modules, cells, batteries and critical minerals. These wider system costs are well established in the variable-renewable literature (Hirth, 2013; Ueckerdt et al., 2013).

The challenge, then, is to reduce fossil-fuel vulnerability without weakening the reliability and flexibility that coal-based generation currently provides. That requires deliberate choices about the mix of renewable sources, the order in which investments are made, the continuing role of coal, the institutions responsible for delivery and the measures used to judge progress.

1.3 What is being explored

How have coal consumption, domestic production, imports and petroleum-products consumption changed, and what direction do simple linear trends suggest?

How are coal, solar and wind changing in the electricity mix, and is the available solar and wind resource large enough to support a much cleaner system?

Which renewable option is better suited to lead India's transition when growth, utilisation, geographic spread, speed of deployment and economic value are considered together?

How do coal, petroleum, solar and wind compare through the Value proposition (QCDFIR) dimensions of Quality, Cost, Delivery, Flexibility, Import Resilience and Responsiveness?

What policies, reforms, governance arrangements, strategy map and scorecard could turn the findings into practical action?

1.4 Strategic-management perspective

This capstone uses Value proposition (QCDFIR) as a practical strategic assessment lens. For greater clarity, the fifth dimension is reworded from "Identity" to "Import Resilience". The revised form therefore stands for Quality, Cost, Delivery, Flexibility, Import Resilience and Responsiveness. Quality refers to the dependability and technical usefulness of an energy source; Cost covers the wider economic burden, not only the unit price; Delivery considers whether energy reaches users when and where it is needed; and Flexibility reflects the ability to operate across changing conditions. Import Resilience examines exposure to imported fuels, equipment, technologies and critical minerals, together with the strength of domestic capability and diversified supply chains. Responsiveness considers how quickly the energy system can react to changes in demand, supply disruption, technology and policy. The framework adapts Porter's value-chain logic and operations-performance objectives to the national energy-security context (Porter, 1985; Slack, Brandon-Jones, & Burgess, 2022; Kruyt et al., 2009).

The Strategic Management Process offered for this capstone serves as the foundation for the execution framework. Setting strategic intent, developing a strategy through internal and external evaluation, putting the plan into practice through operational activities and structures, and assessing, tracking, and reviewing outcomes are the four interconnected steps that make up this process. Because it connects long-

term direction with institutions, delivery duties, and corrective action, the sequence is ideal for a national policy issue.

1.5 Scope and boundaries

The study mainly concerns coal and petroleum, two important non-renewable fuels of India. Solar and wind — the primary sources of renewable electricity — are studied. Other energy sources are only discussed where they are relevant to the overall balancing of the energy system. The common cut-off year for analysis is 2024–25, which is the latest complete period available across the selected datasets. The data from the states are aggregated to provide a national picture, but individual state data are retained where regional information is important.

The study is not intended to be a complete least-cost power-system model. It doesn't forecast hourly electricity demand, price every environmental impact or suggest closure dates for individual coal-fired power plants. The regression analysis is only used to suggest the probable direction and extent of future trends and the underlying assumptions are made clear. It should therefore be regarded as an adjunct analytical device and not as a substitute for the detailed planning undertaken by the Central Electricity Authority.

CHAPTER 2: OBJECTIVE OF STUDY

2.1 Primary objective

The main objective is to examine India's energy security through a strategic-management lens and recommend a workable path that lowers fossil-fuel vulnerability without compromising reliability, affordability or the ability to scale supply.

2.2 Specific objectives

Track the long-term movement in coal consumption, coal production, coal imports and petroleum-products consumption.

Develop transparent linear-trend projections to 2030-31 and explain where those projections may fall short.

Compare solar and wind using resource potential, installed capacity, generation growth, CUF and geographic concentration.

Estimate the possible economic benefit of additional solar and wind generation through lower exposure to imported coal.

Examine whether India has sufficient energy resources and what must be in place before those resources can provide dependable supply.

Assess how coal, petroleum, solar and wind create or reduce strategic value using Value proposition (QCDFIR).

Build a strategic management process map, policy package, governance structure and simple performance scorecard to support implementation.

Offer a short set of practical recommendations aimed at import risk, cost, reliability and transition challenges.

2.3 Research questions and value added

Table 2: Research questions and analytical outputs

Code	Research question	Value added by the study
RQ1	How rapidly are coal and petroleum requirements increasing?	National trend, CAGR and a transparent 2030-31 baseline
RQ2	Is domestic coal growth sufficient to remove import risk?	A comparison of production, demand, imports and import cost
RQ3	Should India prioritise solar or wind?	A practical comparison using potential, growth, CUF and concentration
RQ4	Does India have enough electricity resources?	The gap between resource potential and system readiness
RQ5	How do the four critical energy sources compare through Value proposition (QCDFIR)?	A common strategic assessment covering quality, cost, delivery, flexibility, identity and responsiveness
RQ6	How should strategy be executed and measured?	A four-stage process map, reform plan, simplified scorecard and governance model

Source: Author's research design.

2.4 Expected managerial and policy value

This capstone brings scattered fuel and electricity data into one structured strategic assessment. It explains why fossil fuels still matter, where they create import and economic risk, how solar and wind differ, and what must be in place for renewable potential to become dependable supply. Value proposition (QCDFIR) provides a common comparison, while the four-stage process links planning, implementation and review.

CHAPTER 3: LITERATURE REVIEW

3.1 Energy security as a multidimensional concept

Energy-security research once centred mainly on access to oil and gas. Over time, the discussion widened to include affordability, accessibility, public acceptability, infrastructure, governance, technology and resilience. Chester (2010) describes the concept as inherently context dependent, while Kruyt et al. (2009) show why several indicators are needed to represent availability, accessibility, affordability and acceptability. Sovacool and Mukherjee (2011) add technology development, sustainability and regulation, and Winzer (2012) emphasises continuity of supply relative to demand. Cherp and Jewell (2014) caution that the familiar four "As" should not be treated as a complete theory, and Ang et al. (2015) similarly find that definitions and indexes vary with national circumstances. India-specific research also shows that government, business, academic and civil-society stakeholders place different weights on supply, access, efficiency, self-sufficiency and technology (Bambawale & Sovacool, 2011).

Applied to India, this means that rising domestic coal production is not enough to establish security. Rail congestion, plant efficiency, pollution, import exposure and price volatility can still weaken the system. In the same way, a large renewable resource estimate means little unless projects can be financed, connected, balanced and delivered to consumers. This report therefore looks at availability, affordability, reliability, adaptability and strategic autonomy together.

3.2 India's coal and petroleum dependence

Coal remains important for electricity, industrial heat, steel and cement. India's mines, rail links, generating stations and skilled workforce give it considerable operational value. The weakness is that imports have grown far faster than domestic consumption over the longer period, leaving the economy exposed to international prices and shipping conditions. Petroleum is harder to substitute quickly because it is embedded in road transport, aviation, shipping, agriculture and petrochemicals. Empiri-

cal work for India links oil-price shocks with exchange-rate pressure and volatility (Ghosh, 2011). Research comparing the social costs of coal and renewable electricity also finds that pollution and health externalities materially alter the apparent cost advantage of coal (Chakravarty & Somanathan, 2021). Coal risk can therefore be reduced partly through cleaner electricity, whereas petroleum risk also demands electric mobility, public transport, rail freight, efficiency, biofuels and other alternative fuels.

3.3 Renewable-resource potential and system integration

MNRE estimates India's solar potential at about 748 GW, based on using 3% of wasteland area, and recent onshore wind potential at about 1,163.9 GW at a height of 150 metres (MNRE, 2026a; MNRE, 2026b). The resource base is clearly large. The difficult part is integration. Solar generation is concentrated in daylight hours, while wind is more site-specific and seasonal. A power system with a high renewable share therefore needs transmission, storage, flexible hydro, demand response, better forecasting, ancillary services and sufficient dispatchable capacity. Indian grid studies identify interconnections, flexible thermal operation, storage and market redesign as major enabling options (Palchak et al., 2017; Das et al., 2020). More generally, renewable comparisons based only on plant-level cost can understate profile, balancing and network costs (Hirth, 2013; Ueckerdt et al., 2013).

The Central Electricity Authority follows this portfolio approach in both the National Electricity Plan and the 2026 long-term resource-adequacy plan. These papers allow for significant non-fossil and storage expansion while keeping sufficient dispatchable capacity to ensure dependability (CEA, 2023; CEA, 2026). This emphasizes a core premise of the capstone: renewable potential counts, but operational capacity determines whether that potential impacts energy security.

3.4 Value proposition (QCDFIR) as a strategic assessment lens

Energy choices cannot be judged by cost or emissions alone. A source may be inexpensive but unreliable, dependable but import-intensive, or clean but difficult to

deliver at the time of peak demand. This study consequently employs Value proposition (QCDFIR)—Quality, Cost, Delivery, Flexibility, Import Resilience and Responsive-ness to analyze the strategic contribution and limitations of coal, petroleum, solar and wind on a common foundation. The first four characteristics derive from well-established operations-performance objectives, while Import Resilience and Responsiveness tailor the framework to national energy security and transition risk (Porter, 1985; Slack et al., 2022; Sovacool & Mukherjee, 2011).

Quality covers technical dependability and fitness for use. Cost includes fuel, infrastructure, financing, logistics, integration and wider economic exposure. Delivery concerns whether energy is available at the required time and location; Flexibility concerns the ability to change scale, location or operating pattern. Import Resilience captures dependence on imported fuels, equipment, technologies and critical minerals, as well as the availability of domestic alternatives and diversified suppliers. Responsiveness considers how quickly the source and its supporting system can adjust to demand shifts, supply shocks, technology change and new policy requirements. This rewording is preferred to "Identity" because it is more precise, measurable and directly connected to the central business problem of import exposure.

3.5 Strategic management process and execution

The Strategic Management Process supplied for this project organises strategy into four stages. The first sets strategic intent through vision, mission and objectives. The second formulates strategy by examining the external environment and the organisation or system's internal capacity. The third activates and implements the strategy through structures, processes, systems, behaviour, functional action and operational plans. The fourth evaluates, monitors and reviews performance.

Applied to India's energy security, the process starts by defining the desired balance between reliability, affordability, lower import exposure and cleaner growth. Formulation then compares demand, fuel risks, renewable resources, grid readiness, finance, manufacturing and institutional capacity. Implementation translates these

findings into coordinated programmes for solar, wind, storage, transmission, coal efficiency, petroleum-demand reduction and distribution reform. Evaluation and control close the loop by tracking outcomes and correcting plans when targets, costs or reliability conditions change.

3.6 Research gap

Energy studies often fall into one of two groups: detailed engineering forecasts or broad policy recommendations. Fewer bring together raw fuel trends, renewable viability, import economics, a common Value proposition (QCDFIR) comparison and a practical implementation process with a short scorecard. This capstone attempts to bridge that gap. Its methods are deliberately modest, but the connection between evidence, strategic choice, delivery and review is kept visible throughout.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Research design

Quantitative analysis and strategic interpretation form the basis of the study. Growth rates, energy-mix indicators, and linear trends are calculated by aggregating state and source level information to national annual values. The potential economic value is then demonstrated using a straightforward import-substitution scenario. The four-stage strategic management method, the updated Value Proposition (QCDFIR) assessment lens, and the identified energy-security dimensions are used to analyze the outcomes.

4.2 Data inventory and selection

Table 1: Critical data inventory used in the study

Area	Raw dataset	Period used	Use in analysis
Coal consumption	Sector-wise domestic coal and lignite consumption trend	2005-06 to 2024-25	National total and power-sector use
Coal production	State-wise trend of domestic production	2005-06 to 2024-25	State values aggregated / total validated
Coal imports	Consolidated country- and type-wise imports	2005-06 to 2024-25	Quantity, value and unit cost
Petroleum consumption	State-wise petroleum-products consumption trend	2010-11 to 2024-25	State values aggregated / total validated
Installed capacity	State- and source-wise electricity capacity	2015-16 to 2024-25	Coal, solar, wind and system mix
Electricity generation	Plant/state monthly generation by source	2015-16 to 2024-25	Annual national TWh
PLF/CUF	State- and source-wise PLF/CUF	2015-16 to 2024-25	Capacity-weighted utilisation
Renewable potential	State-wise solar and wind potential	Latest assessment	National potential and geographic concentration

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

4.3 Data preparation

Removed copyright notices, disclaimers, pre-calculated growth rows and blank records that were embedded in the downloaded files.

Kept valid financial-year labels and converted the relevant quantity fields into numeric values.

Selected 2024-25 as the latest common complete year and excluded later partial-year electricity observations.

Converted monthly plant-level generation into annual national TWh and aggregated state capacity into national GW.

Used reported total rows where available and checked them against the sum of the underlying records.

Converted petroleum consumption from thousand tonnes into million tonnes for consistency.

Calculated capacity-weighted PLF and CUF so that small and large state portfolios did not receive equal weight.

4.4 Indicators

The analysis uses the latest value, absolute change, compound annual growth rate, annual generation, installed-capacity and generation shares, potential utilisation, capacity-weighted PLF/CUF, imported-coal share and average import cost per tonne. CAGR is calculated as follows:

CAGR = (Ending Value / Beginning Value)^(1 / Number of Years) - 1

4.5 Linear-regression method

Ordinary least squares regression is used to relate the start year of each financial year to the national value observed in that year. The projection window covers 2015-16 to 2024-25 so that the estimated slope reflects the more recent shape of the energy system. Linear trend models are intentionally simple baselines: they are useful for communicating direction but should not be treated as structural forecasts when policy, prices or technology may change (Hyndman & Athanasopoulos, 2021). The model is:

$$Yt = a + b(Year) + \varepsilon t$$

The coefficient b is the estimated annual change. For presentation, the future trend is anchored to the actual 2024-25 value and extended using this slope, which avoids an artificial jump between the historical series and the projection. R-squared shows the in-sample fit, while a holdout RMSE based on the last three observations is calculated in the notebook as a diagnostic. The model remains easy to interpret, but it does not include fuel prices, policy changes, GDP growth, weather, technology shifts, plant retirements or structural breaks. The projected values should therefore be read as directional baselines rather than official forecasts.

Table 3: Linear-regression model summary

Series	Fit window	Annual slope	R^2	2024-25 actual	2030-31 projection
Coal consumption	2015-16 to 2024-25	42.28 Mt/year	0.879	1069.91	1323.58
Coal production	2015-16 to 2024-25	44.03 Mt/year	0.857	1092.66	1356.84
Coal imports	2015-16 to 2024-25	5.56 Mt/year	0.514	248.50	281.89
Petroleum consumption	2015-16 to 2024-25	4.21 Mt/year	0.635	227.66	252.93
Coal generation	2015-16 to 2024-25	45.50 TWh/year	0.852	1331.21	1604.23
Solar generation	2015-16 to 2024-25	14.81 TWh/year	0.967	144.15	233.02
Wind generation	2015-16 to 2024-25	5.00 TWh/year	0.921	83.35	113.35

Source: Author's regression analysis. Projections are trend-anchored baselines.

4.6 Economic-benefit scenario

The economic scenario asks how much coal-import exposure could fall if the additional solar and wind generation suggested by the 2030-31 trends replaced coal-fired output. Together, solar and wind generation rise by 118.9 TWh above the 2024-25 level. In 2024-25, the power sector used about 0.704 kg of coal for each kWh of coal-based generation. Applying that relationship gives possible coal displacement of 83.7 million tonnes. Imported coal represented about 18.5% of the combined domes-

tic-production-and-import supply base, and its average cost was about ₹10,553 per tonne. On that basis, the estimated gross annual reduction in the import bill is approximately ₹16,369 crore.

This figure is intended to show scale, not net benefit. It assumes that new renewable generation replaces coal rather than being entirely absorbed by additional demand. It also leaves out capital expenditure, transmission, storage, balancing, financing and other integration costs, and it does not distinguish between coal grades or plant efficiencies. The result should therefore be treated as an indicative measure of import-risk reduction.

4.7 Reliability, ethics and limitations

The raw extracts come from official sources, although the ICED manual notes that some series may include assumptions or derived values. Every transformation used in the report is reproduced in the separate Jupyter notebook, and no personal data are involved. Important limitations remain: the analysis uses annual rather than hourly data, the common electricity series is relatively short, trends are assumed to be linear, project-level costs are unavailable and assessed technical potential is used instead of land- and network-constrained economic potential.

CHAPTER 5: RESULTS

5.1 Non-renewable fuel trends

Coal and lignite consumption more than doubled over the study period, rising from 421.24 million tonnes in 2005-06 to 1,069.91 million tonnes in 2024-25. This is equivalent to a CAGR of 5.0%. Domestic production also grew strongly, from 437.08 million tonnes to 1,092.66 million tonnes. India has therefore added a substantial amount of domestic supply, but demand has risen quickly enough to absorb most of that increase.

Imports grew even faster. Coal imports rose from 41.19 million tonnes to 248.50 million tonnes, a CAGR of 9.9%, which is almost twice the long-run growth rate of consumption. Over the same period, the import bill increased from roughly ₹17,128 crore to ₹262,230 crore. Import quantity did fall from its 2023-24 peak, but the longer trend still shows meaningful exposure to overseas supply and prices.

Using the recent linear trend, coal consumption reaches about 1,323.6 million tonnes by 2030-31, domestic production about 1,356.8 million tonnes and imports about 281.9 million tonnes. The import projection has a lower R^2 of 0.514 because imports respond sharply to prices, domestic stocks, power demand and policy decisions. It is more useful as a warning that import risk may persist than as a precise volume forecast.

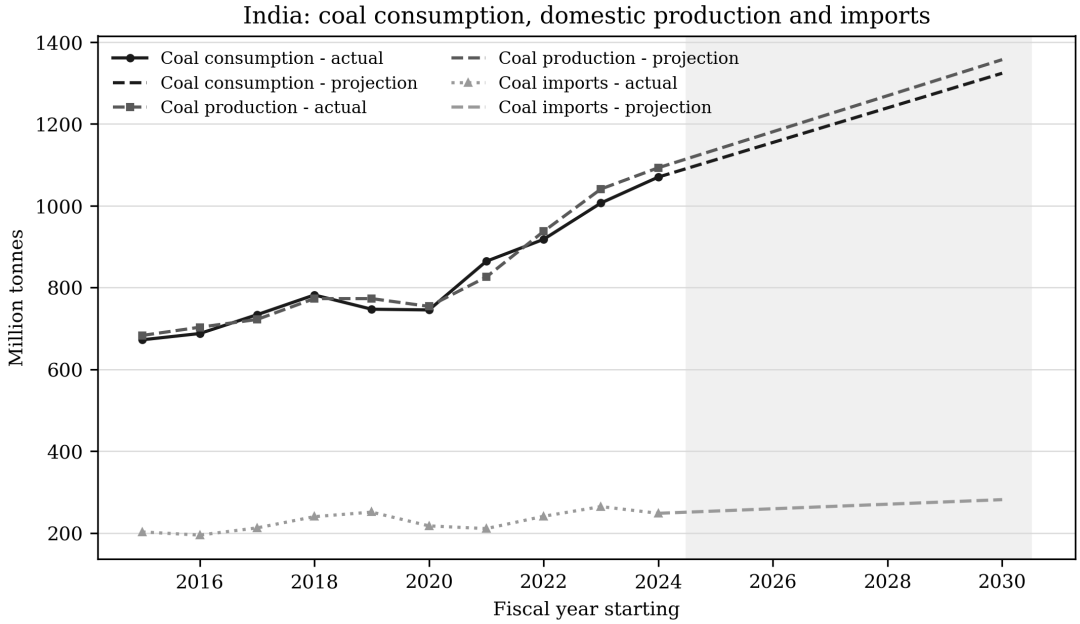

Figure 1: India coal consumption, domestic production and imports with directional projections

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

5.2 Petroleum consumption and macroeconomic exposure

Petroleum-product consumption grew from 141.79 million tonnes in 2010-11 to 227.66 million tonnes in 2024-25 at a CAGR of 3.4%. Consumption fell during the pandemic and recovered in 2024-25, but the longer trend is upward. The anchored linear baseline is about 252.9 million tonnes in 2030-31.

Petroleum poses a broader challenge than power generation alone because it is used across road transport, aviation, shipping, agriculture, petrochemicals and industry. Solar and wind can reduce this dependence only when clean electricity reaches end uses—for example through electric vehicles, railway electrification, electric industrial heat and green hydrogen—or when travel and freight shift to more efficient modes. Power-sector reform must therefore be paired with changes in how energy is consumed.

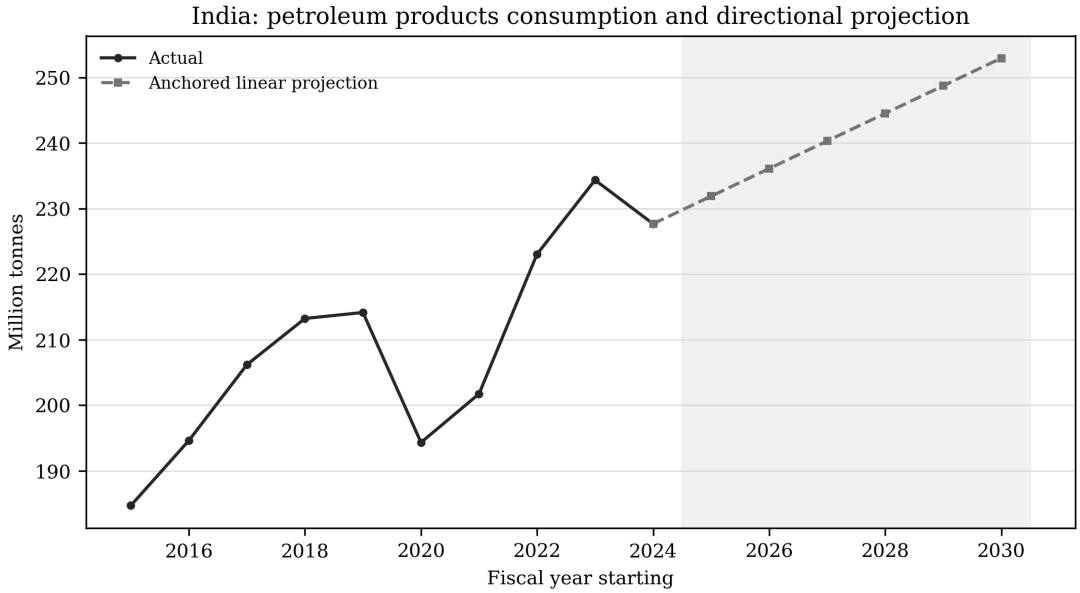

Figure 2: Petroleum-products consumption and directional projection

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

5.3 Electricity-generation transition

Coal-fired generation increased from 895.3 TWh in 2015-16 to 1,331.2 TWh in 2024-25. In the selected dataset, coal produced about 73.0% of electricity in 2024-25 despite representing only about 46.7% of installed capacity. This gap reflects its higher utilisation and dispatchable role. The capacity-weighted coal PLF was approximately 68.5%.

Solar generation rose from 7.34 TWh to 144.15 TWh, a CAGR of 39.2%, while wind increased from 33.03 TWh to 83.35 TWh, a CAGR of 10.8%. Solar has clearly become the main source of renewable scale. Wind, however, brings value at different times of day and in different seasons. Weighted CUF in 2024-25 was about 15.6% for solar and 19.0% for wind, underlining the need for larger capacity, wider geographic spread and enough balancing resources.

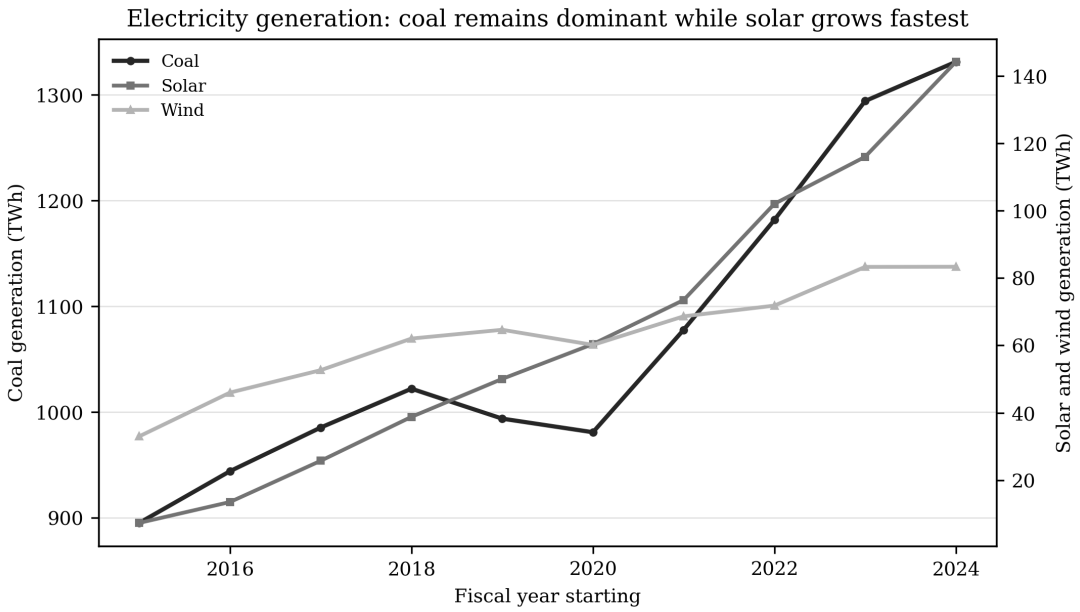

Figure 3: Coal, solar and wind electricity-generation trends

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

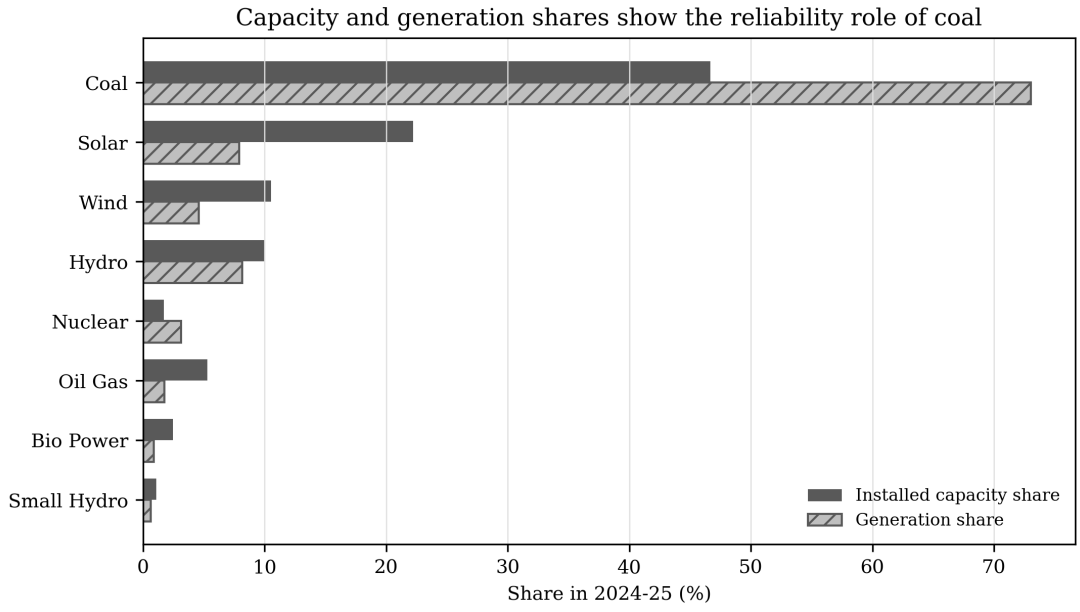

Figure 4: Installed-capacity and generation shares in 2024-25

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

5.4 Does India have enough resources?

On paper, India's renewable resource base is more than sufficient for a large transition. Assessed solar potential is about 748 GW compared with 105.6 GW in-

stalled in 2024-25, which means roughly 14.1% has been used. Wind potential is about 1,163 GW compared with 50.0 GW installed, or 4.3% utilisation. Together, assessed solar and wind potential is more than four times the total installed electricity capacity recorded in the selected dataset for 2024-25.

That does not mean the full potential is immediately usable. Projects still require land, finance, transmission, evacuation capacity, storage, forecasting, balancing and sufficient demand. Wind is especially concentrated: the five leading states hold about 80% of assessed wind potential, while the five leading solar states account for about 56% of solar potential. This makes interstate transmission and centre-state coordination essential. India has enough physical resource for a much cleaner electricity system, but it has not yet converted enough of that resource into connected and flexible capacity to remove coal's reliability role.

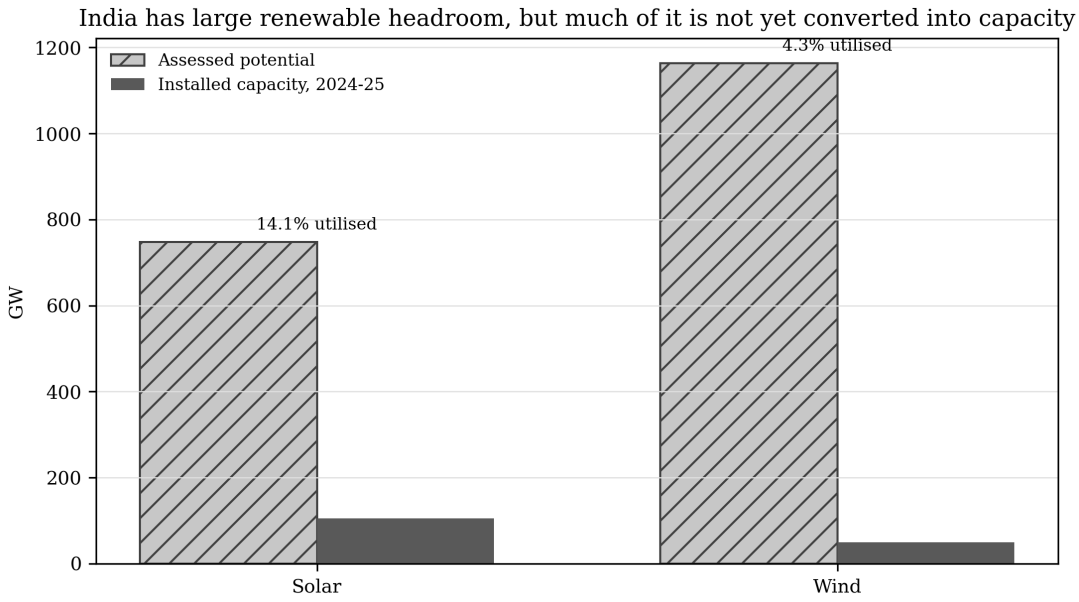

Figure 5: Solar and wind potential compared with installed capacity

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

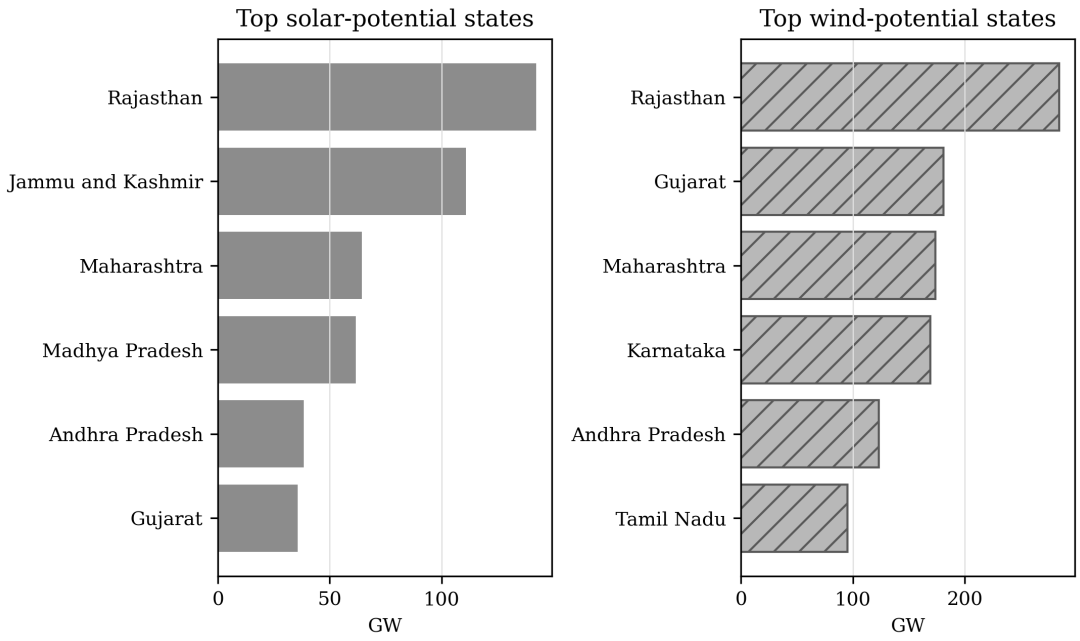

Figure 6: State concentration of assessed solar and wind potential

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

5.5 Which renewable electricity option is viable?

Table 5: Solar and wind viability comparison

Criterion	Solar	Wind	Strategic interpretation
Assessed potential	748 GW	1,163 GW	Wind has the larger technical resource estimate
Installed capacity, 2024-25	105.6 GW	50.0 GW	Solar has moved from potential to capacity more quickly
Potential utilised	14.1%	4.3%	Both sources still have substantial room to grow
Generation CAGR, 2015-16 to 2024-25	39.2%	10.8%	Solar is currently the faster-scaling platform
Weighted CUF, 2024-25	15.6%	19.0%	Wind produces more electricity per MW on average
Geographic concentration	Moderate	High	Wind needs stronger interstate transmission support
Deployment model	Utility, rooftop, agricultural and distributed	Mainly utility-scale and site-specific	Solar allows wider participation and more varied project sizes
Strategic role	Lead source for scale	Complement for diversity and non-solar hours	The best answer is a portfolio, not an either-or choice

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

The choice is not solar or wind. India is better served by a solar-led, wind-complemented and storage-backed portfolio. Solar should take the larger share of near-term additions because it is expanding faster and can be used in utility-scale parks, rooftops, farms and distributed systems. Wind should grow more quickly in high-resource states, older sites should be repowered, and procurement should favour hybrid or firm-and-dispatchable products. Wind's higher CUF and different generation pattern can reduce the amount of storage and coal balancing needed in a solar-heavy system. This portfolio approach is consistent with research showing that diversity improves robustness and reduces concentration risk (Stirling, 2010), while Indian power-system studies emphasise the need for flexibility, coordination and storage (Das et al., 2020).

5.6 Indicative benefit to the Indian economy

Between 2024-25 and 2030-31, the projected increase in solar and wind generation is about 118.9 TWh. At the coal-use intensity observed in 2024-25, this output could replace roughly 83.7 million tonnes of coal. Applying the observed imported-coal share and average import cost produces an indicative gross annual import-bill reduction of about ₹16,369 crore.

Scenario	Indicative gross coal-import-bill relief
50% of estimated displacement realised	₹8,184 crore/year
75% of estimated displacement realised	₹12,277 crore/year
100% of estimated displacement realised	₹16,369 crore/year

Source: Author's scenario using supplied generation, coal-consumption, production and import data. Gross benefit before system costs.

The broader economic benefit may be higher, although this report does not place a value on it. Possible gains include lower exposure to foreign-exchange and commodity-price shocks, less pressure on railways and ports, reduced pollution and carbon costs, additional manufacturing and infrastructure investment, and more competitive low-carbon power for industry. These benefits depend on how much value is created within India. Heavy reliance on imported modules, cells, inverters,

batteries and critical minerals could replace part of the fossil-fuel import bill with a clean-technology import bill. Domestic manufacturing, recycling and diversified supply chains should therefore be viewed as energy-security measures as well as industrial policy. At higher shares of variable renewables, the analysis must also include profile, balancing and network costs rather than relying only on technology-level LCOE (Hirth, 2013; Ueckerdt et al., 2013).

5.7 Critical findings at a glance

Table 4: Critical national energy-security findings

Area	Evidence	Strategic meaning
Coal consumption	1,069.9 Mt in 2024-25; 5.0% long-run CAGR	Demand growth remains strong
Coal imports	248.5 Mt; ₹262,230 crore	Import cost and global price exposure remain significant
Petroleum consumption	227.7 Mt in 2024-25	Transport and industry need separate end-use reforms
Coal electricity role	73.0% of selected-source generation	The transition must be managed rather than abrupt
Solar scale	105.6 GW; generation CAGR 39.2%	Solar is the strongest lead option for near-term scale
Wind value	50.0 GW; weighted CUF 19.0%	Wind is important for diversity and higher utilisation
Resource sufficiency	1,911 GW combined assessed potential	The resource is sufficient; integration is the main constraint
Economic scenario	About ₹16,369 crore annual gross import relief	The potential benefit is material but depends on real displacement and supporting investment

Source: Author's analysis of the supplied NITI Aayog ICED data extracts.

5.8 Strategic fuel assessment through Value proposition (QCDFIR)

In this report, the Value proposition (QCDFIR) framework stands for Quality, Cost, Delivery, Flexibility, Import Resilience and Responsiveness. Import Resilience measures exposure to imported fuels, clean-energy equipment, technologies and critical minerals, together with the strength of domestic alternatives and diversified supply chains. Responsiveness measures how quickly the energy system can respond to demand changes, supply disruptions, technology and policy. No single fuel is expected to lead on every dimension.

Table 6: Strategic fuel assessment through Value proposition (QCDFIR)

Value proposition (QCDFIR) dimension	Coal	Petroleum	Solar	Wind
Quality	Firm output; grade and plant efficiency vary	High energy density; dependable for transport	Clean output; weather-dependent daytime profile	Clean output; higher utilisation but site-dependent
Cost	Domestic base; logistics, pollution and import costs	High import bill and foreign-exchange exposure	No fuel cost; storage and grid costs remain	Competitive at good sites; transmission can add cost
Delivery	Dispatchable if mine, rail and stocks are adequate	Mature network; exposed to international supply	Fast to build; delivery is daylight-concentrated	Seasonal and geographically concentrated
Flexibility	Continuous supply; older units ramp slowly	Highly versatile across transport and industry	Highly modular; storage improves dispatchability	Complements solar; less modular
Import Resilience	Domestic resource base, but import blending and transport dependence create exposure	Weak: high crude-import and foreign-exchange exposure	Strong on fuel independence; equipment and mineral imports still matter	Strong on fuel independence; domestic manufacturing can deepen resilience
Responsiveness	Meets sustained demand; vulnerable to transport and policy shocks	Quick to use; exposed to price and geopolitical shocks	Scales quickly; evening demand needs system support	Useful with forecasting and interstate transfer

Source: Author's strategic assessment based on the supplied data and reviewed literature.

The comparison shows why India needs a managed portfolio rather than a single-fuel answer. Coal remains valuable for dependable delivery and near-term system response when stocks and transport work well, but its pollution, logistics burden and import exposure weaken its wider strategic position. Petroleum is highly versatile, yet its import dependence creates a persistent cost and foreign-exchange risk. Solar improves fuel independence and can be deployed rapidly at different scales, although storage and grid support are needed beyond daylight hours. Wind adds diversity and generally higher utilisation, but its location-specific nature makes forecasting and interstate transmission essential. The practical direction is therefore solar-led expansion, wind as a complement, storage and networks as enablers, coal managed for reliability, and petroleum demand reduced through end-use reform. This emphasis on diversity and complementary capabilities is consistent with portfolio-based energy analysis (Stirling, 2010).

5.9 Strategic management process map

The process map is adapted from the four-step Strategic Management Process supplied for this project. It begins with vision, mission and objectives; uses external and internal appraisal to formulate the strategy; moves into activation, structures, systems and operational delivery; and ends with evaluation, monitoring and review. The map is intentionally simple. It shows who must decide, implement and correct the strategy rather than presenting a broad set of perspectives with weak accountability.

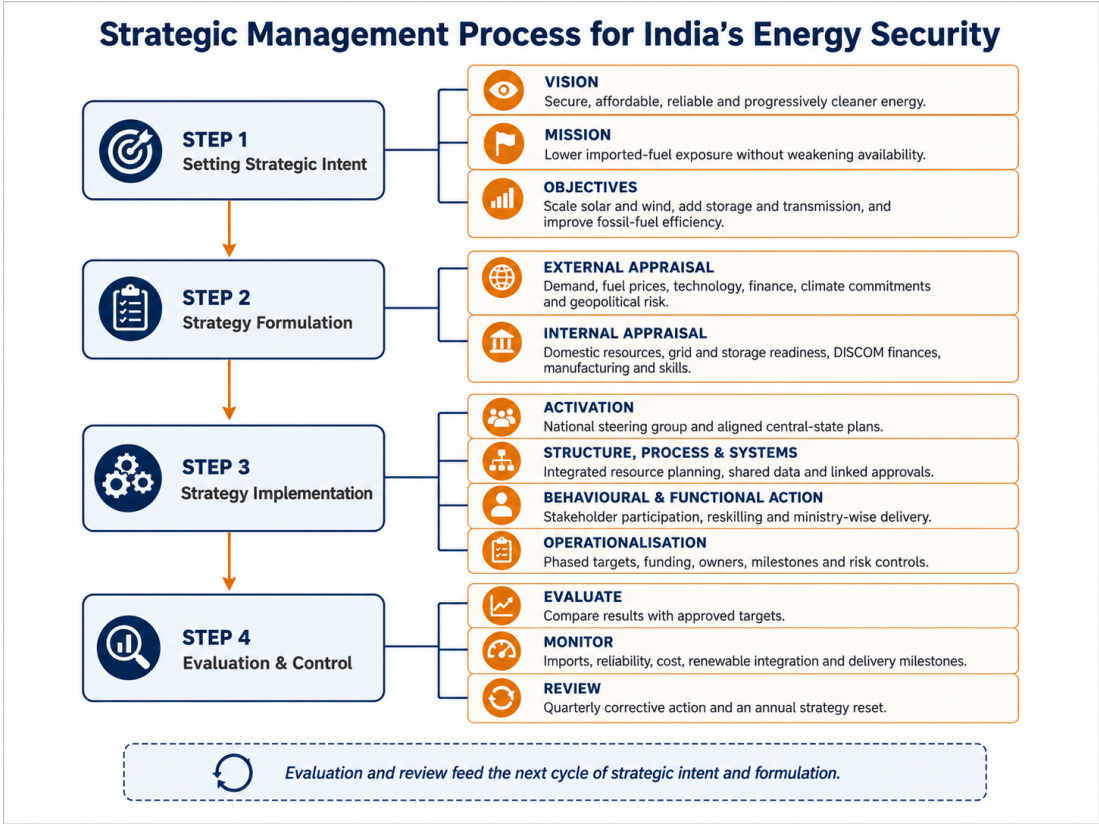

Figure 7: Strategic management process for India's energy security

Source: Author's adaptation of the supplied Strategic Management Process reference.

5.10 Policy and reform portfolio

Table 7: Policy and reform portfolio

Reform	Action	How it addresses the problem	Lead institutions
1. Integrated national resource planning	Combine demand, generation, fuel, storage, transmission and state plans in one rolling adequacy process.	Prevents capacity additions that are disconnected from grid and flexibility needs.	CEA, Ministry of Power, Grid-India, states
2. Solar-led hybrid procurement	Procure solar with wind, storage or firming obligations rather than isolated energy-only capacity.	Reduces balancing need and improves delivery quality.	SECI, DISCOMs, SERCs
3. Storage and flexible-demand market	Accelerate BESS, pumped storage, ancillary services, time-of-day tariffs and industrial demand response.	Converts variable renewable energy into dependable supply.	Ministry of Power, CERC, Grid-India, states
4. Managed coal transition	Improve efficient plants, retire the least efficient units based on adequacy studies, strengthen stocks and diversify imports.	Maintains reliability while lowering coal intensity and stranded-asset risk.	Ministry of Coal, CEA, generators, Railways
5. Petroleum-demand reduction	Scale EVs, public transport, rail freight, fuel efficiency, biofuels and green-hydrogen pilots for hard-to-abate uses.	Addresses the largest structural import vulnerability outside power.	MoPNG, MoRTH, Railways, states
6. Domestic manufacturing and circularity	Deepen the domestic manufacturing base for PV cells, modules, inverters, batteries and wind components; require recycling and material recovery.	Avoids replacement of fuel imports by technology imports.	MNRE, Ministry of Heavy Industries, industry
7. DISCOM and tariff reform	Improve cost recovery, reduce losses, use smart meters and protect vulnerable consumers through transparent targeted support.	Creates bankable demand and enables time-responsive consumption.	Ministry of Power, states, regulators
8. Land, community and just transition	Use land banks, benefit sharing, local jobs, worker reskilling and district transition plans.	Improves legitimacy and reduces project delay and social risk.	States, districts, developers, labour institutions
9. Data and accountability	Publish a quarterly national energy-security scorecard with consistent definitions and forecast-versus-actual review.	Creates execution discipline and early warning.	NITI Aayog, CEA, PPAC, ministries

Source: Author's recommendations aligned with CEA, MNRE and Ministry of Power policy directions.

5.11 Implementation governance

Implementation should be managed as one connected portfolio. A National Energy Security Steering Group, supported by NITI Aayog and data from CEA, Grid-India, PPAC, the Ministry of Coal and MNRE, should review progress quarterly and reset the strategy annually. Each major initiative should have a named owner, baseline, milestones, funding source, dependencies and risk controls. States need aligned plans because they influence land, distribution, approvals and transition impacts. Coal retirements and renewable auctions should proceed only when replacement capacity, transmission, storage and reserve requirements have been verified.

5.12 Strategy scorecard

The scorecard is kept deliberately short and follows the same four stages as the process map. It focuses on a small number of measures that show whether the strategy is being defined clearly, translated into integrated plans, delivered on the ground and corrected when performance moves off course. This approach follows the principle that performance measures should translate strategy into a coherent and reviewable set of outcomes and drivers (Kaplan & Norton, 1992, 2004; Neely, Gregory, & Platts, 1995).

Table 8: Simplified strategy scorecard

Stage	Primary focus	Key actions	Simple checks
1. Strategic intent	Set the national direction	Approve vision, mission, objectives and time-bound energy-security priorities	Annual approval; clear targets for imports, reliability, cost and clean energy
2. Formulation	Match demand, resources and risk	Prepare one rolling fuel, power, storage, grid and state plan	Plan updated annually; scenarios and dependencies documented
3. Implementation	Deliver programmes in sequence	Coordinate renewables, storage, grids, coal efficiency, petroleum-demand and DISCOM reform	Quarterly milestone dashboard; a named owner for each programme
4. Evaluation & control	Correct course	Review results, investigate gaps and revise actions or targets	Quarterly review; annual reset using import, reliability, cost and curtailment indicators

Source: Author's scorecard aligned with the supplied four-stage Strategic Management Process.

CHAPTER 6: CONCLUSIONS

6.1 Conclusions from the exploration

India’s energy-security challenge is fundamentally about managing a transition. Coal consumption, production and generation have all grown, and coal still provides most of the dependable electricity in the selected data. At the same time, imports have risen much faster over the long run, creating avoidable exposure to external prices and supply conditions. Petroleum consumption is also moving upward and will not be solved through power-sector reform alone.

A significant drop in fossil-fuel usage seems possible given the available solar and wind potential. While the physical potential is considerable, progress depends on converting that capacity into a reliable flow of electricity. Generation, transmission, storage, flexibility in demand, a stable supply-side business model, local manufacturing, physical infrastructure, access to land, community enablement, a robust data and institutional framework a whole ecosystem of developments that need to come about simultaneously.

Therefore, with regards to driving the transition solar looks to be the most plausible leader due to its rapid scaling capacity. Solar can be deployed through various means like utility projects, rooftops, farm based and distributed systems.The fact that wind has generally larger capacity utilisation and a different power profile makes it a good complement to solar and can help improve overall balancing. The most sensible mix in this regard appears to be solar-led, wind augmented with storage as a final safety net.

This also has significant economic implications. Assuming that all the extra solar and wind generation between 2030-31 (which is the anticipated growth between 2030-31) substituted coal capacity in the same ratio, there would be about Rupees 16,369 crores of annual 'gross savings' in the coal imports bill. This should be noted as not a net saving estimate, just that renewable integration should help directly in forex conservation and mitigation of risks.

6.2 How the recommendations address the negatives of non-renewables

Import and foreign-exchange exposure can fall as domestic solar and wind replace part of imported coal and as electrification and modal shift reduce petroleum demand.

Long-term renewable contracts and a broader domestic resource base can limit exposure to global fuel-price shocks and imported inflation.

Reliability can be protected through a managed coal transition supported by storage, interstate transmission, demand response and resource-adequacy planning, rather than abrupt closures.

Lower coal movement can ease pressure on ports, railways and working capital, while better digital stock management can protect the reliability of the coal system that remains.

Lower coal intensity, retirement of inefficient units, clean electricity and end-use electrification can reduce pollution and carbon exposure.

Linking plant-retirement decisions to adequacy milestones, re-skilling and district transition plans can limit stranded assets and protect workers and communities.

Domestic manufacturing, quality standards, recycling and diversified critical-mineral supply can prevent one form of import dependence from being replaced by another.

6.3 Prioritised final suggestions

Table 9: Prioritised final suggestions

Priority	Suggestion	Strategic reason	Timing
1	Adopt one national energy-security score-card	Gives ministries and states one common baseline and review process.	Immediate
2	Make storage and transmission a pre-condition for renew-able scale	Reduces curtailment and pro-tects reliability as renewable capacity grows.	Immediate to 2030
3	Use solar as the lead source and wind as the balancing complement	Combines rapid solar expan-sion with wind's higher CUF and seasonal diversity.	2026-31
4	Manage coal by effi-ciency and adequacy, not by uniform dates	Cuts coal intensity without cre-ating shortages or replacing capacity too early.	Continuous
5	Treat petroleum-de-mand reduction as a separate strategic pro-gramme	Addresses transport and indus-trial fuel use that clean power alone cannot solve.	2026-35
6	Strengthen domestic clean-energy manufac-turing and recycling	Keeps more jobs, investment and import savings within In-dia.	2026-32
7	Reform DISCOM economics and de-mand flexibility	Makes procurement bankable and allows demand to support grid balancing.	Immediate to 2030
8	Fund a just transition in coal-intensive dis-tricts	Protects workers, communities and the legitimacy of the transi-tion.	Before major retire-ments
9	Use quarterly forecast-versus-actual reviews	Allows policy to adjust when demand, fuel prices, projects or technology change.	Quarterly

Source: Author's final recommendations.

6.4 Limitations and future scope

A fuller study would combine these annual trends with hourly demand and generation, plant-level heat rates, project costs, storage duration, transmission con-straints, land suitability, employment exposure and state finances. It would also com-pare several demand, fuel-price and technology-cost scenarios rather than extend one historical trend. Future research could develop a state-level energy-security readiness index, provided that its methodology remains transparent and it is not presented as an official NITI Aayog ranking.

REFERENCES

1. Ang, B. W., Choong, W. L., & Ng, T. S. (2015). Energy security: Definitions, dimensions and indexes. Renewable and Sustainable Energy Reviews, 42, 1077-1093. https://doi.org/10.1016/j.rser.2014.10.064

2. Bambawale, M. J., & Sovacool, B. K. (2011). India's energy security: A sample of business, government, civil society, and university perspectives. Energy Policy, 39(3), 1254-1264. https://doi.org/10.1016/j.enpol.2010.11.053

3. Central Electricity Authority. (2023). National Electricity Plan, Volume I: Generation. https://cea.nic.in/wp-content/uploads/irp/2023/05/NEP_2022_32_FINAL_GAZETTE-1.pdf

4. Central Electricity Authority. (2026). Long-term national resource adequacy plan, 2026-27 to 2035-36. https://cea.nic.in/wp-content/uploads/notification/2026/04/Long_term_National_Resource_Adequacy_Plan2026_27_to_2035_36.pdf

5. Chakravarty, S., & Somanathan, E. (2021). There is no economic case for new coal plants in India. World Development Perspectives, 24, 100373. https://doi.org/10.1016/j.wdp.2021.100373

6. Cherp, A., & Jewell, J. (2014). The concept of energy security: Beyond the four As. Energy Policy, 75, 415-421. https://doi.org/10.1016/j.enpol.2014.09.005

7. Chester, L. (2010). Conceptualising energy security and making explicit its polysemic nature. Energy Policy, 38(2), 887-895. https://doi.org/10.1016/j.enpol.2009.10.039

8. Das, P., Mathuria, P., Bhakar, R., Mathur, J., Kanudia, A., & Singh, A. (2020). Flexibility requirement for large-scale renewable energy integration in Indian power system: Technology, policy and modeling options. Energy Strategy Reviews, 29, 100482. https://doi.org/10.1016/j.esr.2020.100482

9. Ghosh, S. (2011). Examining crude oil price-exchange rate nexus for India during the period of extreme oil price volatility. Applied Energy, 88(5), 1886-1889. https://doi.org/10.1016/j.apenergy.2010.10.043

10. Government of India, Ministry of Finance. (2024). Economic Survey 2023-24: Climate change and energy transition. https://www.indiabudget.gov.in/budget2024-25/economicsurvey/doc/eschapter/echap06.pdf

12. Hirth, L. (2013). The market value of variable renewables: The effect of solar and wind power variability on their relative price. Energy Economics, 38, 218-236.

13. Hyndman, R. J., & Athanasopoulos, G. (2021). Forecasting: Principles and practice (3rd ed.). OTexts. https://otexts.com/fpp3/

14. Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard—Measures that drive performance. Harvard Business Review, 70(1), 71-79.

15. Kaplan, R. S., & Norton, D. P. (2004). Strategy maps: Converting intangible assets into tangible outcomes. Harvard Business School Press.

16. Kruyt, B., van Vuuren, D. P., de Vries, H. J. M., & Groenenberg, H. (2009). Indicators for energy security. Energy Policy, 37(6), 2166-2181. https://doi.org/10.1016/j.enpol.2009.02.006

17. Ministry of New and Renewable Energy. (2026a). Solar overview. https://mnre.gov.in/en/solar-overview/

18. Ministry of New and Renewable Energy. (2026b). Wind overview. https://mnre.gov.in/en/wind-

overview/
19. Ministry of New and Renewable Energy. (2026c). National programme on high-efficiency solar PV modules: Production-linked incentive scheme. https://mnre.gov.in/en/production-linked-incentive-pli/
20. Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. International Journal of Operations & Production Management, 15(4), 80-116. https://doi.org/10.1108/01443579510083622
21. NITI Aayog. (2026a). India Climate and Energy Dashboard. https://iced.niti.gov.in/
22. NITI Aayog. (2026b). India Climate and Energy Dashboard manual. https://icedcdn.niti.gov.in/iced-manual.pdf
23. Palchak, D., Cochran, J., Ehlen, A., McBennett, B., Milligan, M., Chernyakhovskiy, I., Deshmukh, R., Abhyankar, N., Soonee, S. K., Narasimhan, S. R., Joshi, M., & Sreedharan, P. (2017). Greening the Grid: Pathways to integrate 175 gigawatts of renewable energy into India's electric grid, Volume I—National study. National Renewable Energy Laboratory. NREL/TP-6A20-68530.
24. Petroleum Planning and Analysis Cell. (2026). Snapshot of India's oil and gas data and ready reckoner. https://ppac.gov.in/
25. Porter, M. E. (1985). Competitive advantage: Creating and sustaining superior performance. Free Press.
26. Slack, N., Brandon-Jones, A., & Burgess, N. (2022). Operations management (10th ed.). Pearson.27. Sovacool, B. K., & Mukherjee, I. (2011). Conceptualizing and measuring energy security: A synthesized approach. Energy, 36(8), 5343-5355. https://doi.org/10.1016/j.energy.2011.06.043
28. Stirling, A. (2010). Multicriteria diversity analysis: A novel heuristic framework for appraising energy portfolios. Energy Policy, 38(4), 1622-1634. https://doi.org/10.1016/j.enpol.2009.02.090
29. Ueckerdt, F., Hirth, L., Luderer, G., & Edenhofer, O. (2013). System LCOE: What are the costs of variable renewables? Energy, 63, 61-75. https://doi.org/10.1016/j.energy.2013.10.072