Working Draft

on

"A Unified National Energy Policy Framework for India: Adequacy, Access, Affordability, and Appropriate Sustainability"

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INSA-Centre for Science, Technology, Innovation and Policy

Contents

Draft

List of Abbreviations

AI	Artificial Intelligence
ANRF	Anusandhan National Research Foundation
BESS	Battery Energy Storage Systems
CBG	Compressed Biogas
CBM	Coal Bed Methane
CCUS	Carbon Capture, Utilisation and Storage
CCTS	Carbon Credit Trading Scheme
CE	Circular Economy
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CST	Concentrated Solar Thermal
DME	Dimethyl Ether
DPI	Digital Public Infrastructure
EBP	Ethanol Blending Programme
EV	Electric Vehicle
GIS	Geographic Information System
HELE	High Efficiency Low Emission
IGCC	Integrated Coal Gasification Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
JETP	Just Energy Transition Partnership
KG	Krishna-Godavari
LCA	Lifecycle Assessment
LNG	Liquefied Natural Gas
MDB	Multilateral Development Bank
MSME	Micro, Small and Medium Enterprises
NECA	National Energy Coordination Authority
NITI	National Institution for Transforming India
OTEC	Ocean Thermal Energy Conversion
PAT	Perform Achieve and Trade

PCM	Phase Change Materials
PFBG	Pressurised Fluidised Bed Gasification
PHS	Pumped Hydro Storage
PMUY	Pradhan Mantri Ujjwala Yojana
PV	Photovoltaic
R&D	Research and Development
RDI	Research, Development, and Innovation
SATAT	Sustainable Alternative Towards Affordable Transportation
TRL	Technology Readiness Level
UCG	Underground Coal Gasification
VLE	Village Level Entrepreneur

"Energy is the golden thread that connects economic growth, increased social equity, and an environment that allows the world to thrive."

Former UN Secretary-General, Ban Ki-moon

1 Introduction: India's Energy Imperative: Context and the Case for a Unified Framework

India's energy system is entering a defining phase of transformation. Evolving global energy markets, shifting geopolitical dynamics, including ongoing conflicts in West Asia and Ukraine and rapidly accelerating domestic energy demand have collectively elevated energy security from a sectoral concern to a matter of national strategic priority. A substantial share of India's crude oil imports transits through the Strait of Hormuz and other sensitive maritime chokepoints, exposing supply chains to external disruption risks that domestic policy cannot fully control.[1] Of the three fossil fuels – crude oil, coal and natural gas, that are essential for India's energy security on a business-as-usual basis, only coal reserves are abundant. Yet this domestic resource is under-leveraged for liquid and gaseous fuel applications and used primarily for heat and power.

At the same time, the climatically fragile Himalayan and coastal ecosystems of India underscore the urgency of reducing the carbon intensity of the national energy system, consistent with India's commitments under the Paris Agreement and its own net-zero target of 2070.[2] However, it may be noted that India's climate vulnerability is not a consequence of India's own emissions, but by a legacy of cumulative emissions for over 250 years from the industrialisation of the Global North before environmental impact of anthropogenic activity began to gain recognition in the second half of the twentieth century. Therefore, rather than treating geopolitical risk and climate ambition as competing constraints, the present moment represents a strategic inflection point, one that enables India to evolve from a predominantly import-dependent energy structure toward a more diversified, resilient, and domestically anchored integrated energy ecosystem. This cannot be achieved merely by imports of energy value chain products like solar cells and battery storage materials, or by investing in natural gas or hydrogen infrastructure if that only leads to further foreign exchange outflows for the long term or places unforeseen strain on land or water resources. A conscious policy path towards capacity and capabilities to align energy demand growth with domestic supplies and multilateral negotiating leverage for balancing energy imports is evidently imperative.

[1] https://www.business-standard.com/economy/analysis/datanomics-strait-of-hormuz-still-remains-critical-for-crude-oil-import-125062400864_1.html?utm_source=chatgpt.com

[2] https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1945472

This document seeks to identify key opportunities, challenges, and the structural shifts necessary to transition India from its current import-dependent, fossil fuel–dominated energy landscape towards a more resilient, diversified, and sustainable system within a Unified National Policy Framework. In doing so, it situated the energy transition within the broader national development trajectory, aligning sectoral priorities and policy design with the already articulated long-term goals of achieving *'Viksit Bharat'* by 2047 and Net Zero emissions by 2070.

1.1 A Decade of Progress

Over the past decade, India has made substantial and measurable advances across multiple dimensions of energy access, supply, and efficiency. For instance, The Saubhagya scheme (Pradhan Mantri Sahaj Bijli Har Ghar Yojana) achieved near-universal household electrification[3]. India's renewable energy installed capacity grew from 76.38 GW in 2014 to over 262 GW of non-fossil capacity by November 2025, and reached 283.46 GW by March 2026, a nearly 3.6-fold increase in a decade.[4] Energy efficiency initiatives such as the Perform-Achieve-Trade (PAT) scheme[5] and the Ethanol Blending Programme (EBP)[6] have further reduced carbon dioxide emissions and foreign exchange outflow. The Pradhan Mantri Ujjwala Yojana (PMUY) extended clean cooking access to over 9 crore beneficiary households, significantly reducing reliance on traditional biomass combustion and delivering measurable improvements in public health and gender outcomes (MoPNG, 2023).[7] These achievements are significant; while they provide the foundation on which the next phase of India's energy transition must be built, these cannot be independent, disconnected initiatives but must work within an overall architecture that recognizes the importance of holistic energy policy as pivotal to the nation's aspirations and specific desired outcomes for sustainable development.

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[3] Ministry of Power, Government of India. 'Electrification of Households under Saubhagya Scheme.' https://www.pib.gov.in/PressReleasePage.aspx?PRID=2157549

[4] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2209478&reg=3&lang=2

[5] Bureau of Energy Efficiency, Government of India. 'Perform Achieve and Trade (PAT) Scheme.' https://beeindia.gov.in/en/programmes/perform-achieve-and-trade-pat

[6] Ministry of Petroleum and Natural Gas. 'Ethanol Blending Programme (EBP).' https://www.pib.gov.in/PressReleasePage.aspx?PRID=1944964

[7] https://mopng.gov.in/en/annual-reports

The Structural Gap: Why a Unified Framework is essential.

India's experience also reveals a deeper structural challenge: the absence of an integrated, unified framework in energy policy and implementation. Energy systems mature with scale and reliability of demand, and it is important that industrial production and commercial services capacities be ramped up in line with the 2047 Viksit Bharat goals while energy capacities are scaled to service such demand. The Draft National Energy Policy (2017) by NITI Aayog[8] was one of the few attempts to provide a comprehensive, cross-sectoral roadmap. In the absence of such an approved and confirmed policy built on alignment and consensus of all concerned stakeholders, energy governance has remained dispersed across multiple ministries, Power, Petroleum and Natural Gas, Coal, New and Renewable Energy, Heavy Industries, and others, producing siloed optimisation, inconsistent incentives, and repeated mismatches between supply-side investment and downstream market readiness.

An example of such conflicts is the simultaneous policy push for renewable energy expansion alongside the continued structural support for coal-based generation. While renewable energy is driven by instruments such as mandatory procurement obligations and competitive bidding, coal power remains entrenched through long-term power purchase agreements and assured fuel supply mechanisms. This dual commitment creates a lock-in effect, where distribution companies are obligated to absorb increasing volumes of renewable power while continuing to bear fixed costs of existing coal capacity, resulting in overcapacity, financial stress, and the risk of stranded assets.

Another example of such conflicts is the mismatch between mandated renewable procurement and the continued regulation of retail electricity tariffs. Distribution companies are required to procure renewable energy, but their ability to recover associated costs is constrained by politically determined tariffs. This creates a structural gap between cost and revenue, leading to persistent financial stress, delayed payments to generators, and weakened investor confidence. This is further discussed in detail in Section 2.2.

The fuel-side opportunity can be understood from two data points: in 2018, India brought in roughly 350 MMT of carbon atoms embedded in petroleum, coal and natural gas imports. By 2022, in spite of increased fuel demand underpinned by economic growth and post-COVID recovery, this had

[8] NITI Aayog, Government of India. 'Draft National Energy Policy.' June 2017. https://www.niti.gov.in/sites/default/files/2022-12/NEP-ID_27.06.2017.pdf.pdf

fallen to ~330 MMT of carbon atoms as the ethanol blending program (EBP) and energy efficiency initiatives gathered momentum. Yet, India continues to discard over 450 MMT of carbon atoms annually; harnessing these wastes through circular economy efforts can supplement appropriate use of our nation's coal reserves, which translate to roughly 340,000 MMT carbon atoms – a thousand-fold in excess of our annual imports.

Future progress will depend not only on continued investment in supply-side technologies, but on strengthening the institutional coherence and governance mechanisms that allow electricity, fuels, and molecules to function as an integrated national energy system. Absence of overarching focus on technology imports with a caveat of affordability needs to be highlighted as a historical shortcoming due to lack of adequate interministerial coordination.

1.2 Purpose and Scope

In this context, the present document proposes a Unified National Energy Policy Framework aligned with India's aspiration for energy self-reliance by 2047 and net-zero emissions by 2070.[9] The framework treats biomass residues, municipal waste streams, indigenous coal resources, and renewable power not as competing priorities but as complementary feedstocks within a diversified, integrated national energy portfolio whose priority is to ensure adequate and affordable energy supply, consistent with India's long-term development objectives. The unified policy framework treats decarbonisation as a strategic objective, but not independently of adequacy, affordability, and national developmental realities.

While the opportunity to address greenhouse gas mitigation pathways (IPCC, 2023)[10] is important, effective energy policy in the same global context requires clarity on India's stated position aligned with the principle of common but differentiated responsibilities and respective capabilities as the basis of global action towards international climate equity. Therefore, India must consciously navigate the space between aspirational goals and practical constraints, balancing what is desirable with what is feasible given economic limits, technology readiness, institutional capacity, and resource availability. This reinforces the fact that while India is committed to sustainable development, it cannot come at the cost of adequacy, access and affordability of energy, given the well-established correlations

[9] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2216661&reg=3&lang=2
[10] https://www.ipcc.ch/report/ar6/syr/

between energy and quality of life[11]. The Energy Policy Architecture Schematic (Figure 1) illustrates this balance and frames the policy design approach adopted throughout this brief.

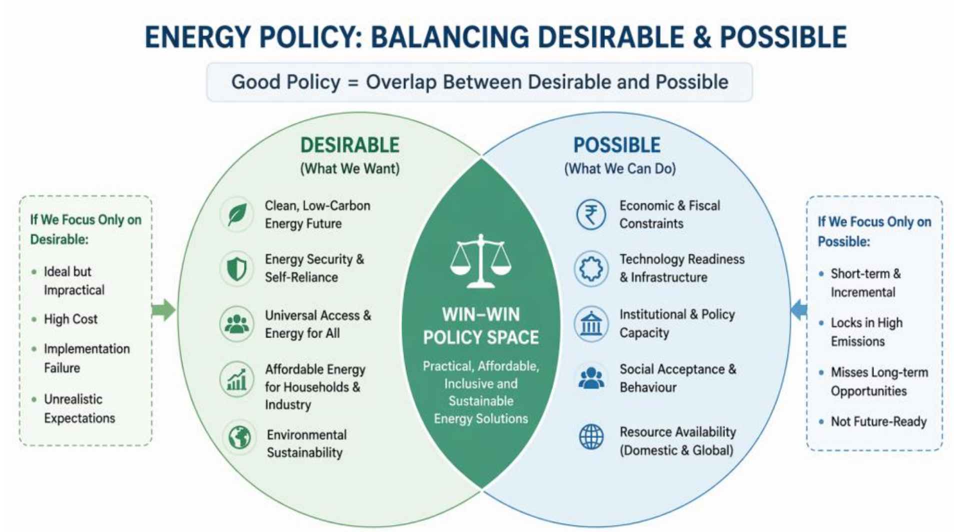

Figure 1 Energy Policy Architecture Schematic

The framework is structured around four mutually reinforcing pillars:

1. **Adequacy** — Secure reliable energy supply using domestic resources and diversified pathways
2. **Access** — Ensure equitable and resilient energy delivery through an efficient grid for power, sufficient integration of domestic carbon resources into fuel production facilities, pipeline capacity for existing and emerging liquid and gaseous fuels, infrastructure adequacy for E-vehicles charging and maintenance, and last-mile decentralised systems wherever necessary.
3. **Affordability** — Incentivise whole-system efficiency; invest in R&D, infrastructure and user awareness to ensure that energy is financially accessible to all consumers and economically competitive for Indian industry, with energy costs remaining within bearable shares of household income and not impairing industrial competitiveness.
4. **Appropriate Sustainability** — Continue to address climate goals while preserving national energy sovereignty; investment in adaptation efforts alongside mitigation efforts is also important but outside the scope of this Unified National Policy Framework.

[11] World Bank Group, & International Energy Agency. (2015). *Sustainable energy for all 2015: Progress toward sustainable energy.* World Bank. https://documents1.worldbank.org/curated/en/293681637734966389/pdf/Sustainable-Energy-for-All.pdf

The sections that follow diagnose the structural challenges this framework must address (Section 2), present the four-pillar strategic framework in detail (Section 3), outline the governance and financing reforms required to operationalise it (Section 4), and conclude with actionable recommendations and a time-bound implementation roadmap (Sections 5–6).

Key areas where a unified framework can add immediate and measurable value include:

Reducing long-term dependence on imported fuels and critical materials through domestic innovation and resource mobilisation

- Strengthening grid resilience and flexibility to absorb variable renewable generation
- Improving inter-ministerial coordination to enable integrated energy planning across the full value chain
- Aligning production ambitions with downstream industrial demand, pricing structures, and consumer markets
- Enhancing convergence between electricity, fuels, and industrial energy systems to maximise efficiency and economic returns
- Deploying Digital Public Infrastructure, including deep data analytics and AI, across Centre, State, and Local Government levels to enable real-time demand-distribution-supply monitoring and evidence-based periodic policy review.

2 Current Challenges in India's Energy Sector

2.1 Structural Import Dependence

India imports various energy sources, including fossil fuels (coal, crude oil and natural gas, along with a small volume of lignite), electricity (mainly hydropower from Bhutan) to address shortfalls in domestic energy capacities, production and scheduling. In addition to these, dependence of imports is significant for some petroleum products (particularly LPG) and liquefied natural gas (LNG), as well as for critical minerals such as uranium, polycrystalline silicon and rare-earth metals (Li, Co, Ni, Mn, etc) required to support nuclear power production, photovoltaic (PV) energy generation and battery energy storage systems (BESS), respectively as shown in Table 1.

Table 1 Gross Import of Energy Resources during 2024-25

Energy Resources	**Gross Import**	**% Import dependency**
Coal	243.62 MMT	18.91[12]
Lignite	0.14 MMT	0.18*[13]
Crude oil	243.22 MMT	88.1**[7]
Petroleum products	50.90 MMT	22.7***[7]
Natural Gas	35.72 BCM	51.3[14]
Electricity	7639.76 GWh	11.02****[15]
Rare-earth metals, scandium and yttrium	1,122,480 kg[16]	85-90[17]
Uranium	250 MTU	100
Polycrystalline silicon	~20,000 MT[18]	~98%

** Share of in global imports, Ranking 11/100*

***April-December (2024-25)*

****Petroleum imports as percentage of India's gross imports*

*****CAGR*

Natural gas presents a strategic paradox within India's energy transition. On one hand, dependence on imported LNG exposes critical sectors such as fertilisers and flexible power generation to external supply disruptions and price volatility, creating energy security vulnerabilities. On the other hand, existing gas-based generation assets and industrial gas networks represent valuable system infrastructure that can support grid balancing, industrial heat requirements, and lower-emission transition pathways relative to more carbon-intensive alternatives. India may therefore benefit from a strategy of selective gas utilisation, prioritising sectors where alternatives remain limited in the near

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[12] https://ppac.gov.in/download.php?file=rep_studies/1737011904_Snapshot-of-Indias-Oil-and-Gas-Data_WebUpload_December-2024_compressed.pdf

[13] Lignite in India Trade | The Observatory of Economic Complexity

[14] https://energy.economictimes.indiatimes.com/news/oil-and-gas/indias-natural-gas-consumption-rises-9-1-in-fy25-lng-imports-surge-by-19-4/119237196

[15] https://mospi.gov.in/sites/default/files/publication_reports/Energy_Statistics_2025/Chapter4_27032025.pdf

[16] https://wits.worldbank.org/trade/comtrade/en/country/IND/year/2024/tradeflow/Imports/partner/ALL/product/280530

[17] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2222413&reg=3&lang=2#:~:text=Need%20to%20Explore%20and%20Invest,global%20leader%20in%20advanced%20materials.

[18] https://www.indexbox.io/store/india-polysilicon-market-analysis-forecast-size-trends-and-insights/

term (e.g., fertilisers, peaking power, select industrial applications), while avoiding lock-in to long-term import dependence. In this context, the progressive integration of domestically produced compressed biogas (CBG) into gas infrastructure could play an important complementary role, particularly where pipeline quality specifications and grid injection standards can be met. Such an approach could gradually reduce fossil gas dependence, strengthen waste-to-energy linkages, and support rural circular bioeconomy models without compromising system reliability**.**

2.2 Fragmented Policy Architecture

Energy governance in India remains fragmented, with responsibilities dispersed across multiple ministries and statutory bodies. This fragmentation spans the entire energy ecosystem; including generation, distribution, trading, end-use, and capacity building, leading to challenges in coordination and policy coherence across the following areas: power sector, petroleum & natural gas, coal, renewable energy, industry, transport and buildings (Annexure I)[19]. This leads to: siloed optimisation, technology bias, inconsistent incentives and market distortions (e.g., ethanol oversupply vs demand gaps). Table 2 gives a few examples of such conflicts due to fragmented policy architecture.

Despite these institutional fragmentation challenges, India has achieved significant progress in expanding energy access, promoting clean energy, and improving energy efficiency through a series of sector-specific policy interventions.

While governance challenges persist, sustained policy efforts across the energy sector have delivered tangible developmental outcomes, especially in expanding access to modern energy services and promoting inclusive growth.

Over the past decade, India has made remarkable progress in expanding energy access and improving social inclusion. Flagship initiatives such as the Pradhan Mantri Ujjwala Yojana (PMUY) have transformed household energy consumption patterns by extending clean cooking access to more than 9 crore beneficiary households, significantly reducing dependence on traditional biomass fuels and improving health and gender outcomes (MoPNG, 2023) . vSimilarly, large-scale renewable deployment under India's national energy transition efforts has positioned the country among the fastest-growing renewable energy markets globally (IEA, 2021) . Energy efficiency initiatives such as

[19] Annexure 1: Overview of Policies/Rules/Acts/Guidelines/Schemes/ Missions across India's Energy Value Chain.

Perform-Achieve-Trade (PAT) and domestic fuel capacity enhancement through ethanol blending in petrol (EBP) have delivered tangible benefits in mitigation of carbon dioxide emissions and foreign exchange outflow.

India’s experience also reveals an important structural challenge: the absence of an integrated, unified framework in energy policy and implementation. The Draft National Energy Policy (2017) by NITI Aayog was one of the few attempts to provide a comprehensive, cross-sectoral roadmap, with targets spanning universal energy access, renewable expansion, improved efficiency, and reduced import dependence. While notable progress has been achieved, such as near-universal household electrification driven by the Saubhagya scheme (Pradhan Mantri Sahaj Bijli Har Ghar Yojana). India's renewable energy capacity experienced massive growth, rising from roughly 38 GW in 2015 to nearly 254 GW (including large hydro) or 266.78 GW (total non-fossil) by late 2025 .

Table 2 Examples of conflicts due to fragmented policy architecture

Conflict Area	Policies Involved	Nature of Conflict	Impact	Market Distortion
Renewable push vs Coal lock-in	National Solar Mission, Wind RPO, Hybrid Policy vs SHAKTI, NCDP, Coal linkage policies	Mandatory renewable procurement coexists with long-term coal PPAs and assured fuel supply	Locks both systems simultaneously; affects majority of generation mix	Overcapacity, stranded coal assets, rising fixed costs, DISCOM burden
Renewable procurement vs Retail tariff control	RPOs, competitive RE bidding vs State tariff regulations	DISCOMs must buy renewables but cannot fully pass costs to consumers	Directly impacts financial viability of	Payment delays, rising DISCOM debt, investor risk

			distribution sector	
Rooftop solar vs DISCOM revenue model	PM Surya Ghar vs existing grid cost recovery structure	Consumers shift to self-generation while grid costs remain socialised	Erodes DISCOM revenue base at scale	“Utility death spiral”, cross-subsidy stress, stranded network investments
Gas supply push vs demand prioritisation	HELP, OALP vs CGD priority allocation, gas pricing guidelines	Gas produced/imported but allocated preferentially to transport/households, not power	Affects energy transition flexibility and balancing capacity	Idle gas-based power plants, poor upstream investment signals
Bioenergy/CBG push vs subsidised LPG	SATAT, CBG programmes vs Ujjwala Yojana	Competing clean cooking fuels with uneven subsidy structures	Affects rural energy transition and waste-to-energy ecosystem	Weak CBG demand; underdeveloped decentralised energy markets
Transmission expansion vs decentralised generation	Green Energy Corridor vs rooftop solar,	Centralised transmission planning vs	Leads to misaligned infrastructure investment	Underutilised transmission assets; inefficient capital allocation

	distributed RE schemes	decentralised generation growth		
Ultra-low RE tariffs vs project viability	Competitive bidding guidelines vs RPO-driven demand	Aggressive tariff discovery reduces margins while demand is mandated	Impacts long-term sustainability of RE sector	Project delays, renegotiations, risk of quality compromise

2.3 Resource–Impetus Mismatch

India possesses strong domestic energy resources that, in principle, exceed its total energy import requirements, yet a clear resource–impetus mismatch persists. Coal production crossed one billion tonnes in FY 2024–25, but imports remained high due to logistics and quality constraints rather than resource scarcity, even as coal plants operated at suboptimal capacity[20]. Similarly, India's vast solar potential estimated at over 3.3 million MW[21] is constrained not by availability of sunlight but by inadequate transmission infrastructure, leaving significant commissioned capacity stranded[22]. Emerging resources such as geothermal and ocean energy also remain largely untapped despite assessed potential, reflecting regulatory gaps and high upfront costs.

A similar pattern is visible across other energy domains. India's substantial thorium reserves offer long-term strategic potential but require complex technological advancement, while biomass, already a major energy source, remains dominated by inefficient traditional use rather than modern applications. Industrial sectors continue to waste significant recoverable heat due to limited adoption of waste heat recovery systems, particularly among MSMEs. In parallel, India's target of achieving 500 GW of non-fossil fuel-based electricity generation capacity by 2030 will require large-scale deployment of Energy Storage Systems (ESS), with the Central Electricity Authority projecting a

[20] Press Information Bureau, Government of India. 'Coal Imports During FY 2024-25 Drops by 7.9%.' https://www.pib.gov.in/PressReleasePage.aspx?PRID=2131632

[21] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2170261&reg=3&lang=2

[22] IEEFA. 'Transmission Expansion Trails Renewable Energy Growth in India.' 2025. https://ieefa.org/articles/transmission-expansion-trails-renewable-energy-growth-india

need for 208 GWh of Battery Energy Storage Systems (BESS) by 2030, while only 35.8 GWh is currently under construction, highlighting the scale of infrastructure and integration challenges associated with variable renewable energy sources[23]. Details are provided in Figure 2. These gaps highlight the need for stronger policy alignment with resource availability, technological readiness, and market conditions, including consumer acceptance, to fully realise India's domestic energy potential.

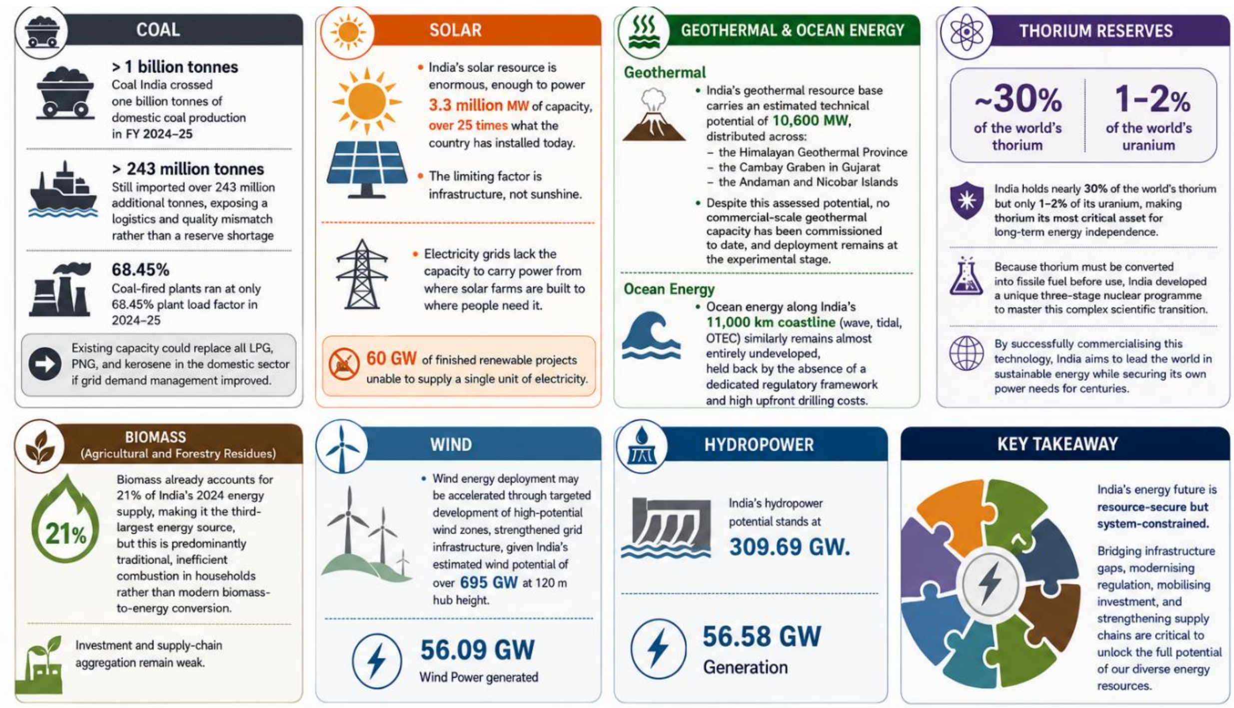

Figure 2: Resource Impetus Mismatch in India's Energy Mix[24]

2.4 Capacity–Generation Mismatch in Renewables

[23] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2246898&reg=3&lang=2

[24] Figure 2 is generated from the following sources:
https://www.pib.gov.in/PressReleasePage.aspx?PRID=2040094&reg=3&lang=2
https://iced.niti.gov.in/energy/fuel-sources/hydro/potential
https://www.pib.gov.in/PressReleasePage.aspx?PRID=2149193&reg=3&lang=2
https://www.pib.gov.in/PressReleasePage.aspx?PRID=2131632&reg=3&lang=2
https://www.pib.gov.in/PressReleasePage.aspx?PRID=2003561&reg=3&lang=2
https://www.businessworld.in/article/rajasthan-s-solar-expansion-faces-grid-constraints-with-60-gw-awaiting-connectivity-602025
https://swarajyamag.com/science/india-enters-stage-two-of-its-nuclear-programme-the-three-stages-explained
https://www.pib.gov.in/FactsheetDetails.aspx?id=150617&reg=3&lang=2
https://www.iea.org/commentaries/unlocking-indias-bioenergy-potential
https://zerodha.com/z-connect/rainmatter/biogas-and-indias-energy-mix-a-long-term-bet-we-are-making
https://www.cmaindia.org/enhancing-energy-efficiency-through-waste-heat-recovery-system

Despite renewable energy reaching 42.4% of installed capacity by March 2026, it contributed only 15.8% to actual electricity generation, while coal continued to supply 71.8%[25]. This highlights a structural dependence on coal as the primary baseload source due to intermittency in renewables, limited storage, and grid constraints. With minimal retirement of fossil fuel capacity since 2018 and continued exposure to global fuel price shocks, India's transition remains constrained by reliability and system integration challenges.

2.5 Efficiency Gap: Fuels vs Electricity.

End-use efficiency varies significantly across equipment categories, with internal combustion engines typically operating at relatively low efficiency levels of around 20–25%[26], whereas electric motors can achieve efficiencies exceeding 90%[27], highlighting the substantial energy-saving potential of electrification. For example, steam pre-heating of fuel and material lines in refineries involves steam generation through boiler fuel combustion and super-heating of water, followed by transportation of the same steam through pipelines to the processed equipment where heat is required. Direct heating of these pipelines and equipment inlets through electricity significantly improves energy efficiency of refineries[28]. In general, the mechanical power for a motor, if it has to come from a fossil fuel, would come from a device having lower efficiencies due to thermodynamic constraints relative to the same motor being actuated directly by electricity.

Electricity produced from fossil fuels may have only ~30–45% conversion efficiency at the power generating station[29]. Energy decisions must consider whole-system efficiency, upstream generation + downstream usage. Further, lifecycle greenhouse gas emissions also need to be kept in mind in the context of India's Net-Zero commitment by 2070[30].It may be argued that an "electrify quickly, decarbonise continually" approach – as demonstrated by the Indian Railways[31] - could work well for

[25] https://www.thehindu.com/opinion/op-ed/indias-green-transition-still-runs-on-coal/article71018368.ece

[26] Goyal, H., Nyrenstedt, G., Moreno Cabezas, K., Panthi, N., Im, H., Andersson, A., & Johansson, B. (2021). A simulation study to understand the efficiency analysis of multiple injectors for the Double Compression Expansion Engine (DCEE) concept. *SAE WCX Digital Summit 288440*.

[27] US Department of Energy. 'Improving Motor and Drive System Performance: A Sourcebook for Industry.' https://www.energy.gov/sites/default/files/2014/04/f15/motor.pdf

[28] https://blog.se.com/energy-management-energy-efficiency/2024/10/01/process-electrification-helps-cut-co2-in-refining/

[29] Graus, W. H. J., Voogt, M., & Worrell, E. (2007). International comparison of energy efficiency of fossil power generation. *Energy policy*, *35*(7), 3936-3951.

[30] Press Information Bureau, Government of India. 'India's Updated Nationally Determined Contribution.' https://www.pib.gov.in/PressReleasePage.aspx?PRID=1848208

[31] https://www.newsonair.gov.in/indian-railways-on-track-to-achieve-net-zero-emissions-by-2025-union-minister-ashwini-vaishnaw/

India if nuclear energy capacities including Small Modular Reactors – which offer 24x7 uptime – can be put in place in the medium term to complement and supplement affordable coal power, while work continues towards a reliable renewables-rich grid.

2.6 The Supply–Demand Synchronisation Problem

India's ethanol blending programme (EBP) illustrates this dynamic clearly. Assured offtake mechanisms and blending mandates successfully stimulated upstream production capacity, but rapid expansion has in several instances outpaced demand growth, affecting producer economics and straining feedstock supply chains. Similarly, the Compressed Biogas (CBG) sector under the SATAT scheme continues to face structural underperformance: while over 5,000 Letters of Intent have been issued, operational plants remain a small fraction of targets, constrained by demand uncertainty, absence of pricing parity with CNG, and inadequate pipeline evacuation infrastructure.

This pattern, where **production capacity is built ahead of market readiness** — reflects a systemic absence of **value-chain thinking** in policy design. Energy transition policies have tended to focus on the production end (capacity targets, production-linked incentives) without equal attention to:

- **Demand creation and end-use adoption** — including consumer awareness, appliance availability, and switching costs
- **Pricing reform** — ensuring that new energy carriers are price-competitive without permanent subsidy dependence
- **Logistics and evacuation infrastructure** — pipelines, storage depots, grid interconnections, and last-mile distribution networks
- **Offtake certainty** — long-term purchase agreements or blending mandates that de-risk private investment across the full value chain

2.7 Demand-Side Adoption and Market Readiness

A recurring but insufficiently recognised challenge across multiple energy pathways in India is not merely a supply–demand imbalance, but a deeper issue of market readiness. While policy efforts have prioritised scaling production, the corresponding market ecosystems required for absorption and sustained uptake have evolved more slowly. This has resulted in situations where supply-side capacity exists, but adoption remains constrained due to underdeveloped end-use markets.

Barriers such as high switching costs, limited availability of compatible appliances and equipment, fragmented service networks, behavioural inertia, and low consumer awareness continue to inhibit market deepening. This challenge cuts across sectors including electric cooking, rooftop solar, compressed biogas, industrial fuel switching, decentralised biomass systems, and emerging hydrogen applications. As a result, energy transitions cannot be treated solely as supply-side engineering problems; they also require deliberate demand-side activation strategies that reduce adoption friction and support market formation.

2.8 Electricity generation growth vs power grid system stability

India's electricity sector faces a structural paradox: generation capacity has expanded rapidly, with over 266 GW of non-fossil capacity commissioned by late 2025[32], yet the grid's ability to absorb, transmit, and dispatch that power has not kept pace. The result is a system where renewable energy is simultaneously being curtailed during the day and unable to meet peak evening demand, while gas-based assets worth approximately 25 GW sit idle for want of pipeline infrastructure and despatch incentives[33]. These are not isolated technical failures; they are symptoms of a generation-first planning model that has consistently under-invested in the integration infrastructure that makes renewable power generation sufficiently useful. The specific challenges driving this systemic instability are highlighted in Figure 3. While RE is available at grid parity is true in terms of price bids for generation projects, microanalysis suggests that anomalies exist in terms of transmission and distribution costs as well as time-of-day pricing models[34].

2.9 Water-Energy Stress

Water is also a key consideration for the adequacy and affordability pillars. The alternatives discussed e.g. coal gasification, pumped hydro storage and green hydrogen[35] through electrolysis all require significant quantities of fresh water as well as energy for pretreatment to make it quality-appropriate for each of these applications. A significant share of India's coal reserves and thermal power plants are located in water-stressed regions, creating a structural mismatch where water-intensive coal-based

[32] Press Information Bureau, Government of India. '2025 Marks Highest-Ever Renewable Energy Expansion in India's Energy Transition Journey.' https://www.pib.gov.in/PressReleasePage.aspx?PRID=2209478

[33] IEEFA. 'Flexible Generation: A Role for India's Stressed and Stranded Gas-based Power Plants?' October 2022. https://ieefa.org/resources/flexible-generation-role-indias-stressed-and-stranded-gas-based-power-plants

[34] https://www.iisdindia.in/blogs_Rahul-Tongia.php

[35] Kumar, P., Date, A., Mahmood, N., Das, R. K., & Shabani, B. (2024). Freshwater supply for hydrogen production: An underestimated challenge. *International Journal of Hydrogen Energy*, *78*, 202-217.

power generation competes with limited local water availability, increasing operational and sustainability risks[36].

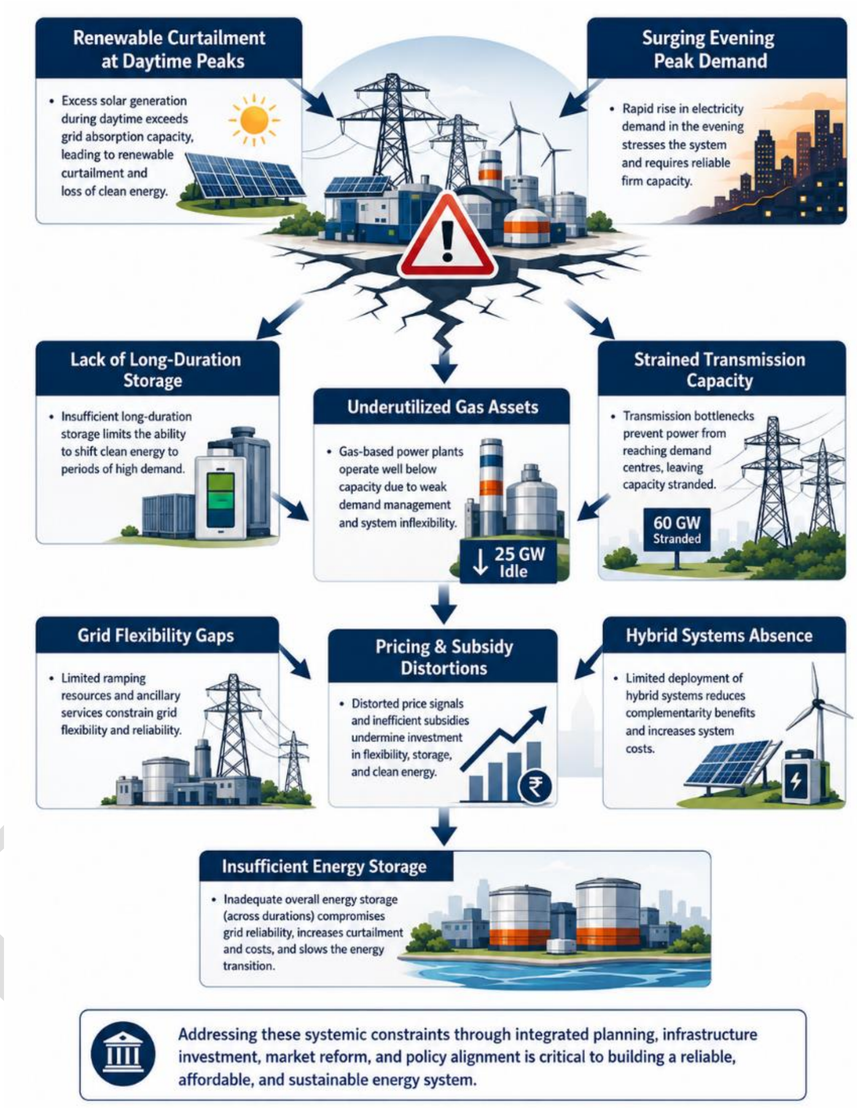

Figure 3 Threats to Grid System Stability

2.10 Discom Financial Stress

India's power distribution companies (discoms) continue to face significant financial and operational stress despite recent reform efforts. High aggregate technical and commercial (AT&C) losses, delayed tariff revisions, subsidy dependence, and mounting debt have weakened the long-term sustainability of the distribution sector. National assessments indicate that AT&C losses, although reduced from

[36] https://india.mongabay.com/2023/03/water-is-needed-for-green-hydrogen-production-but-concerns-remain-about-its-availability/

over 25% in FY2015 to nearly 15% in FY2025, still remain high in several states[37]. Similarly, the Average Cost of Supply–Average Revenue Realisation (ACS–ARR) gap stood at around 46 paise per unit in FY2024, reflecting persistent under-recovery of electricity supply costs[32]. While subsidies are available for renewable energy projects, developers, certain categories of consumers – the arbitrage risk has a direct impact on the financial health of the discoms.

2.11 The Financing Gap

India's energy transition investment requirements are substantial. Achieving its 500 GW non-fossil capacity target by 2030 alone is estimated to require cumulative capital investment in the range of USD 150–200 billion[38]. The challenge is not only one of scale, but also of financing architecture: current capital markets, banking structures, and public finance mechanisms remain insufficiently aligned with the long tenure, risk profile, and blended funding requirements of energy transition infrastructure. While technology-specific innovation constraints exist (discussed separately in Section 2.14), the financing challenge considered here relates primarily to system-wide capital mobilisation and allocation.

Current financing mechanisms present several structural constraints:

A. **High cost of capital**: Domestic interest rates and risk premiums inflate the levelised cost of energy for new technologies, making projects uncompetitive without concessional finance or viability gap funding[39].

B. **Tenure mismatch**: Long-gestation infrastructure projects (pumped hydro storage, nuclear, CO_2 pipelines) require financing tenures of 20–30 years, which domestic capital markets are not yet structured to provide at scale[40].

[37] Prayas (Energy Group). (2021). *Study on power sector for the Fifteenth Finance Commission*. Prayas (Energy Group). https://fincomindia.nic.in/asset/doc/commission-reports/16th-FC/studies/commission/Study%20on%20Power%20sector%20by%20Prayas.pdf

[38] IBEF. 'India Renewable Energy Sector Overview.' 2025. (citing USD 190-215 billion for 500 GW renewable capacity) https://www.ibef.org/industry/renewable-energy

[39] IRENA. 'Renewable Power Generation Costs in India 2024.' International Renewable Energy Agency. https://www.irena.org/Publications/2024/Sep/Renewable-Power-Generation-Costs-in-2023

[40] RBI. 'Report on Currency and Finance 2023-24: India's Fiscal Policy Framework.' Reserve Bank of India. https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/RCF23_24FULL2CA41413A1E843A6B65F58D7D85948B1.PDF

C. **MSME financing exclusion**: Decentralised energy systems, including biogas plants, rooftop solar, and waste heat recovery, often depend on small-ticket, distributed financing models that remain poorly served by conventional banking channels. This creates a structural financing bottleneck for commercially viable but fragmented energy investments, particularly in rural and industrial MSME settings. Blended finance instruments and first-loss guarantee facilities remain underutilised[41].

D. **Underdeveloped green capital markets**: India's green bond market[42], while growing, lacks standardised taxonomy, disclosure norms, and secondary market liquidity sufficient to attract large institutional investors at the scale required.

E. **Limited mobilisation of international climate finance**: Given India's low per capita GHG emissions compared to developed countries and the aforementioned principal of common but differentiated responsibility, efforts to ensure international climate finance commitments are met from historical emitter nations must take priority. Instruments such as the Just Energy Transition Partnership (JETP)[43], multilateral development bank (MDB) co-financing[44], and Article 6[45] carbon market mechanisms remain insufficiently integrated into India's domestic energy investment planning frameworks in the absence of such support.

2.12 Carbon Markets

India's carbon credit market is nascent. The Carbon Credit Trading Scheme (CCTS) framework[46], notified in 2023, is yet to be fully operationalised with a functioning registry, verified offset methodology, and price discovery mechanism. Without a credible domestic carbon price signal, investment in CCUS, waste-to-energy, and industrial decarbonisation cannot be commercially justified on standalone economics. Strengthening the domestic carbon market and linking it

[41] Climate Policy Initiative. 'Landscape of Green Finance in India 2023.' https://www.climatepolicyinitiative.org/publication/landscape-of-green-finance-in-india/

[42] https://urr.shodhsagar.com/index.php/j/article/view/1524

[43] Clean Energy Wire. 'India, Donor Countries Give Up on Just Energy Transition Partnership.' November 2024. https://www.cleanenergywire.org/news/india-donor-countries-give-just-energy-transition-partnership-german-official

[44] World Bank Group. 'Climate Finance Report 2024: Mobilising Private Finance for Clean Energy.' https://www.worldbank.org/en/topic/climatechange/brief/climate-finance

[45] UNFCCC. 'Article 6 of the Paris Agreement: Market Mechanisms and Carbon Trading.' 2021. https://unfccc.int/topics/negotiations/the-big-picture/what-is-the-paris-agreement/article-6

[46] Ministry of Power / BEE, Government of India. 'Carbon Credit Trading Scheme (CCTS), 2023.' Gazette of India. https://icapcarbonaction.com/en/ets/indian-carbon-credit-trading-scheme

selectively to international mechanisms is a prerequisite for unlocking private investment in hard-to-abate sector decarbonisation. However, a delicate balance is required here in the absence of global climate finance; imposition of carbon costs without assurance of affordable industrial energy can disadvantage domestic producers relative to imported goods, potentially defeating not just the intent to reduce foreign exchange outflows but also to generate and protect jobs through a holistic Unified Energy Policy. Hence, carbon pricing should evolve gradually and focus selectively on hard-to-abate sectors where compensatory mechanisms exist on the credit utilisation side, while establishing firm, traceable, inviolable systems for the decentralised credit generation side where risks of the system becoming compromised are much higher.

2.13 Fuel–Fertiliser Supply Risk

India's fertiliser production remains highly vulnerable to disruptions in natural gas supply, given its central role as a feedstock. Recent policy measures mandating at least 70 per cent assured gas supply to fertiliser plants underscore the severity of this risk, particularly amid global LNG disruptions linked to geopolitical tensions in West Asia[47]. Such contingencies highlight the structural dependence of fertiliser manufacturing on external energy dynamics. Any sustained fuel shortage can directly constrain fertiliser output, posing downstream risks to agricultural productivity and input availability.

2.14 Innovation and Deployment Gap

Beyond macro-level financing constraints, India faces a distinct technology commercialisation challenge often described as the "valley of death" between research and market deployment. While academia and public laboratories frequently generate promising early-stage innovations (TRL 3-4), private industry generally engages only with technologies approaching commercial maturity (TRL 8-9), leaving a significant translational gap in the intermediate stages of validation, piloting, and demonstration. This challenge is not merely a shortage of capital, but a mismatch between the type of financing, institutional support, and risk-sharing required for technology maturation. As a result, strategically important technologies central to India's long-term energy pathway, including advanced biofuels, green hydrogen electrolysers, long-duration storage, CCUS systems, and small modular reactors, often struggle to progress from laboratory proof-of-concept to bankable deployment.

[47] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2237803&reg=3&lang=1

Recent initiatives such as the Anusandhan National Research Foundation (ANRF) and the Research, Development, and Innovation (RDI) Scheme are expected to help bridge this gap.

2.15 Just Transition and Social Equity

India's energy transition is not only a technological and economic challenge it is fundamentally a social one. The communities most dependent on the incumbent energy system, whether coal miners in Jharkhand and Odisha, biomass-dependent households in rural Uttar Pradesh and Bihar, or informal workers in energy-intensive industries, are often the least equipped to absorb the disruptions that a rapid, unmanaged transition can produce[48]. A Unified National Energy Policy that does not explicitly account for these distributional consequences risks deepening existing inequalities even as it advances national energy security objectives.

The concept of a just transition requires that the costs and benefits of the energy transition be distributed equitably across geographies, income groups, and generations. For India, this means that the coal transition should be characterised less by abrupt phase-out and more by functional transformation, from combustion-dominant use toward higher-efficiency generation, chemicals, gasification, and CCUS-integrated systems. This would simultaneously manage the decline of carbon-intensive livelihoods, expanding clean energy access to the most energy-poor populations, and ensure that the productivity gains from the transition are broadly shared rather than concentrated.

2.1.1 The Coal Community Challenge

India's coal sector supports around 4 lakh formal workers in Coal India Limited and related enterprises[49], with indirect employment several times higher. While coal-dependent districts in states like Jharkhand, Chhattisgarh, Odisha, West Bengal, and Madhya Pradesh are heavily reliant on coal for jobs and state revenues[50], the energy produced from these states services the entire nation in significant measure However, as domestic coal consumption evolves due to renewable energy expansion, coal gasification policies, and long-term decarbonisation goals, these regions face potential economic disruption without clear alternative livelihood pathways. The lack of a formal just transition framework in India's energy policy means this risk is growing without adequate planning, even though

[48] ILO. 'Guidelines for a Just Transition towards Environmentally Sustainable Economies and Societies for All.' 2015. https://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_432859.pdf

[49] Press Information Bureau, Government of India. 'Coal Sector Created Substantial Employment Opportunities in Last 10 Years.' March 2024. https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2013330

[50] Ministry of Coal, Government of India. 'Annual Report 2024-25.' https://coal.nic.in/en/annual-reports

global experiences such as Germany's Kohleausstieg programme and South Africa's Just Energy Transition Partnership show that early intervention can significantly reduce social and economic costs[51]. For India, an important first step in this direction has been taken through the recently announced Coal Gasification Mission[52] and the CCUS Mission[53], which can be integrated with existing coal mining and thermal power generation infrastructure, respectively.

2.1.2 Energy Poverty and Last-Mile Access Gaps

Despite near-universal electrification under Saubhagya, energy access in rural India remains unequal, with many households receiving limited and unreliable power that restricts meaningful usage, highlighting a structural energy poverty gap particularly concentrated in coal-dependent states. A similar issue exists in clean cooking, where although PMUY has provided LPG connections to over 10.33 crore households[54], sustained use is limited by refill costs, leading many beneficiaries to continue relying on traditional biomass in a dual-fuel pattern that reduces the programme's health and environmental benefits; as a result, ensuring consistent access rather than just initial connections remains critical, especially given the significant burden of household air pollution on women and children[55].

2.1.3 Gender Dimensions of Energy Access

Energy access is inherently gendered, with women and girls in energy-poor households bearing the burden of biomass collection, limiting their time for education, income generation, and participation, while also facing disproportionate health risks from indoor air pollution due to greater exposure to cooking smoke; in addition, unreliable electricity access affects their safety, economic opportunities, and access to services[56]. While decentralised energy solutions such as biogas, solar microgrids, improved cookstoves, and productive use applications offer significant potential for gender co-benefits, these outcomes depend on intentional policy design that includes women as decision-makers, beneficiaries of green skills, and priority users, with models like the Village Level

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[51] https://www.germanwatch.org/sites/default/files/germanwatch_irid_overview_of_the_south_african_jet-p_2023.pdf

[52] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2260621&reg=3&lang=1

[53] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2198607&reg=3&lang=1

[54] https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154355&ModuleId=3&reg=3&lang=1

[55] https://www.iea.org/reports/sdg7-data-and-projections/access-to-clean-cooking

[56] IEA / World Bank. 'Tracking SDG 7: Access to Clean Cooking.' 2023. https://www.iea.org/reports/sdg7-data-and-projections/access-to-clean-cooking

Entrepreneur framework[57] providing pathways for inclusion if supported by gender-responsive criteria and structures from the outset.

2.1.4 Informal Workers and Energy-Intensive Industry Transitions

India's energy transition will reshape employment not only in coal but also in sectors like petroleum refining, thermal power, and hard-to-abate industries such as steel, cement, and fertilisers, where many workers are informal and lack social protection, making them highly vulnerable to displacement as technologies like CCUS, coal gasification, and circular economy practices change skill needs; this underscores the need for proactive workforce planning rather than reactive job losses. At the same time, emerging sectors such as renewable energy, green hydrogen, and battery storage will create new jobs, but their geographic and skill requirements often do not align with those of displaced workers, necessitating targeted reskilling, wage support during transitions, and focused economic diversification in coal-dependent regions[58].

2.1.5 Affordability and the Risk of Regressive Energy Costs

Energy affordability varies sharply across income groups, with low-income households spending a higher share of their income on energy and therefore being more vulnerable to price increases[59], especially as subsidies are rationalised, shifts to LPG or electricity raise cash expenditures, and time-of-use pricing is introduced, potentially placing a disproportionate burden on those least able to afford it and risking setbacks in clean energy access. Financing and Market Alignment Gaps.

A persistent but underacknowledged structural challenge in India's energy transition is the **misalignment between policy ambition, financing availability, and market absorption capacity**. Supply-side mandates and production incentives have repeatedly outpaced the development of downstream demand infrastructure, pricing mechanisms, and end-use market readiness undermining the commercial viability of otherwise well-designed programmes.

2.2 Policy Design Implications

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[57]Ministry of Power, Government of India. 'Pradhan Mantri Ujjwala Yojana and Village Level Entrepreneur Framework.' https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1945472

[58]https://www.ilo.org/sites/default/files/wcmsp5/groups/public/%40ed_emp/%40emp_ent/documents/publication/wcms_432859.pdf

[59]CEEW. 'The Distributive Impacts of India's Energy Transition.' 2023. https://www.ceew.in/publications/distributive-impacts-india-energy-transition

Addressing financing and market alignment gaps requires a fundamental shift in how energy policy is designed, moving beyond a narrow focus on production targets and capacity mandates toward a full value-chain approach that integrates production, logistics, pricing, and demand creation. Current reliance on budgetary subsidies and conventional bank lending must evolve to more diversified financing architectures that can better absorb risk and crowd in private capital, while the prevailing tendency for risk to remain either state-absorbed or undefined calls for more deliberate and structured risk-sharing frameworks. Similarly, policy support has traditionally concentrated on early-stage R&D, leaving a gap in the critical middle stages of technology development, and has often assumed market readiness rather than actively enabling it.

The Unified National Energy Policy Framework proposed in this brief must therefore treat **financing architecture and market design as priority policy instruments**, not downstream implementation details. Supply-side ambition, however well-resourced, cannot substitute for the market scaffolding that converts installed capacity into delivered energy value.

The foregoing challenges may be understood through four interdependent dimensions: adequacy (supply reliability and resilience), access (equitable availability), affordability (economic sustainability), and appropriateness (context-sensitive and socially just deployment). Issues such as structural import dependence, resource–impetus mismatch, supply–demand synchronisation gaps, electricity generation vis-à-vis grid stability, and water–energy stress primarily fall within adequacy, as they affect the reliability, resilience, and systemic balance of supply. Challenges including energy poverty, last-mile access gaps, and gendered disparities are rooted in access, reflecting persistent inequities in availability and utilisation.

Affordability concerns are most visible in discom financial stress, the financing gap, carbon market uncertainties, and the risk of regressive energy costs, all of which shape the economic sustainability of both providers and consumers. Meanwhile, fragmented policy architecture, the efficiency gap between fuels and electricity, innovation and deployment constraints, fuel–fertiliser supply risks, and the broader just transition agenda, including impacts on coal communities and informal workers, are best understood under appropriateness, as they relate to context-sensitive, coordinated, and socially just deployment pathways. These overlaps also highlight that several challenges are cross-cutting, reinforcing the need for integrated policy responses rather than siloed interventions.

3 Suggested Strategic Framework:

A unified national energy policy framework, built around four interdependent pillars-adequacy, access, affordability, and appropriateness can provide the necessary coherence. Together, these pillars move beyond conventional energy planning by integrating security, equity, economic viability, and contextual sustainability into a single, reinforcing architecture (Figure 4).

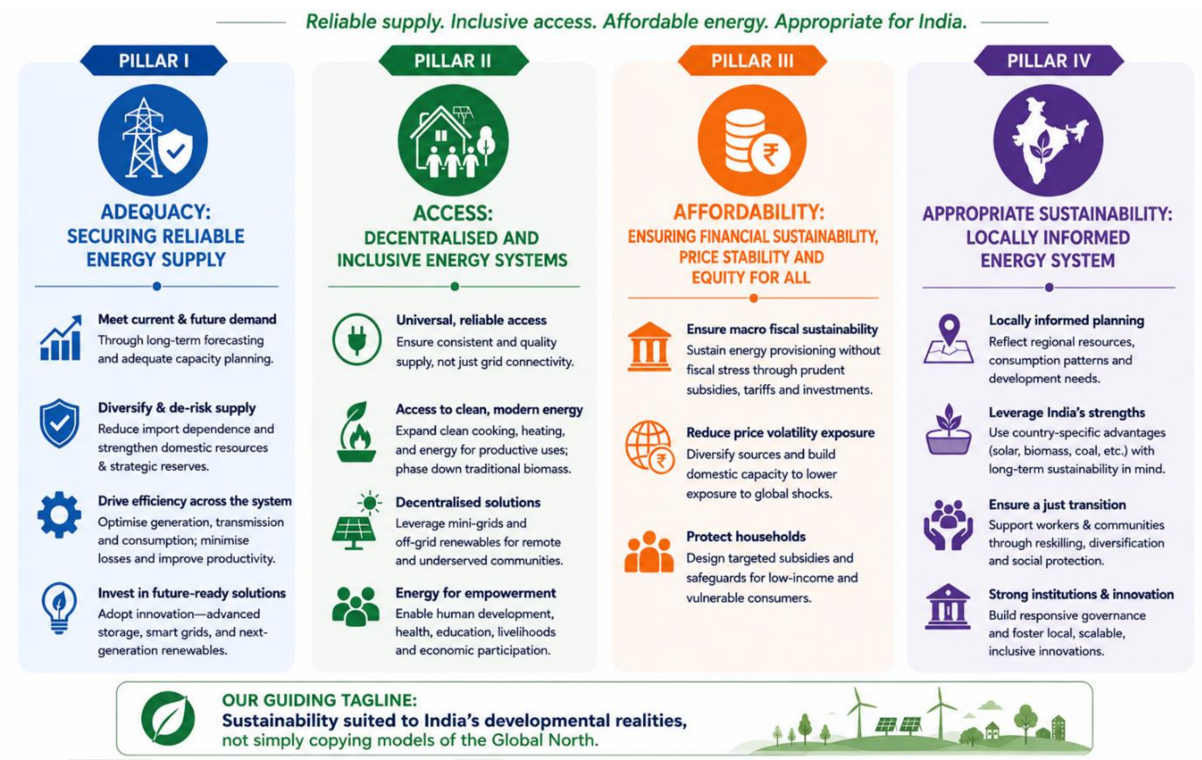

Figure 4 Four Pillars of a Unified National Energy Policy

3.1 Pillar I: Adequacy: Securing Reliable Energy Supply

The adequacy pillar focuses on ensuring that energy supply is consistently sufficient to meet both current and future demand. This goes beyond simple capacity addition to encompass long-term demand forecasting, diversification of energy sources, and resilience against disruptions. A risk-averse energy system under this pillar would prioritise reducing overdependence on imports, strengthening domestic resource utilisation, and building strategic reserves where necessary. Efficiency is another core principle optimising generation, transmission, and consumption to reduce systemic losses and improve overall productivity of energy use. Finally, adequacy must be forward-looking, embedding innovation as a central feature. Investments in emerging technologies such as advanced storage, smart grids, and next-generation renewables are essential to ensure that the system remains future-ready and adaptable to evolving demand patterns and technological shifts.

3.2 Pillar II: Access: Decentralised and Inclusive Energy Systems

The access pillar addresses the equitable distribution of energy, ensuring that all segments of society can reliably obtain it. While India has made significant strides in expanding physical connectivity, this pillar emphasises the quality and type of access as much as its reach. Universal access must include reliability and consistency of supply, not just grid connectivity. Equally important is access to clean, non-polluting forms of energy, particularly for cooking, heating, and productive uses, where reliance on traditional biomass still persists in some regions. This pillar also recognises the need for decentralised solutions such as mini-grids and off-grid renewable systems to serve geographically remote or economically marginalised communities. In this sense, access is not only a social objective but also a foundation for human development and economic participation. Such decentralised local solutions are intended to complement the economies of scale from centralised grid architecture and large-scale fuel production, balancing last-mile delivery and distribution costs through conscious modelling studies for areas where energy resources (sunshine, biomass, wind, geothermal etc) may be concentrated and where geographical access to centralised generation or fuel production may be logistically challenging (e.g. the Hill States, island Union Territories, Thar desert).

3.3 Pillar III: Affordability

Affordability ensures that energy remains financially accessible at both the macro and micro levels. At the national level, the government must be able to sustain energy provisioning without creating fiscal stress, which requires careful calibration of subsidies, tariffs, and investment strategies. Reducing exposure to volatile global energy prices through diversification and domestic capacity becomes a key strategy under this pillar. At the household level, affordability means that energy costs should not impose a disproportionate burden, particularly on low-income populations. This includes designing targeted subsidy mechanisms, promoting energy efficiency to lower consumption costs, and managing transitions such as shifts to cleaner fuels or time-of-use pricing in a way that does not exacerbate inequality. Affordability, therefore, is not merely about low prices but about equitable and sustainable cost structures across the system.

Building an Efficient Circular Energy Economy is also an important contributor to energy affordability. For example, disposed batteries contain critical minerals that are largely imported; for every battery that does not find its way to effective recycling additional minerals must be imported for the next battery being purchased. Similarly, improperly disposed plastics misses an opportunity to be recycled either mechanically or chemically back into its own value chain. This results in unnecessary extra demand for virgin materials, driving up prices (also imports) of wantonly wasted goods and materials in the absence of enabling mechanisms.

3.4 Pillar IV: Appropriate Sustainability: Locally Informed Energy System

The appropriateness pillar anchors the energy system in India's socio-economic and geographic realities. It calls for locally informed energy planning that reflects regional resource endowments, consumption patterns, and developmental needs. This includes leveraging country-specific advantages such as solar potential, agricultural residues, or domestic coal reserves while aligning with long-term sustainability goals. A just transition is central to this pillar, ensuring that communities and workers dependent on legacy energy systems are supported through economic diversification, reskilling, and social protection measures. Appropriateness also emphasises institutional design and governance frameworks that are responsive, context-sensitive, and capable of coordinating across sectors and levels of government.

Finally, it encourages innovation that is not merely technologically advanced but also relevant to local challenges, enabling solutions that are scalable, inclusive, and grounded in India's development trajectory. Ultimately, we must adopt sustainability suited to India's developmental realities, not simply copy models of the Global North. This requires attention to synergistic resources for the energy ecosystem such as water, arable land and air quality. For instance, when ramping up biofuel crops, the water resource utilisation of such crops has to be considered. Similarly, solutions like agrivoltaics can enable use of land for large solar projects without displacing available crop lands.

Together, these four pillars provide a structured yet flexible framework for navigating India's complex energy transition. By balancing adequacy, access, affordability, and appropriateness, the framework ensures that energy policy is not only technically sound but also socially equitable, economically viable, and strategically aligned with national priorities.

3.5 Cross – Cutting Levers

Expert consultations highlight two major cross-cutting, non-generation pathways for strengthening energy security. Circular Economy (CE) strategies, such as material efficiency, recycling, and waste valorisation, can significantly reduce overall energy demand by lowering dependence on primary resource extraction and improving material productivity across sectors[60]. At the same time, Carbon Capture, Utilisation and Storage (CCUS) has potential to support emissions reduction in hard-to-abate industries, enable cleaner utilisation of domestic coal resources, and facilitate blue hydrogen production[61]. Together, these approaches represent key systemic levers for advancing long-term energy security and are therefore integrated as cross-cutting priorities within the proposed framework.

3.5.1 Role of Circular Economy

The circular economy offers a powerful framework for rethinking how carbon-rich materials are managed in an energy-dependent world. In contrast to the traditional linear model of extract-produce-dispose, a circular economy aims to decouple economic growth from material throughput by promoting systemic changes in product design, production, consumption, and waste valorisation — with strategies such as reuse, recycling, repair, and energy recovery at its core. As already discussed in section 2.1, India has huge import dependency on carbon-based fossil fuels, estimated at 330 MMT of carbon atoms imported annually as petroleum, coal and natural gas. This which stands in sharp contrast to the abundance of untapped domestic carbon that India already possesses. The annual surplus of agriculture-based biomass alone is approximately 230 MMT, and the estimated potential for compressed biogas from sources including cattle dung, agricultural residues, municipal solid waste, and sewage treatment plants is around 62 MMT[62]. Another study estimated that untapped domestic carbon in the form of agricultural and forest residue, municipal solid waste, biogas and used cooking oil, has the potential to supply more than 500 MMT of carbon every year[63]. When applied to India's domestic waste streams, agricultural residue, forest biomass, municipal solid waste, used

[60] Recycling across solar, battery, and steel sectors can reduce reliance on primary resources and imports. Solar panel recycling can meet up to 20 per cent of global material demand by 2040–2050, while battery recycling can lower raw material costs by 25–30 per cent and reduce critical mineral dependence by 15–20 per cent. In steel, recycling can cut water use by 40 per cent and mining waste by 97 per cent, improving overall resource efficiency. (G20 Secretariat, India, CEEW, RMI, & WRI India. (2024). *Unlocking India's circular waste economy potential for sustainability*. CEEW. https://www.ceew.in/sites/default/files/india-circular-economy-potentialwebceew16dec.pdf)

[61] Global CCS Institute. 'Global Status of CCS Report.' 2024. https://www.globalccsinstitute.com/resources/global-status-of-ccs-report/

[62] Negi, H., Suyal, D. C., Soni, R., Giri, K., & Goel, R. (2023). Indian scenario of biomass availability and its bioenergy-conversion potential. Energies, 16(15), 5805. https://doi.org/10.3390/en16155805

[63] Ray, A., Sinha, A. K., Atray, N., & Kumar, S. (2019). Converting indigenous waste carbon sources to useful products. In Special issue on environment. The Journal, 18, 204–206. Centre for Governance.

cooking oil, and biogas, circular economy principles can convert these from environmental liabilities into strategic energy assets.

3.5.2 Role of Carbon Capture, Utilisation and Storage

Carbon Capture, Utilization, and Storage represents a complementary and increasingly critical pillar in the broader decarbonization architecture. CCUS captures CO_2 at the source, transports it, and either stores it permanently in geological formations or utilizes it in industrial applications and has emerged as a critical technology capable of significantly reducing carbon dioxide emissions from fossil-fuel-based power generation, industrial processes, and bioenergy systems[64]. Its strategic relevance lies particularly in sectors where electrification or direct renewable substitution is not technically or economically viable. CCUS offers the most cost-effective option in many regions for the deep decarbonization of hard-to-abate industries including iron, steel, and chemicals, and is also virtually the only known technological option for removing existing CO_2 from the atmosphere at scale[65]. Beyond emissions reduction, CCUS also contributes to energy security by enabling the continued, cleaner use of domestic fossil fuel reserves while low-carbon alternatives are scaled up. Based on current project pipelines, by 2030 annual CO_2 capture capacity is projected to reach around 95 Mt from hydrogen production, 90 Mt from power generation, and 50 Mt from industrial facilities[66]. CCUS thus complements decarbonization through electrification and renewable deployment by offering solutions for industrial applications where those alternatives are not yet fit for purpose or cost-competitive.

[64] Zhang, Y., Wang, X., Li, J., & colleagues. (2025). Circular economy and carbon neutrality: Synergies, pathways, and policy implications. *Journal of Environmental Management, 385*, 125018. https://doi.org/10.1016/j.jenvman.2025.125018

[65] Grantham Research Institute on Climate Change and the Environment. (2023, March 13). *What is carbon capture, usage and storage (CCUS) and what role can it play in tackling climate change?* London School of Economics and Political Science

[66] International Energy Agency (IEA) – Carbon Capture, Utilisation and Storage. (2026). *Carbon capture utilisation and storage*. International Energy Agency.

4 Recommendations

4.1 Pillar I: Adequacy

Diversifying energy partnerships: It may be useful to consider broadening the portfolio of energy suppliers beyond the Middle East to include partners from Russia, the Americas, and Africa. A more diversified supplier base can help reduce dependence on single corridors while strengthening procurement flexibility and resilience.

Evolving procurement frameworks: There is a need to gradually transition towards resilience-oriented, long-term supply contracting. Such an approach could incentivise domestic localisation of equipment and services, support the creation of inventory buffers, and reduce exposure to spot market volatility during periods of price fluctuation.

Maximising the strategic role of coal

- Coal should be repositioned within the power mix by focusing on clean coal solutions going forward, for instance adoption of advanced technologies such as **IGCC** (Integrated Coal Gasification Combined Cycle)[67] and **HELE power plants** (High Efficiency Low Emission)[68] to improve efficiency and emissions performance.
- Due to recent rapid integration of RE power into the grid, PLFs of thermal power plants have fallen. A comprehensive and realistic assessment of techno-economic models is required to ensure proper phasing and effective optimisation of additional thermal generation capacities as well as new grid-integrated RE projects being planned as new units come on-stream over the next few years.
- Further, it is important to extend coal resource utilisation to **Coal Bed Methane** (CBM) for which 33 blocks have been awarded to date with daily production exceeding 1.6 MMSCMD by 2026. [69]

[67] BHEL, IGCC technology for high-ash Indian coal. https://www.bhel.com/bhel-signs-mou-cil-and-nlcil-coal-gasification-business-strategic-move-aimed-harnessing-nations
[68] IEA Clean Coal Centre, HELE pathway for India. https://www.nsenergybusiness.com/features/coal-power-india-emissions/
[69] https://dghindia.gov.in/index.php/page?pageId=38

- Greater emphasis could be placed on utilising coal as a feedstock rather than solely as a fuel, by accelerating coal gasification for the production of methanol, DME, and ammonia, thereby supporting import substitution[70].
- There may be merit in aligning coal pathways with renewable energy through hybrid **"renewables-to-chemicals"** systems that combine coal-based and hydrogen-derived outputs for industrial applications as illustrated in Figure 5.

[70] Ministry of Coal, Coal Gasification Mission 100 MT target. https://www.newsonair.gov.in/government-sets-target-of-100-million-tonnes-of-coal-gasification-by-2030/

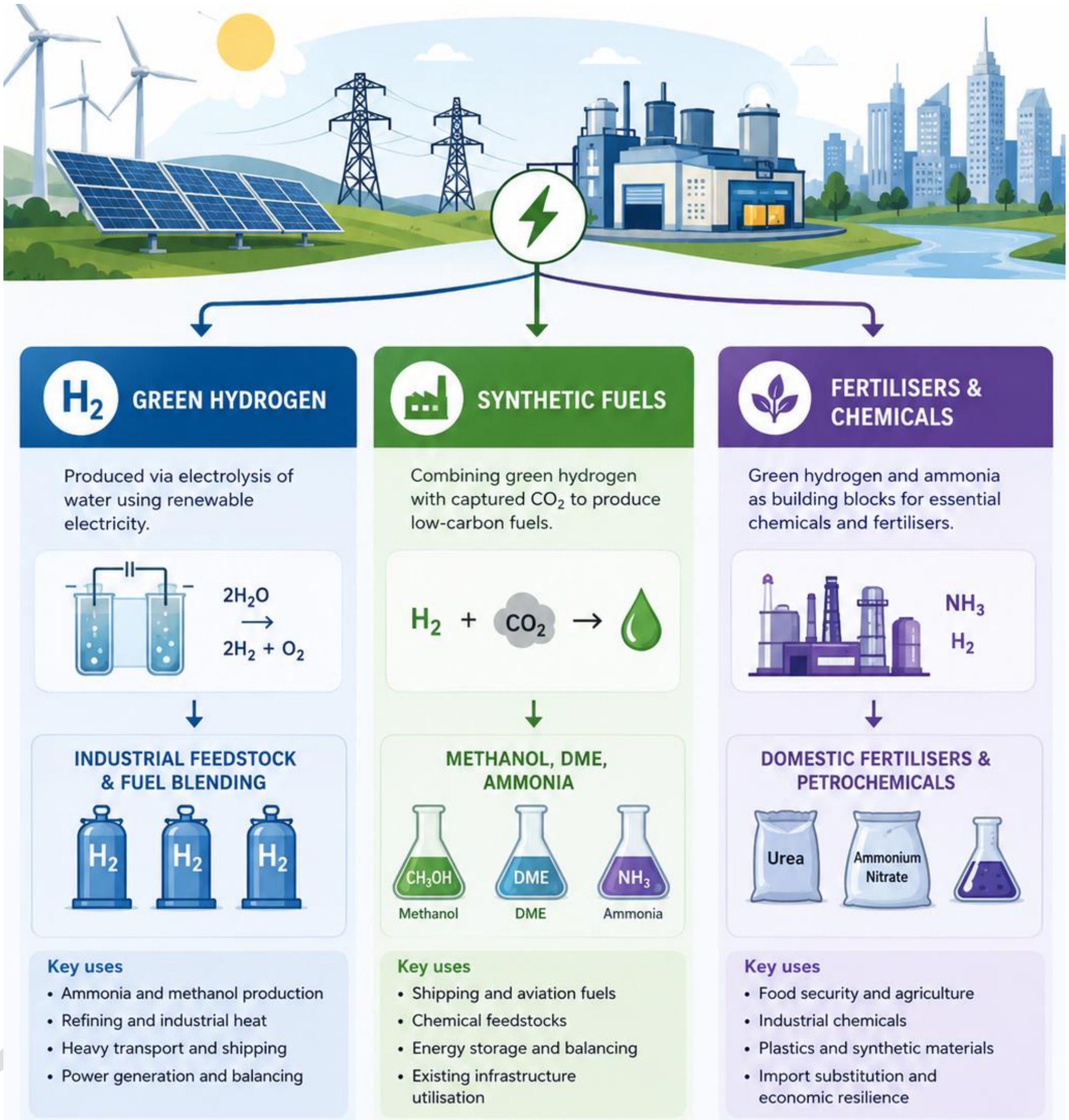

Figure 5 Renewables-to-Chemicals

- **Underground Coal Gasification** (UCG) could be explored for deep or stranded reserves, subject to appropriate environmental safeguards[71].
- Integrating **Carbon Capture, Utilisation and Storage** (CCUS) across coal-linked industrial clusters could help reduce emissions while enabling CO_2-to-value pathways. The development of shared CO_2 transport and storage infrastructure may be considered as strategic public infrastructure to support commercial-scale deployment.

[71] Ministry of Coal, UCG Draft Guidelines 2025. https://coal.gov.in/sites/default/files/2025-10/27-10-2025a-wn_0.pdf

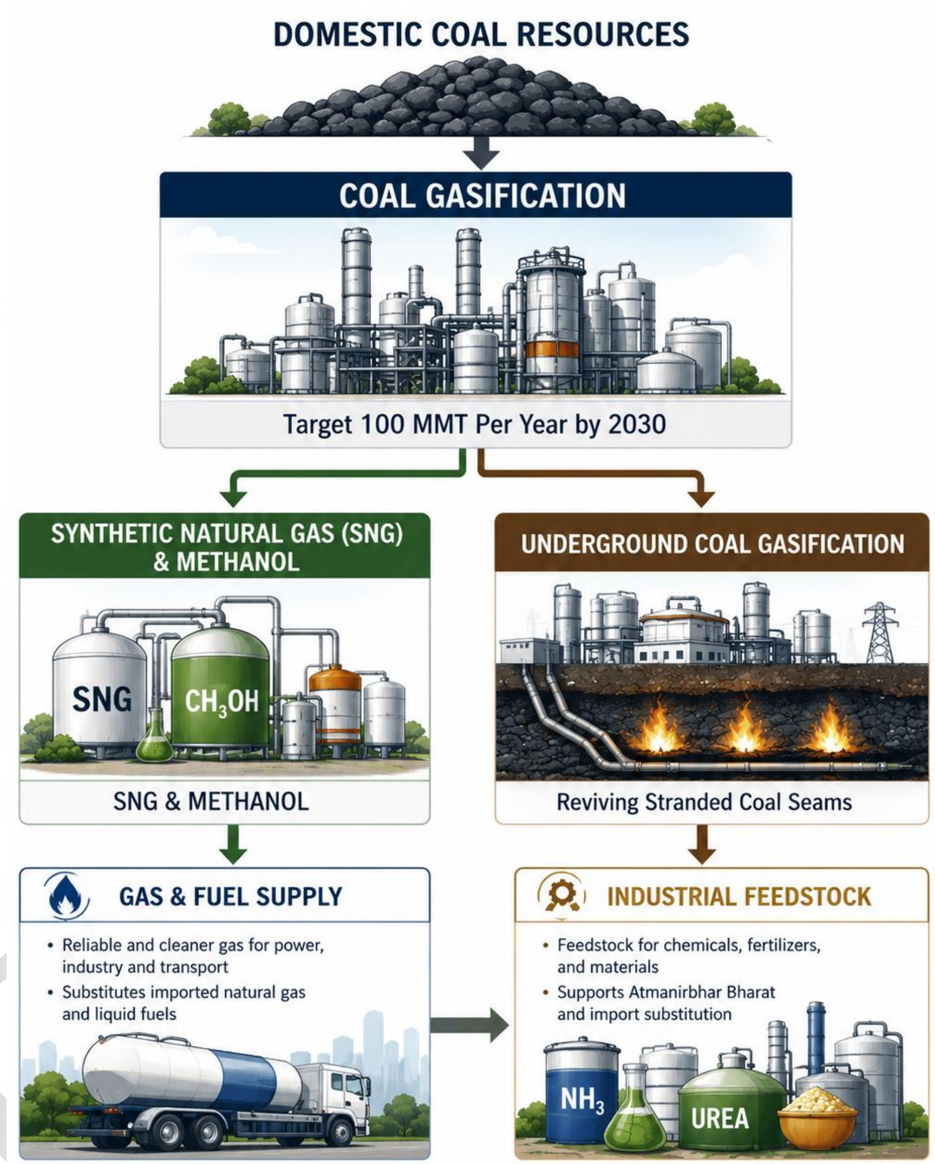

Figure 6 New Pathways for Coal Utilisation

Scaling up and diversifying non-coal energy sources:

- It may be useful to accelerate the expansion of gas infrastructure through a dedicated pipeline development programme, helping to better utilise existing gas-based capacity and support a gradual shift away from liquid fuel imports.
- Greater emphasis could be placed on scaling **compressed biogas** (CBG) as a decentralised energy source, particularly by linking it with waste management systems and rural energy systems.

- A phased approach to hydrogen adoption may be considered by introducing 5–10% **green hydrogen** blending in industrial gas networks and refinery operations, while simultaneously supporting domestic electrolyser manufacturing and market development[72].
- There is a need to prioritise transmission network expansion to evacuate currently stranded renewable capacity, enabling more efficient utilisation of installed solar and wind assets.
- It may be worthwhile to promote **concentrated solar thermal** (CST) technologies for industrial process heat, particularly in sectors such as textiles, food processing, and chemicals, where direct fossil fuel substitution is feasible[73].
- Nuclear energy expansion could be strategically aligned with India's **thorium reserves**, alongside the development of **small modular reactors (SMRs),** to provide a stable, low-carbon baseload while strengthening long-term energy security[74]. Figure 7, indicates the suggested pathways for investment in the Nuclear Programme.
- **Biomass utilisation** may be further strengthened through co-firing in coal power plants and expanded use of biomass briquettes for industrial heating and clean cooking applications, building on existing localised initiatives[75].
- India's hydropower potential stands at 21,133.61 MW. Schemes such as the **Small Hydro Power** Development Scheme should be strengthened through targeted incentives, streamlined clearances, and support for decentralised low-carbon energy generation[76].
- **Wind energy** deployment may be accelerated through targeted development of high-potential wind zones, strengthened grid infrastructure, given India's estimated wind potential of over 695 GW at 120m hub height. Offshore wind energy may also be prioritised through dedicated funding, streamlined regulatory frameworks, and domestic manufacturing support.[77]

[72] PIB, Cabinet approval National Green Hydrogen Mission 2023. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1888547&reg=3&lang=2

[73] MNRE, Concentrated Solar Thermal for industrial process heat. https://mnre.gov.in/en/concentrated-solar-thermal/

[74] DAE, India's Three-Stage Nuclear Programme and thorium. https://www.pib.gov.in/FactsheetDetails.aspx?id=150617&NoteId=150617&ModuleId=16&reg=3&lang=1

[75] MNRE, Biomass co-firing and briquette programmes. https://mnre.gov.in/en/skill-development-programme/

[76] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2255609&reg=3&lang=1

[77] https://mnre.gov.in/en/wind-overview/

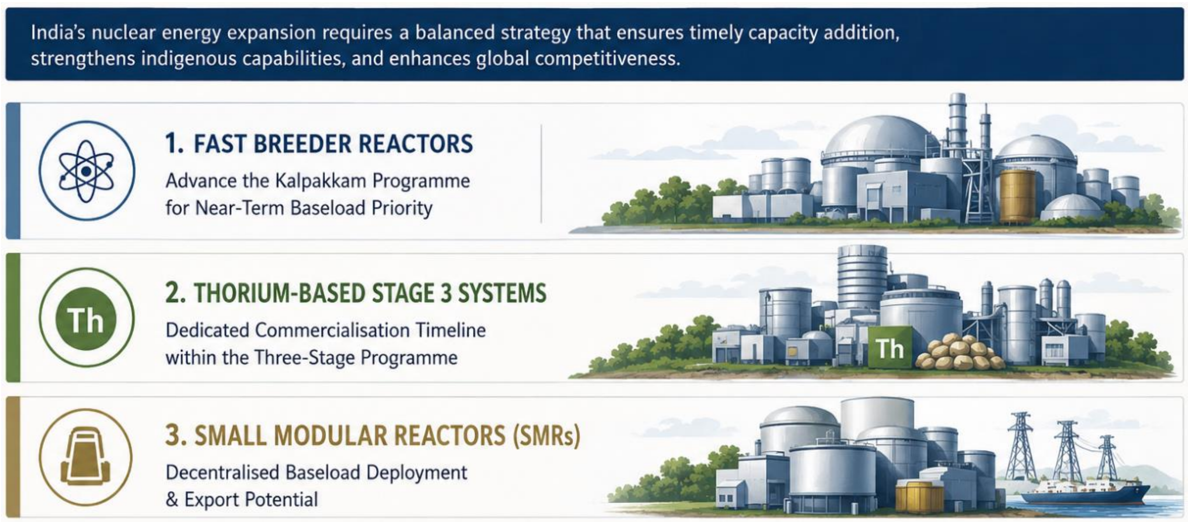

Figure 7 Suggested Priority Investments for Nuclear Power Programme

Integrated Water-Energy Planning: There is a need to adopt integrated water–energy planning approaches that account for regional water availability while siting and scaling energy infrastructure. This could prioritise deployment of less water-intensive technologies, incentivise the use of treated wastewater and closed-loop systems, and encourage location-specific planning to reduce the mismatch between water resources and energy production.

Strengthening energy security buffers: It may be useful to expand strategic reserves for petroleum, crude oil, and LNG towards a minimum 90-day storage capacity to strengthen energy security against external disruptions.

Building digital energy infrastructure: Consideration could be given to developing a national, real-time energy monitoring dashboard as part of a digital public infrastructure for energy, integrated across central, state, and local levels to capture demand, distribution, and supply across energy sources.

Scaling diversified storage solutions: A diversified energy storage strategy may be prioritised by scaling technologies such as PHS (Pumped Hydro Storage)[78], PCM (Phase Change Materials)[79], thermal storage, flow batteries, and lithium-ion through a technology-neutral programme to meet the ~200+ GWh requirement by 2030[80], while enhancing grid stability and reliability (Figure 8). It should

[78] https://www.sciencedirect.com/topics/engineering/pumped-storage-hydroelectricity
[79] https://pubs.rsc.org/en/content/articlelanding/2024/cc/d3cc06063b
[80] MNRE, Energy storage requirement for 500 GW target by 2030. https://mnre.gov.in/en/wind-overview/

be noted that without an efficient e-waste collection and recycling ecosystem that can de-risk local battery production supply chains from both import risks and end-of-life environmental implications, indigenous storage development may not yield the necessary long-term benefits. Policy support on recycling is therefore essential to ensure medium-term competitiveness for chemistries dependent upon critical minerals (especially lithium rare earths).

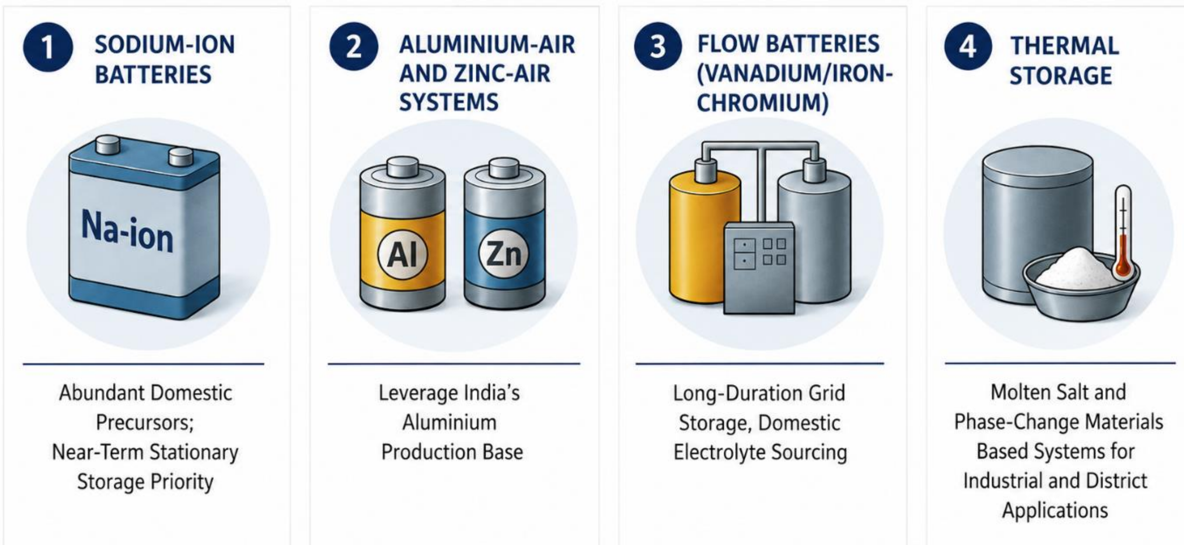

Figure 8 Suggested Priority Platforms for Indigenous Energy Storage

Advancing grid modernisation efforts: Grid modernisation could be advanced through investments in smart grids, advanced metering infrastructure, and digital control systems to improve efficiency and responsiveness as shown in Figure 9. Strengthening transmission and distribution networks, alongside better forecasting and demand-side management, may further enhance grid resilience and integration of diverse energy sources. An additional note of caution must be sounded for the increased and the imperative digitalisation of the power grid. This leaves it vulnerable to malicious activity exploiting gaps in cyber security. The same concern is echoed for critical fuel infrastructure such as refineries depots and pipelines which are progressively being digitalised.

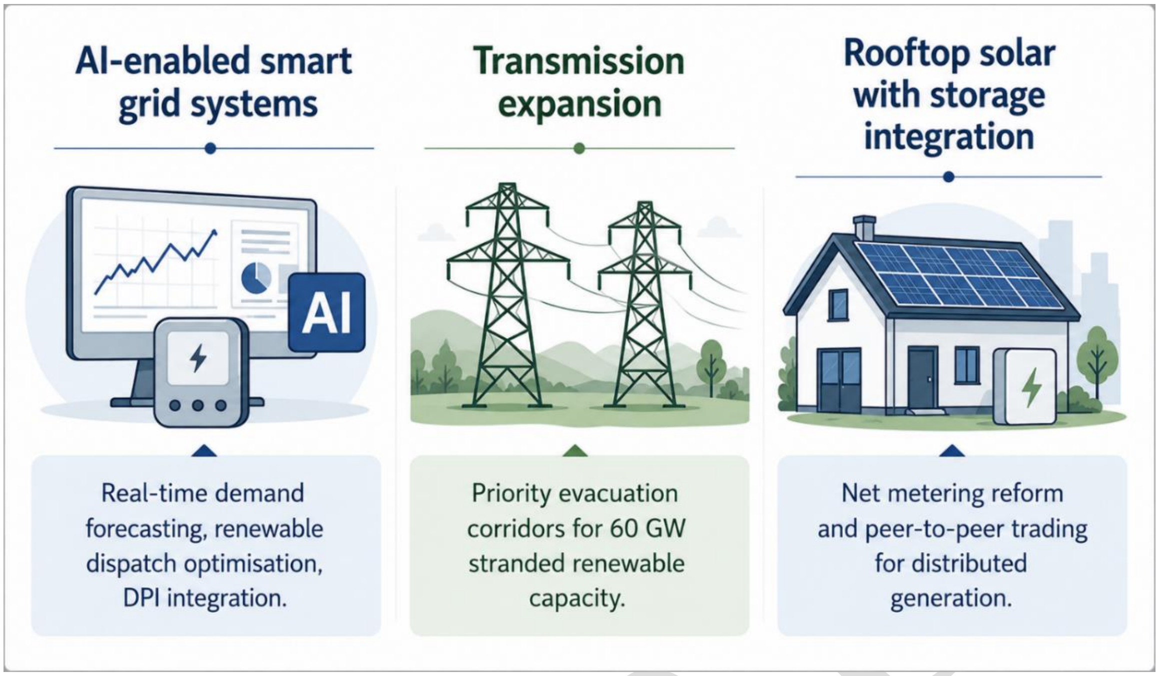

Figure 9 Suggested Pathways for Grid Modernisation

Prioritising circular industrial transitions: It may be useful to prioritise circular economy interventions in hard-to-abate sectors such as steel, cement, aluminium, petrochemicals, and fertilisers, with a focus on material efficiency and recycling (Figure 10). For instance, night soil (fresh human sewage) can be valuable organic fertiliser as demonstrated by Japan, Malaysia, Thailand since 1950. Modern nutrient recovery from treated wastewater can be significant contributors to meeting Phosphorous and nitrogen demand, currently met by synthetic fertiliser[81]. Recycling infrastructure may be strengthened through investments in modern recycling plants and material recovery facilities, particularly in high-waste-generating states, to support resource recovery, reduce landfill dependency, and generate green employment[82].

Scaling waste heat recovery adoption: There is significant potential to expand waste heat recovery across energy-intensive sectors, particularly by supporting MSMEs through targeted financing and aggregation models. Heat pumps are emerging as a potentially valuable localised solution in this context.

[81] https://www.hindustantimes.com/opinion/can-waste-solve-india-s-fertilizer-challenge-a-circular-economy-opportunity-101781188521688-amp.html

[82] https://www.resposeindia.com/post/recycling-plants-demand-india-top-states-2026

Sustainable Heating and Cooling: There is opportunity in revisiting heating and cooling across industrial, building and transport applications. One suggestion is to maximise heating and cooling from dry ice decreased temperature of -80ºC to superheated low pressure steam temperature of 150ºC and replace their heating through renewables.

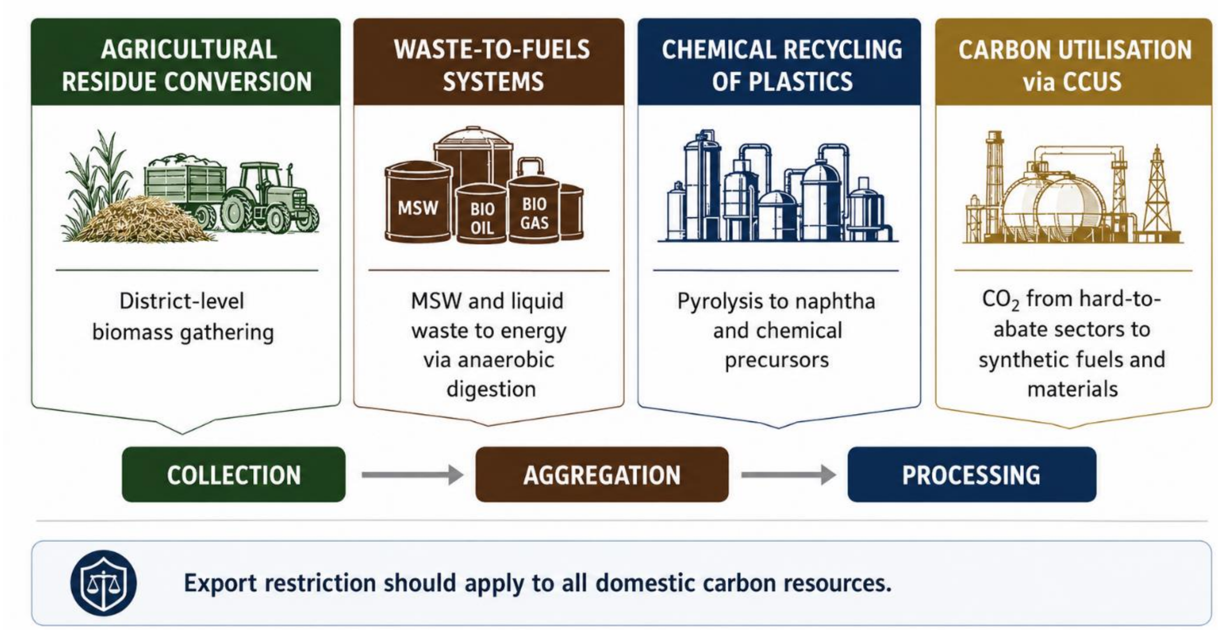

Figure 10 Suggested priority interventions for Circular Carbon Economy

Accelerating efficient electrification: Electrification across transport, industry, and cooking offers high efficiency gains and may be advanced through efficient technologies, existing policy mechanisms, and expansion of clean electricity supply.

Ensuring Reliable Power Supply: Consumers should receive continuous 24×7 electricity with stable voltage and frequency. This requires discoms to strengthen buffering, load management, and grid balancing mechanisms to ensure consistent and reliable power delivery.

Grid capacity enhancement: Strengthen and modernize the national grid to handle significantly higher power flows by upgrading transmission infrastructure, enhancing inter-regional connectivity, and improving grid management systems to ensure reliability, efficiency, and future readiness.

Hybrid AC–DC optimisation: It is recommended to explore the adoption of DC power transmission, particularly at the end-user level, to improve efficiency and reduce conversion losses.

A carefully designed hybrid AC–DC grid may offer a viable pathway, warranting detailed technical and feasibility assessment.

4.2 Pillar II: Access

Adopting Hybrid Renewable Systems: It may be useful to enhance the reliability of electricity access by promoting decentralised hybrid grids based on locally available energy sources (such as solar, wind, hydro, and others), supported by adequate storage to address intermittency (Figure 11).

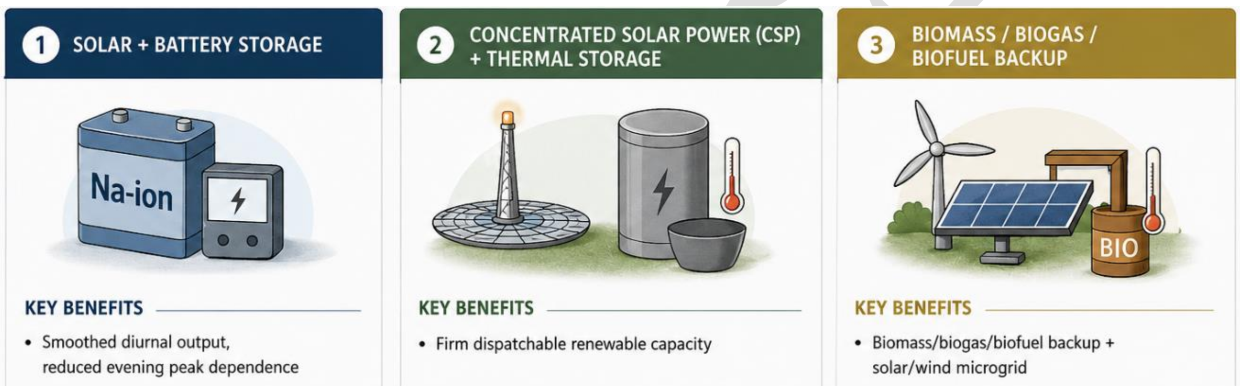

Figure 11 Suggested Hybrid Renewable Systems

Supporting clean cooking access: Targeted LPG refill support for PMUY beneficiaries, alongside scaled deployment of domestic and modular biogas plants (e.g., up to 1 crore units over five years), may help reduce reliance on traditional biomass. Further, electrification of cooking for the beneficiaries should be explored.

Expanding CBG ecosystem: Strengthening the SATAT scheme through demand-side measures such as pipeline access, blending mandates, and pricing alignment with CNG could help bridge the gap between planned and operational CBG capacity.

Promoting decentralised biodiesel: It may be worthwhile to support low-cost, decentralised biodiesel production at farm and community levels using ambient-condition technologies, building on existing demonstration models.

Enabling local biomass value chains: Establishing decentralised biomass pre-treatment units for drying, shredding, and densification into briquettes and pellets may improve local fuel availability and utilisation. The biomass can also be used for the manufacturing of bio-fertilisers.

Demand-side activation: There is a need to encourage wider end-use adoption through improved consumer awareness, greater appliance availability, and measures to ease switching costs. Such efforts could support market creation and accelerate the uptake of cleaner energy solutions.

Supporting farm-level cold chains: Integrating renewable energy hubs with low-energy cold-chain solutions, such as portable dry ice systems, could support local produce storage without requiring complex infrastructure.

Empowering community energy systems: Strengthening Village Level Entrepreneur (VLE) networks to manage local energy distribution, storage, and maintenance may improve last-mile delivery while generating rural employment opportunities.

4.3 Pillar III: Affordability

Mobilising blended green finance: It may be useful to develop a standardised Indian green bond taxonomy with disclosure norms, while leveraging multilateral and international climate finance and establishing first-loss guarantees to support MSME-scale decentralised energy investments.

Operationalising carbon markets: There is a need to fully operationalise the Carbon Credit Trading Scheme (CCTS) through a robust registry, verified methodologies, and transparent price discovery via multilateral funding, enabling credible carbon pricing and supporting CCUS and industrial decarbonisation.

Competitive pricing reform: There is a need to move towards pricing frameworks that ensure emerging energy carriers remain competitive without prolonged subsidy dependence. This could enhance market sustainability while maintaining affordability for end users.

Offtake assurance: There is a need to strengthen demand certainty through long-term purchase agreements or blending mandates. Such mechanisms could help de-risk private investments and support scale-up across the energy ecosystem.

Strengthening discom financial discipline: There is a need for effective apportionment of the energy budget, with transparent allocation of resources to individual states based on demand and performance. This, along with timely tariff revisions, improved billing efficiency, and performance-linked support, could help reduce losses and strengthen discom financial sustainability.

Implementing time-of-day pricing: All states must be encouraged to transition to Time-of-Day (ToD) tariffs to better reflect peak demand pressures and enable more effective demand-side management and load balancing.[83]

Embedding affordability safeguards: It may be important to ensure that a Unified National Energy Policy incorporates affordability safeguards, including targeted support mechanisms to mitigate the impact of rising energy costs on vulnerable consumers.

Protecting vulnerable consumers: Subsidy rationalisation and tariff reforms may be designed with safeguards such as lifeline tariffs and direct benefit transfers to protect low-income households during the energy transition.

4.4 Pillar IV: Appropriate Sustainability

Decentralised resource planning: It may be useful to undertake district-level energy resource mapping, recognising regional variations in biomass, solar, wind, and industrial demand, to better align technology deployment with local resource endowments which can be done by GSI using latest GIS (Geographic Information System) technologies as indicated in Table 3. Such local resource deployments can meet part of local demand and reduce net GHG emissions on lifecycle basis while generating employment, especially where heat energy requirements are concerned or in areas where logistics might be geographically challenging.

Table 3 Suggested district-level renewable energy source inventories at regional level

Region/District Cluster	Biomass Availability	Renewable Potential	Industrial Demand (Heat/Power)	Technology Match Examples
Northern (e.g., Punjab, Haryana, W. UP)	High: Paddy straw, wheat stalk, mustard husk.	Solar: High (300+ sunny days).	Heavy: Rice mills, textiles, brick kilns, food processing.	Biomass Pelleting & Co-firing: Multi-fuel boilers for MSME steam; DRE solar for power.

[83] https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1934673&reg=3&lang=2

Western (e.g., Nashik, Solapur, Surat)	High: Sugarcane bagasse, cotton stalk, fruit waste.	Wind/Solar: Very High (Hybrid potential).	Very High: Textiles, chemicals, sugar refineries, foundries.	Bagasse Cogeneration: Waste-to-Heat; Hybrid Wind-Solar farms for high-load industrial clusters.
Southern (e.g., Belagavi, Coimbatore, Guntur)	Medium-High: Coconut shell, rice husk, coffee waste.	Wind/Small Hydro: Leading wind capacity.	Moderate-High: Foundries, textiles, pharma, metal MSMEs.	CBG (Compressed Biogas): Bio-CNG for transport/heat; Small-scale wind for MSME clusters.
Eastern (e.g., Bardhaman, Patna)	High: Rice husk, forest residues, municipal waste.	Solar/Hydro: Strong solar and small-hydro potential.	Moderate: Food processing, metallurgical MSMEs, brick kilns.	Gasification: Bio-syngas for thermal heat in kilns; Rice husk-based power plants for local grids.
Central (e.g., Indore, Raipur, Nagpur, Bhopal)	Medium: Soybean husk, maize cob, cotton waste.	Solar: High irradiance; central logistics hub.	Moderate: Pharma, food processing, logistics hubs.	Distributed Solar: Rooftop solar (PM Surya Ghar); Waste-to-Energy for urban MSME clusters.

Shallow geothermal cooling: These systems may be promoted for buildings as a low-energy, climate-resilient cooling solution, particularly in urban and high-density developments, to reduce dependence on conventional electricity-intensive cooling systems and improve overall energy efficiency in the building sector.

Strengthening biomass value chains: It may be useful to reform biomass utilisation by developing local aggregation, processing, and conversion infrastructure to enable production of biogas, 2G ethanol, CBG, and bio-based chemicals, thereby reducing waste, retaining value domestically, and lowering import dependence. The details are illustrated in Figure 12.

Figure 12 Biomass Value Chain

Enabling coordinated energy governance: It may be considered appropriate to establish a National Energy Coordination Authority (NECA) as a statutory inter-ministerial body to support integrated planning, coordination, and monitoring, including the development of a rolling national energy plan[84].

Energy Translation Missions: Consideration could be given to redirecting ANRF/RDI[85] funding towards Technology Readiness Level (TRL) 4–7 pilot and demonstration projects in key transition technologies such as CCUS, 2G biofuels, advanced energy storage, and green hydrogen, supported through a blended financing approach combining grant funding, concessional debt, and guaranteed offtake mechanisms to facilitate de-risking and accelerate pathways to commercial deployment.

Lifecycle Governance and Circular Economy Regulatory Alignment: It may be useful to consider adopting lifecycle assessment (LCA)[86] and circular resource planning across sectors, as existing circular economy regulations in India remain fragmented and are yet to be integrated within a unified energy security framework.

Emerging Energy Sources: India's long-term energy sovereignty requires investment in emerging technologies with low current readiness but high indigenous or geographic potential. In this context, strategic investments in ocean energy, geothermal resources, naturally occurring hydrogen, and fusion research may be considered as part of a long-term option-value approach to energy security and technological preparedness. For mitigation of natural gas imports, significant gas hydrate deposits (about 1.9 trillion cubic metres, TCM) that have been identified. Specifically, the concentrated reserves in the Krishna-Godavari (KG), Mahanadi, and Andaman offshore basins need to be leveraged, but technical, environmental and economic challenges have to be overcome through concerted efforts[87]. Moisture-based energy generation technologies may also be promoted through targeted research, pilot projects, and innovation support, given their potential as a simple, green, and environmentally sustainable solution for low-power-density applications, particularly in remote and wearable devices[88].

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[84] It may be noted that several countries have a single Ministry of Energy or equivalent central executive Energy authority, for instance United Kingdom (Department for Energy Security and Net Zero) France (Ministry of the Environment, Energy and Marine Affairs), United States (Department of Energy), Saudi Arabia (Ministry of Energy), Indonesia: Ministry of Energy and Mineral Resources.

[85] DST/ANRF, Research Development and Innovation (RDI) Fund. https://rdifund.anrf.gov.in/

[86] IBEF, Circular Economy in India – MoEFCC committees. https://www.ibef.org/research/case-study/sustainable-circular-economy-in-india

[87] https://www.dghindia.gov.in/index.php/page?pageId=39

[88] https://pubs.acs.org/doi/10.1021/acsnano.4c01416

Leveraging Indigenous Technologies: Significant scope exists to prioritise proven domestic technologies such as BHEL's Pressurised Fluidised Bed Gasification (PFBG)[89], designed for high-ash, high-moisture Indian coal, to improve cost effectiveness, strengthen domestic manufacturing, and enhance supply chain localisation.

Transitioning to 2G Biofuels: The transition from grain-based ethanol to lignocellulosic (2G)[90] ethanol derived from agro-residues such as bagasse, rice straw, and bamboo may be accelerated, thereby addressing concerns related to food-versus-fuel competition while also enabling productive utilisation of an estimated 150 million tonnes of surplus agricultural residues[91].

Exploring White Hydrogen and Geothermal Resources: Systematic geological mapping and exploration may be undertaken for naturally occurring ("white") hydrogen, geothermal resources in the Himalayan Geothermal Province and Cambay Graben, and ocean thermal energy conversion (OTEC) potential along India's 11,000 km coastline[92].

Adopting Zero-Waste Integrated Biorefineries: Integrated biorefineries may be supported to co-produce green heat, steam, biofuels, and value-added chemicals from waste biomass and sewage streams, with emphasis on domestic value addition and minimising export of raw biomass and carbon-rich waste streams.

Indigenous Storage Manufacturing: India's comparative advantage in aluminium, zinc, iron, and its electrochemical engineering base may be leveraged to develop sodium-ion, flow battery, and metal-air storage systems at scale, alongside the promotion of non-lithium storage chemistries to strengthen domestic energy storage capabilities.

Inclusive Architecture for Just Transition

- Investing in Green Skills with Equity Targets: The Skill Council for Green Jobs[93] may be expanded with dedicated training programmes covering decentralised energy systems, biogas

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[89] BHEL, PFBG first commercial-scale application, Jharsuguda. https://www.bhel.com/bhel-secures-coal-gasification-package-bcgcl-project

[90] This reduces the food vs fuel dilemma and cuts the biofuel to water ratio from about 1:1000-10,000 to about 1:10. Still, with clean water being a resource under stress for the country, we need to be cautious. See https://www.pnas.org/doi/10.1073/pnas.0812619106

[91] IEA / TIFAC, Surplus crop residue in India for biofuel production. https://www.iea.org/commentaries/unlocking-indias-bioenergy-potential

[92] Sciencedirect, Ocean energy potential along India's coastline and EEZ. https://www.sciencedirect.com/science/article/abs/pii/S0301421521005061

[93] SCGJ, Skill Council for Green Jobs – MNRE promoted green skills body. https://sscgj.in/about-us/

plant management, EV servicing, grid modernisation, and CCUS plant operations, with explicit inclusion targets for workers from coal-dependent communities, women, and marginalised groups.

- Social Impact Assessment for Energy Infrastructure: Mandatory social impact assessments may be required for large-scale energy projects, including solar parks, transmission corridors, pumped hydro storage facilities, and industrial CCUS clusters, covering displacement, livelihood impacts, gender considerations, and community consent.
- Just Transition Fund: A dedicated fund may be established, drawing on international climate finance, to support economic diversification, reskilling, and social protection in alignment with defined implementation timelines under the energy transition roadmap in line with the findings of such Social Impact Assessment.
- Participatory Governance at the Community Level: Village-level and district-level energy planning processes may be designed to ensure meaningful participation of women, marginalised communities, and displaced worker groups as decision-makers, rather than only as beneficiaries.

5 Foundational Enablers for the Recommendations

The four pillars of the Unified National Energy Policy Framework — Adequacy, Access, Affordability, and Appropriate Sustainability are interdependent by design. A coal gasification programme that advances Pillar I will stall without financing structures capable of funding long-gestation capital projects (Pillar III). Decentralised microgrids that expand Pillar II access will underperform without a digital monitoring layer that can optimise distributed generation in real time (Pillar IV), and may benefit from digitally managed alignment with central grids wherever feasible. Green hydrogen investments under Pillar III depend on the same grid modernisation infrastructure that Pillar IV requires. This interdependence means that the four pillars cannot be assigned to individual ministries and optimised in isolation — they require a layer of shared institutional, financial, and technological infrastructure that sits *across* all four, enabling coordination that no single pillar can achieve on its own.

This section defines five such cross-cutting enablers: a unified governance authority capable of integrated planning; a research and innovation pipeline that bridges the valley of death between laboratory science and commercial deployment; a financing architecture that mobilises the USD 150–

200 billion the transition requires without relying solely on domestic public budgets; a digital infrastructure layer that provides real-time system visibility for evidence-based policy; and inter-ministerial coordination principles that prevent the siloed optimisation and market misalignment discussed in Section 2.6. These are not support functions, they are the connective tissue without which the four pillars remain structurally separate rather than mutually reinforcing.

5.1 Unified Energy Governance: National Energy Coordination Authority (NECA)

Expert consultations converged on a clear consensus: electricity and fuels must be planned jointly, and grid stability is India's main future systemic risk. Addressing this requires a statutory, cross-ministerial governance architecture that does not currently exist.

The framework proposes the establishment of a National Energy Coordination Authority (NECA) — a statutory, inter-ministerial body with planning, coordination, and monitoring authority across the Ministries of Power, Petroleum and Natural Gas, Coal, New and Renewable Energy, and Heavy Industries. NECA would be distinct from NITI Aayog's advisory function: it would carry operational coordination authority over a rolling Integrated National Energy Plan (INEP), covering generation, transmission, storage, fuels, and demand-side management as a unified system rather than as parallel ministry-level plans.

Strong inter-ministerial coordination is required to ensure coherence across sectors such as power, environment, finance, industry, and transportation. Since energy issues intersect with climate action, economic growth, and social welfare, isolated decision-making often leads to inefficiencies, policy overlap, or regulatory conflicts. A coordinated approach allows for integrated planning, efficient resource allocation, and streamlined implementation of cross-cutting initiatives like renewable energy expansion, grid modernisation, and energy security. Strengthening institutional mechanisms for collaboration among ministries enhances policy alignment, reduces duplication, and accelerates progress toward national sustainability and energy transition goals.

Key institutional mandates for NECA can include:

Integrated National Energy Plan: A rolling five-year plan updated on an annual basis, with binding inter-ministerial implementation targets across generation, transmission, storage, fuels, and demand management.

Grid and Logistics Coordination Cell: A dedicated cell within NECA to synchronise transmission expansion, renewable energy evacuation infrastructure, gas pipeline development, and storage deployment, the four infrastructure threads that currently proceed on uncoordinated timelines across separate ministries.

Market Alignment Oversight: Authority to review and flag production-demand mismatches across biofuel, biogas, green hydrogen, and other transition fuel programmes - addressing the structural problems illustrated and discussed in Section 2.6.

Just Transition Monitoring: Responsibility for tracking social equity indicators across the transition, including coal community reskilling progress, PMUY refill utilisation, and green skills pipeline performance.

Policy Design Review: A formal function combining subsidies and incentives, market mechanisms (carbon credits, flexibility markets), and hybrid system incentives into coherent, whole-chain policy packages rather than isolated production-side mandates.

5.2 Bridging the Innovation–Deployment Gap: Energy Translation Missions

India faces a well-documented "valley of death" in energy innovation: academia develops early-stage technologies at TRL 3–4 while industry adopts only near-commercial solutions at TRL 8–9, leaving the critical mid-stage demonstration and piloting phase chronically underfunded. The recently launched Anusandhan National Research Foundation (ANRF) and Research, Development, and Innovation (RDI) Scheme are expected to provide important impetus in this direction, but their current focus skews toward basic research rather than translational deployment.

The framework proposes redirecting a significant share of public energy R&D funding toward dedicated Energy Translation Missions covering TRL 4–7 pilot and demonstration projects. Each mission would combine grant funding, concessional debt, and guaranteed offtake to de-risk private investment and accelerate commercialisation of technologies that are ready for demonstration but not yet investable at market terms. Priority missions proposed are:

- **CCUS Demonstration Mission:** Industrial-scale CO_2 capture pilots at cement, steel, and refinery sites, with integrated CO_2 transport and utilisation pathways. Experts strongly recommended establishing national CO_2 transport and storage infrastructure as strategic public infrastructure.

- **2G Biofuel Scale-Up Mission:** Lignocellulosic ethanol and biogas demonstration at agro-residue collection hubs, with assured offtake linkage to oil marketing companies and pipeline access mandates.

- **Advanced Storage Technology Mission:** Non-lithium long-duration storage pilots covering flow batteries, thermal storage, compressed air, and aluminium-based systems, with performance benchmarking against projected grid storage requirements of ~200+ GWh by 2030.

- **Green Hydrogen Industrial Blending Mission:** Phased blending pilots at 5–10% in industrial gas networks and refinery operations, linked to domestic electrolyser manufacturing scale-up under the National Green Hydrogen Mission.

- **Underground Coal Gasification (UCG) Demonstration:** Pilot commissioning at deep or stranded coal seams unsuitable for conventional mining, building, for example - on BHEL's Pressurised Fluidised Bed Gasification (PFBG) capability tailored to high-ash Indian coal characteristics.

5.3 Mobilising Green Finance

The scale of India's energy transition, spanning generation, storage, transmission, industrial decarbonisation, and decentralised energy systems, requires financing at a magnitude that cannot be met through public budgets alone. Mobilising private capital, both domestic and international, requires credible frameworks, risk mitigation instruments, and market structures that do not yet fully exist.

The following financing architecture is proposed:

- **Indian Green Bond Taxonomy:** Develop a standardised, mandatory green bond taxonomy with disclosure norms aligned to international best practice but calibrated to India's developmental context. A credible domestic taxonomy is a prerequisite for channelling institutional capital- insurance funds, pension funds, sovereign wealth funds, toward long-duration energy infrastructure.

- **First-Loss Guarantee Facilities:** Establish government-backed first-loss guarantee instruments for MSME-scale decentralised energy investments, community biogas plants, EV charging infrastructure, and rooftop solar, where perceived risk currently prices out private finance.
- **Multilateral and Climate Finance Engagement:** Actively engage multilateral development banks and international climate finance mechanisms, including the Just Energy Transition Partnership (JETP) and Article 6 carbon markets under the Paris Agreement for co-financing of large-scale infrastructure: pumped hydro storage, CCUS clusters, long-duration storage, and transmission expansion.
- **Carbon Credit Trading Scheme (CCTS) Operationalisation:** Seek commitment and fulfilment of international climate finance to operationalise the CCTS with a functioning registry, verified offset methodology, and transparent price discovery mechanism. Without multilateral funding, it would be difficult to establish a credible domestic carbon price, which, in turn, is a prerequisite for commercial CCUS investment and for making industrial decarbonisation economically rational for hard-to-abate sectors.
- **Just Transition Fund:** Establish a dedicated fund drawing on international climate finance to support economic diversification, reskilling, and social protection, as outlined in Section 4.4.

5.4 Digital Public Infrastructure (DPI) and Real-Time Energy Monitoring

Effective energy governance in a system as large and diverse as India's requires real-time visibility across the entire demand-distribution-supply chain. Current monitoring is fragmented by ministry, fuel type, and geography, making integrated planning and dynamic demand response management structurally difficult.

The framework proposes building a national real-time energy monitoring dashboard, integrated across center, state, and local government levels, capturing generation, transmission, storage, fuel production, and end-use demand across all energy categories. The proposed DPI layer under IES (India Energy Stack)[94] could include:

- Evidence-based policy review at the national level, replacing anecdotal or lagged administrative data
- Dynamic demand response management, activating idle gas-based capacity (~25 GW) during peak events, managing renewable curtailment in real time
- District-level energy service tracking, including PMUY refill utilisation, electrification quality metrics, and CBG plant performance
- Carbon market registry integration, providing verified activity data for CCTS
- Early-warning signals for supply-demand imbalances, storage depletion risks, and transmission congestion
- Deep data analytics and AI capabilities applied at multiple governance levels from center to state to local bodies would allow both real-time operational decisions and periodic strategic policy reviews to be grounded in system-level evidence rather than sectoral reporting.

5.5 Policy Design Principles

Beyond institutional architecture, the effectiveness of the Unified National Energy Policy Framework depends on embedding a set of policy design principles that prevent the coordination failures, market distortions, and implementation gaps documented in Section 2.16. Expert consultations converged on several consensus findings that should be treated as standing design principles for all future energy policy formulation.

Electricity and fuels must be planned jointly. No energy sub-sector plan should be approved without demonstrating consistency with plans across the other sub-sectors. Generation targets must be accompanied by storage, transmission, and demand-side management plans.

[94] https://recindia.nic.in/india-energy-stack

Domestic resources must anchor policy choices. Before committing to import-dependent technology pathways, policy should demonstrate that indigenous resource options, coal gasification, biomass, solar, geothermal, thorium, have been assessed and either incorporated or explicitly ruled out.

Policy must cover the full value chain. Production targets without demand creation, pricing reform, and infrastructure readiness create the structural mismatches documented in biofuels and CBG. Every new energy programme must demonstrate market absorption capacity before supply expansion is incentivised.

Addressing financing and market alignment gaps requires a shift in how energy policy is architected is illustrated in Table 4.

Table 4 Policy Evolution recommendations

Policy Dimension	**Current Approach**	**Required Evolution**
Focus	Production targets and capacity mandates	Full value-chain design: production → logistics → pricing → demand
Financing instruments	Budgetary subsidies and bank loans	Blended finance, green bonds, first-loss guarantees, MDB co-financing
Risk allocation	State-absorbed or unallocated	Structured risk-sharing between government, DFIs, and private sector
Technology support	Early R&D funding (TRL 1–4)	Translational missions targeting TRL 4–7 demonstrations
Carbon pricing	Sector-specific PAT scheme	Unified domestic carbon market with international linkage options
Market readiness	Assumed or unaddressed	Explicit demand-side policy: procurement mandates, pricing parity, switching incentives

6 Implementation Roadmap

The four-pillar framework and its cross-cutting enablers span a twenty-year transformation horizon. Not all of it can be initiated simultaneously, nor should it be. The Implementation Roadmap below sequences the framework's priority actions across three planning horizons, Immediate (0–5 years), Medium Term (5–20 years), and Long Term (20+ years), structured around a clear internal logic: each phase creates the governance, infrastructure, and market conditions that make the next phase both feasible and efficient (Figure 13 & Table 5). Actions within each horizon are mapped to the responsible implementing ministry or agency to support accountability and inter-ministerial coordination under NECA. The roadmap is designed to be read alongside the Recommendations.

Figure 13 Pathway to a sustainable energy future

Table 5 India's Energy Transition Roadmap (2025–2050+)

Theme / Topic	Immediate Priorities (0–5 Years)	Medium-Term Priorities (5–20 Years)	Long-Term Priorities (20+ Years)
Coal	• Phase out inefficient subcritical plants; adopt PFBG/IGCC for improved efficiency and emissions • Accelerate coal gasification for methanol, DME, and ammonia production (import substitution) • Diversify coal supply partnerships; evolve towards resilience-oriented long-term procurement contracts • Pilot CCUS at select coal-linked industrial clusters; begin shared CO_2 infrastructure planning	•Scale coal gasification and hybrid 'renewables-to-chemicals' systems combining coal-based and green hydrogen outputs • Explore Underground Coal Gasification (UCG) for deep/stranded reserves with environmental safeguards • Expand shared CO_2 transport and storage infrastructure as strategic public assets	• Complete repositioning of coal as a chemical feedstock rather than a primary fuel • Phase down coal in power generation; retain only in CCUS-integrated or gasification configurations • Fully integrate coal-industrial clusters into commercial-scale CCUS and circular carbon value chains
Renewables (Solar & Wind)	• Prioritise transmission network expansion to evacuate stranded renewable capacity • Promote concentrated solar thermal (CST) for industrial process heat in	• Significantly scale utility-scale solar and wind capacity aligned with 500 GW target • Advance grid modernisation: smart grids, advanced metering	• Achieve deep penetration of renewables as the primary generation source • Fully integrate variable renewable energy with storage, smart grids, and

	textiles, food processing, chemicals • Undertake district-level energy resource mapping for solar, wind, and hybrid potential	infrastructure (AMI), digital control systems • Strengthen demand forecasting and demand-side management to improve VRE integration	AI-driven grid management • Develop offshore wind and hybrid renewable configurations for coastal and island regions
Gas & LNG	• Accelerate gas pipeline expansion programme to better utilise existing gas-based capacity • Expand strategic petroleum, crude oil, and LNG reserves to a minimum 90-day storage capacity • Begin phased reduction of liquid fuel imports through gas infrastructure buildout	• Use gas as a bridging fuel while scaling up low-carbon alternatives • Introduce 5–10% green hydrogen blending in industrial gas networks and refinery operations • Align gas procurement frameworks with long-term decarbonisation pathways	• Transition gas networks to carry increasing proportions of green hydrogen and biomethane • Phase down unabated fossil gas in power and industry; retain only in peaking or hydrogen-ready configurations • Achieve near-zero emissions from the gas sector through fuel switching and CCUS

Biogas & Biomass	• Strengthen SATAT scheme: pipeline access, blending mandates, and CNG pricing alignment for CBG • Establish decentralised biomass pre-treatment units (drying, shredding, densification into briquettes/pellets) • Support targeted LPG refill for PMUY beneficiaries; deploy up to 1 crore domestic biogas units over 5 years • Support low-cost decentralised biodiesel production at farm/community level	• Scale compressed biogas (CBG) as a decentralised energy source linked to waste management systems • Transition from grain-based to lignocellulosic (2G) ethanol from agro-residues (bagasse, rice straw, bamboo) • Develop integrated biomass aggregation and conversion infrastructure for biogas, 2G ethanol, and bio-chemicals • Expand biomass co-firing in coal power plants and biomass briquettes for industrial heating	• Deploy zero-waste integrated biorefineries co-producing green heat, biofuels, and value-added chemicals • Achieve full domestic value retention from biomass and sewage streams; eliminate raw biomass exports • Build a mature circular biomass economy with traceable, LCA-governed supply chains
Hydrogen	• Introduce 5–10% green hydrogen blending in industrial gas networks and refinery operations • Support domestic electrolyser manufacturing and market development • Redirect R&D funding (ANRF/RDI) to TRL 4–7 pilot projects in green hydrogen	• Scale green hydrogen production for hard-to-abate industrial sectors (steel, chemicals, fertilisers) • Undertake systematic geological mapping for naturally occurring ('white') hydrogen in sedimentary basins	• Establish hydrogen as a major fuel for industry, heavy transport, and grid balancing • Commercialise white hydrogen if geological assessments are favourable • Integrate hydrogen into renewables-to-chemicals systems for

		• Develop hydrogen storage, transportation, and refuelling infrastructure	long-duration energy storage and export potential
Nuclear	• Strategically align nuclear expansion programme with India's thorium reserves • Initiate regulatory and site development processes for new nuclear capacity • Invest in domestic nuclear manufacturing capabilities (BHEL and public sector partnerships)	• Commission new large-scale nuclear plants aligned with thorium fuel cycle roadmap • Develop and pilot small modular reactors (SMRs) for flexible, distributed low-carbon baseload • Deepen international nuclear technology partnerships for advanced reactor designs	• Achieve stable, large-scale low-carbon baseload from nuclear, displacing coal in the grid • Deploy SMRs at industrial clusters for co-generation (heat + power) • Advance towards a closed thorium fuel cycle, strengthening long-term energy sovereignty
Energy Storage	• Scale diversified storage portfolio — PHS, thermal storage, flow batteries, lithium-ion — to meet 200+ GWh by 2030 • Adopt a technology-neutral storage programme to enhance grid stability and reliability • Initiate R&D investment in indigenous sodium-ion, flow battery,	• Develop domestic manufacturing capacity for non-lithium storage chemistries (sodium-ion, zinc-air, iron-air) • Leverage India's aluminium, zinc, and iron reserves for storage manufacturing competitiveness • Integrate storage with renewable energy zones for firm power delivery	• Achieve large-scale indigenous storage manufacturing at globally competitive cost • Deploy long-duration storage solutions (multi-day/seasonal) to support deep renewable penetration • Export storage technology and systems as part of India's clean energy industrial base

	and metal-air storage systems		
CCUS & Carbon Markets	• Fully operationalise the Carbon Credit Trading Scheme (CCTS) with registry, verified methodologies, and price discovery • Pilot CCUS at select industrial clusters (cement, steel, fertilisers) with co-located CO_2 utilisation • Redirect ANRF/RDI funding to TRL 4–7 CCUS demonstration projects	• Develop shared CO_2 transport and storage infrastructure as strategic public infrastructure • Scale CCUS across coal-linked and hard-to-abate industrial clusters • Link CCTS to international carbon mechanisms available like Article 6 and JETP mechanisms	• Achieve commercial-scale CCUS deployment across major emission point sources • Develop CO_2-to-value pathways (e-fuels, building materials, chemicals) at industrial scale • Position India as an emerging market for carbon removal credits and green industrial products
Grid & Digital Infra-structure	• Develop a national real-time energy monitoring dashboard as digital public infrastructure (central, state, local levels) • Invest in smart grid pilots, AMI rollout, and digital SCADA systems in priority distribution zones • Strengthen transmission and distribution networks to	• Achieve full smart grid coverage across major urban and industrial load centers • Implement Time-of-Day (ToD) tariffs to reflect peak demand and enable demand-side management • Deploy AI-based demand forecasting, load balancing, and outage management systems	• Operate a fully integrated, AI-driven national energy management system • Enable real-time cross-border energy trading and load balancing with neighbouring countries • Transition to a demand-responsive, decentralised digital grid architecture

	reduce technical losses and improve reliability		
Circular Economy & Waste Heat	• Expand waste heat recovery across energy-intensive sectors; support MSMEs through targeted financing and aggregation • Adopt lifecycle assessment (LCA) frameworks across key sectors; begin circular resource planning pilots • Prioritise circular economy interventions in steel, cement, aluminium, petrochemicals, and fertilisers	• Scale material efficiency and recycling in hard-to-abate sectors as part of industrial decarbonisation strategy • Develop integrated circular economy regulatory framework aligned with energy security goals • Support zero-waste industrial parks combining waste heat, material recycling, and low-carbon energy	• Achieve full lifecycle governance and circular economy regulatory alignment across sectors • Integrate circular resource flows into national energy planning and industrial policy • Establish India as a global model for circular industrial transition in the Global South
Emerging Energy Sources	• Redirect ANRF/RDI funding to TRL 4–7 pilots in ocean energy, geothermal, advanced storage, and white hydrogen • Promote shallow geothermal cooling for buildings in urban and high-density areas • Leverage indigenous technologies (e.g., BHEL's PFBG) for	• Undertake systematic geological mapping for white hydrogen and geothermal potential (Himalayan Province, Cambay Graben) • Assess OTEC potential along India's 11,000 km coastline for island and coastal energy supply • Pilot ocean thermal, tidal, and wave energy	• Commercialise geothermal and ocean energy technologies where resource assessments are favourable • Invest in fusion energy research as a long-term option-value technology • Position India as a first mover in naturally occurring hydrogen

	domestic cost-effectiveness and localisation	systems in suitable coastal geographies	exploration and white hydrogen geoscience
Finance & Afford-ability	• Develop standardised Indian green bond taxonomy with robust disclosure norms • Establish first-loss guarantees and blended finance vehicles to support MSME-scale decentralised energy • Embed affordability safeguards (lifeline tariffs, direct benefit transfers) in all tariff reform processes • Integrate targeted support for vulnerable consumers in a Unified National Energy Policy	• Leverage multilateral climate finance (JETP, Article 6) for transition-critical investments • Implement ToD tariffs at scale; operationalise demand-side incentives for industrial and commercial users • Develop subsidy rationalisation pathway with built-in protections for low-income households	• Establish a mature, liquid carbon market integrated with global mechanisms • Develop a self-sustaining green finance ecosystem with domestic institutional investors • Achieve full cost-reflective energy pricing with robust social protection architecture
Energy Governan ce	• Establish a National Energy Coordination Authority (NECA) as a statutory inter-ministerial body • Develop a Unified National Energy Policy incorporating affordability, security, and sustainability objectives	• Publish and implement a rolling National Energy Plan with defined milestones and accountability mechanisms • Undertake district-level energy resource mapping to align technology	• Achieve fully integrated, adaptive energy governance that responds dynamically to technology and climate changes • Position NECA as a permanent strategic institution driving India's

	• Build national energy monitoring dashboard for integrated data across all fuels and sectors	deployment with local endowments • Enable coordinated procurement and infrastructure planning across central and state levels	energy sovereignty agenda • Develop international energy diplomacy framework leveraging India's transition experience
Just Transition & Access	• Establish a Just Transition Fund (coal cess revenues + international climate finance) for coal-dependent districts • Launch district-level transition plans for 30+ most coal-dependent districts (reskilling, diversification, social protection) • Strengthen Village Level Entrepreneur (VLE) networks for last-mile energy delivery and rural employment • Promote decentralised hybrid grids (solar, wind, hydro + storage) for reliable local energy access	• Expand Skill Council for Green Jobs with programmes in biogas, EV servicing, grid modernisation, CCUS operations • Mandate social impact assessments for large-scale energy projects (solar parks, transmission corridors, pumped hydro storage) • Design participatory governance mechanisms ensuring meaningful inclusion of women, marginalised communities, and displaced workers • Support farm-level cold chains using renewable energy hubs to reduce post-harvest losses	• Achieve full economic diversification of coal-dependent districts with green jobs replacing fossil fuel employment • Embed equity targets and inclusion metrics in all national energy programmes • Establish India's just transition model as a replicable framework for emerging economies

The long-term horizon is not a residual category of deferred ambitions it is the destination the entire framework is architected to reach. Each action in this horizon depends critically on foundations established in Phases 1 and 2: commercial thorium reactors at Stage 3 of the nuclear programme require the Fast Breeder Reactor progress of the medium term; the renewables-to-chemicals industrial ecosystem requires the green hydrogen blending markets, electrolyser manufacturing capacity, and CO_2 infrastructure built in the medium term; and the integrated circular carbon economy's demand reduction potential can only be realised once the CCUS infrastructure, CE regulatory alignment, and waste-to-energy systems initiated in earlier phases have achieved industrial scale. Long-term actions are therefore best understood not as new starts, but as the compounding returns on investments made earlier, returns that arrive on a decade-plus horizon precisely because their underlying science, infrastructure, and market development cannot be compressed. India's experience with the three-stage nuclear programme, now spanning six decades, illustrates both the patience required and the sovereign energy security payoff that patient investment eventually delivers. For planning purposes, NECA's rolling Integrated National Energy Plan should include formal long-term scenario modelling extending to 2047 and 2070, ensuring that near-term decisions in transmission, storage chemistry selection, and industrial cluster siting are made with awareness of their long-run implications for the strategic assets targeted in this horizon.

7 Conclusion

India's energy transition stands at a critical juncture, where the convergence of rising demand, persistent import dependence, and evolving global uncertainties necessitates a decisive shift in policy architecture. While the country has made notable progress in expanding energy access, scaling renewable capacity, and improving efficiency, these gains are increasingly constrained by structural challenges—fragmented governance, supply–demand mismatches, infrastructure gaps, and financing limitations. The absence of an integrated approach has led to inefficiencies across the energy value chain, where advances in one segment are often offset by bottlenecks in another. This underscores the central argument of this A Unified National Energy Policy Framework: that India's energy future cannot be secured through incremental, sector-specific interventions, but requires a coherent, system-wide framework.

The proposed Unified National Energy Policy Framework responds to this need by bringing together the four pillars of adequacy, access, affordability, and appropriate sustainability into a single, reinforcing architecture. By treating electricity, fuels, and industrial energy systems as interconnected components rather than isolated domains, the framework enables more efficient resource utilisation, reduces systemic risks, and aligns policy incentives across the full value chain. Importantly, it recognises that energy security, economic growth, and climate commitments are not competing priorities but can be pursued simultaneously through strategic policy design.

At the same time, the transition must be grounded in India's developmental realities. This includes leveraging domestic resource endowments, strengthening decentralised energy systems, and ensuring that affordability and equity remain central to policy decisions. The transition also carries significant social implications, particularly for coal-dependent regions and energy-poor households, making a just and inclusive approach essential. Without deliberate planning, the benefits of the transition risk being unevenly distributed, potentially exacerbating existing inequalities.

The brief also highlights that achieving India's long-term goals, Viksit Bharat by 2047 and Net Zero by 2070, will depend as much on institutional and financial innovation as on technological advancement. Establishing mechanisms such as a National Energy Coordination Authority, strengthening digital public infrastructure for real-time energy monitoring, and mobilising large-scale green finance are not ancillary measures but foundational enablers of the transition. Equally, bridging the innovation–deployment gap and ensuring market alignment across emerging energy sectors will be critical to translating policy ambition into tangible outcomes.

Ultimately, India's energy transition must move from a capacity-driven paradigm to a systems-driven approach - one that integrates production, infrastructure, markets, and end-use within a unified policy framework. The pathway outlined in this brief provides a structured yet flexible roadmap to navigate this transition, balancing ambition with feasibility. If implemented with coherence and continuity, it offers the potential to not only enhance energy security but also position India as a global leader in building a resilient, inclusive, and sustainable energy future.

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Annexure 1

Overview of Policies/Rules/Acts/Guidelines/Schemes/ Missions across India's Energy Value Chain.

Vertical	Generation stage	Transmission-stage	Consumption-stage
Power Sector			
Coal Power	Scheme for Harnessing and Transparently in India [SHAKTI] 2017, National Green Tribunal [NGT Act 2010];	Coal Block Allocation 2020 rules, National Electricity Policy [NEP 2005]; National Coal Distribution Policy [NCDP 2007]; MMDR (The Mines and Minerals (Development and Regulation)1957) (Amendment 2021) Coal Mines Act 2015	CoalSETU 2025; National Coal Gasification Mission 2020; Scheme for promotion of Coal/Lignite Gasification, 2024
Gas Power	Hydrocarbon Exploration Licensing Policy [HELP 2016], Sustainable Alternative Towards Affordable Transportation [SATAT 2018],	PNGRB Tariff Act 2008(Petroleum and Natural gas Pipline Tarrif Regulatons); Sustainable Alternative Towards Affordable Transportation [SATAT 2018],	PM Ujjwala Yojana 2021
Nuclear Power	The Sustainable Harnessing and Advancement of Nuclear Energy For Transforming India ACT 2025 (SHANTI ACT 2025) The Atomic Energy Act, 1962;	India-US Civil Nuclear Agreement	Atomic energy (safe disposal of radioactive wastes) rules, 1987

	Three-Stage Nuclear Programme 2026;		
Petroleum and Natural Gas Sector			
Imported LPG	-	Petroleum and Natural Gas Regulatory Board Act, 2006	PM Ujjwala Yojana 2021
CBG	National Policy on Biofuels 2018; (Amendment 2022) Biogas Programme 2022, Biomass Programme 2026, Waste to Energy Programme 2022, GOBARDHAN Scheme 2022	Auto fuel vision and policy 2025; Sustainable Alternative Towards Affordable Transportation [SATAT 2018],	Scheme Guideline for Development of Pipeline Infrastructure (DPI) for Facilitation of Compressed Biogas (CBG) offtake.
Biogas / Cooking Fuel	Biogas Programme 2022, Biomass Programme 2026, Waste to Energy Programme 2022, Biogas based Power Generation (Off-grid) and Thermal energy application Programme (BPGTP) (2018) National Biogas & Organic Manure Programme 2018;	-	PM Ujjwala Yojana 2021;

	Waste to Energy Programme 2022, National Policy on Biofuels (NPB 2018)		
Renewable Energy Sector.			
Solar PV	Jawaharlal Nehru National Solar Mission JN-NSM 2010; PM-JANMAN and PM JUGA Solar Scheme (New Solar Power Scheme 2024) Production Linked Incentive (PLI) Scheme: National Programme on High Efficiency Solar PV Modules 2021	Guidelines For Implementation Of The Scheme Intra State Transmission System Green Energy Corridor Phase-II 2022; PM-KUSUM Guidelines 2019	PM-Surya Ghar: Muft Bijli Yojana 2024
Wind	Wind-Solar Hybrid Policy 2018; National Repowering & Life Extension Policy for Wind Power Projects 2023; National Offshore Wind Energy Policy 2015	Renewable Purchase Obligation (RPO) and Energy Storage Obligation Trajectory till 2029-30 Wind Data Sharing 2016	Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Wind Solar Hybrid Projects. 2023.
Geothermal	National Geothermal Policy 2025; MMDR (The Mines and Minerals (Development and Regulation)1957) (Amendment 2021)	-	-
Ocean Energy	Deep Ocean Mission 2021	-	-

Hydrogen	National Green Hydrogen Mission 2023; Scheme Guidelines for implementation of "Strategic Interventions for Green Hydrogen Transition (SIGHT) Programme - Component I: Incentive Scheme Electrolyser Manufacturing Tranche – I 2024; Scheme Guidelines for setting up Hydrogen Hubs in India under the National Green Hydrogen Mission (NGHM) 2024	National Green Hydrogen Mission 2023; Scheme Guidelines for setting up Hydrogen Valley Innovation Cluster (HVIC) and Green Hydrogen Hubs in India under National Green Hydrogen Mission (NGHM), 2025.	National Green Hydrogen Mission 2023;
Industry			
Hard-to-abate industrial	R&D Roadmap to enable India's Net Zero Targets through Carbon Capture, Utilization and Storage (CCUS) 2025	-	-
Circular Economy	-	-	National Critical Mineral Mission 2025; E-waste Management rules 2022 Carbon Credit Trading Scheme, 2023 Steel Scrap Recycling Policy (2019) National Non-Ferrous Metal Scrap

			Recycling Framework (2020) National Mineral Policy 2019
Transport Sector			
DME	-	-	-
Methanol	Methanol Economy Research Programme (MERP) 2016 National Policy on Biofuels 2018 (Amendment 2022) National Green Hydrogen Mission 2023	-	-