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Evaluating the dynamics of India's energy economy: trends in production, trade, consumption, and sustainability (2013-2023)

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Abstract
From 2013 to 2023, India's energy economy stood at the crossroads of ambition and urgency-grappling with surging demand and fossil fuel dependence, while steadily orchestrating a calculated shift toward a resilient, renewables-led future. Coal remained the backbone of domestic energy production, while crude oil and gas imports surged, exposing economic vulnerabilities. Electricity generation nearly doubled, with a sharp rise in renewable capacity from 34,988 MW to 1,25,160 MW, reflecting policy ambition. However, this growth was uneven-constrained by infrastructure gaps, regional disparities, and energy inefficiencies in transport and agriculture. Industrial energy intensity improved, but the rising Wholesale Price Index in petrol and diesel pointed to inflationary pressures. Despite these challenges, India's refining efficiency, export performance in petroleum products, and public responsiveness to clean energy alternatives signaled a maturing energy landscape. The study concludes that India's energy future hinges on integrative policy, grid modernization, fiscal reforms, and equitable resource allocation to ensure long-term economic and environmental sustainability.

Keywords: India energy economy, coal dependency, renewable energy growth, energy imports, refining efficiency, electricity generation, energy intensity, fossil fuel trade, sustainability, policy transition

Introduction

India's energy economy over the past decade tells a story of electrifying ambition, hardwired growth, and daunting contradictions. As the world's third-largest energy consumer, India stands at the threshold of a monumental energy revolution-one that is fueled by its relentless industrial expansion, surging urban population, and the pressing imperative to balance economic aspirations with environmental responsibilities. By 2015, total primary energy consumption had reached a staggering 527 million tonnes of oil equivalent (Mtoe), with the industrial sector alone devouring 185 Mtoe-more than 30% of the national share (Sharma *et al*., 2019) [1]. Behind this voracious appetite lies a profound dependence on coal: in 2020, coal constituted 79.6% of total energy production and 52.89% of energy consumption (Singh & Jana, 2024a) [2].

But this dominance of fossil fuels comes at a steep cost. Despite vast coal reserves, India remains alarmingly energy-insecure, relying on imports to meet over 75% of its oil and gas demand-a vulnerability that severely constrains both its economy and sustainability outlook (Singh & Jana, 2024b) [3]. The energy import bill continues to surge, even as the demand-supply gap widens, and domestic production struggles to keep pace with consumption, which has been skyrocketing year after year (Pradhan, 2020) [4].

Against this backdrop, a critical turning point emerged through policy innovation. The Energy Conservation Act of 2001, reinforced by the launch of the Perform, Achieve and Trade (PAT) mechanism in 2012, began to alter the energy intensity landscape. In the iron and steel sector-a notorious energy guzzler-efficiency gains were palpable, with energy intensity falling from 10 GCal/tcs to 6.9 GCal/tcs by 2011 (Sharma *et al*., 2019) [1]. Yet, the PAT's overall impact remains nuanced, prompting a broader call for deep structural reforms in India's energy sector (Sharma *et al*., 2020) [5].

Still, India is not merely a passive consumer-it is also an innovator, investing strategically in renewable energy. Solar photovoltaic systems have emerged as promising game-changers,

with projections suggesting that by 2025, solar power-supported by hydrogen storage-could outcompete fossil fuels in cost and accessibility in major Indian cities (Muneer *et al*., 2005) [6]. Yet, this transition is not just economic-it is environmental. India's energy use has been a major driver of carbon emissions, with total energy consumption contributing 34.12% to national CO_2 output between 1990 and 2015 (Basu *et al*., 2020) [7].

And public attitudes are evolving too. In a compelling behavioral study, affluent consumers in South Delhi were found willing to pay over $5,000 more for five-star energy-efficient vehicles, signaling a cultural shift toward responsible consumption (Bansal *et al*., 2021) [8]. This shift is vital, for India's per capita electricity use-though still below global averages-has shown a definitive causal link with GDP growth, emphasizing that power is not just a utility, but a foundation for prosperity (Yadav, 2020) [9].

India stands at a crossroads-poised between the shadows of fossil dependence and the dawn of a cleaner, smarter energy future. Its next steps will define not only the trajectory of its economy but the shape of its environmental legacy.

Objectives of the Research

1. To analyze the production trends of major energy resources
2. To examine the evolution of India's energy trade profile
3. To evaluate the consumption patterns and sector-wise distribution of energy
4. To assess the status and potential of India's energy reserves
5. To analyze the expansion and performance of energy infrastructure
6. To identify the structural inefficiencies and losses

Indian Energy Economy

India's economic progress is fundamentally linked to the availability, accessibility, and affordability of energy [1]. As a core input for industrial production, agriculture, transportation, urbanization, and technological advancement, energy influences every macroeconomic indicator-be it GDP growth, inflation, trade balance, or employment generation [2]. In the India where population size and economic diversity are vast, energy is not merely a utility but a vital economic infrastructure [3].

India's energy economy is currently experiencing a major shift as it tries to meet growing developmental needs while moving toward sustainable practices. As the third-largest energy consumer globally, its energy demand has surged due to industrialization and urban growth. Coal still dominates with over 70% of electricity generation, yet India is aggressively expanding its renewable capacity, aiming for 500 GW of non-fossil fuel energy by 2030, a sharp rise from its existing 172 GW (Zeniewski & Singh, 2021) [4].

However, challenges such as inadequate infrastructure, financing gaps, and land-related issues continue to obstruct progress. At the same time, the country plans to increase coal-based capacity to ensure energy security, projecting growth from 222 GW to 302 GW by 2031-32. Despite this, India has committed to achieving net-zero emissions by 2070, a goal that hinges on policy reforms and clean energy technologies. Encouragingly, studies show that continuous cost reductions in solar power and storage systems may enable India to phase out coal completely by mid-century (Mohan *et al*., 2021) [5].

India's supply systems are expanding in sync with demand [6]. Coal remains the dominant domestic source, while crude oil production has declined and natural gas stagnated. Electricity generation, however, has recorded steady growth, driven by both thermal and renewable sources.

Table 1: Yearwise Production of Energy Resources (2013-2023)

Financial Year	Coal (Million Tonnes)	Lignite (Million Tonnes)	Crude Oil (Million Tonnes)	Natural Gas (Billion Cubic Metres)	Electricity Generation (Billion kWh)
2013-14	565.77	44.28	37.79	35.40	1116.27
2014-15	609.18	43.84	37.46	33.65	1137.41
2015-16	639.23	42.60	36.95	32.25	1173.39
2016-17	657.87	43.85	36.01	31.10	1220.44
2017-18	675.40	45.23	35.68	32.65	1306.27
2018-19	728.72	44.28	34.20	32.87	1373.53
2019-20	729.10	42.64	32.17	31.18	1389.12
2020-21	716.08	37.94	30.49	28.67	1354.60
2021-22	778.21	45.28	29.69	34.02	1491.85
2022-23 (P)	893.19	46.27	29.20	34.95	1602.82

(Source: Energy Statistics India - 2024, Note*p - Provisional

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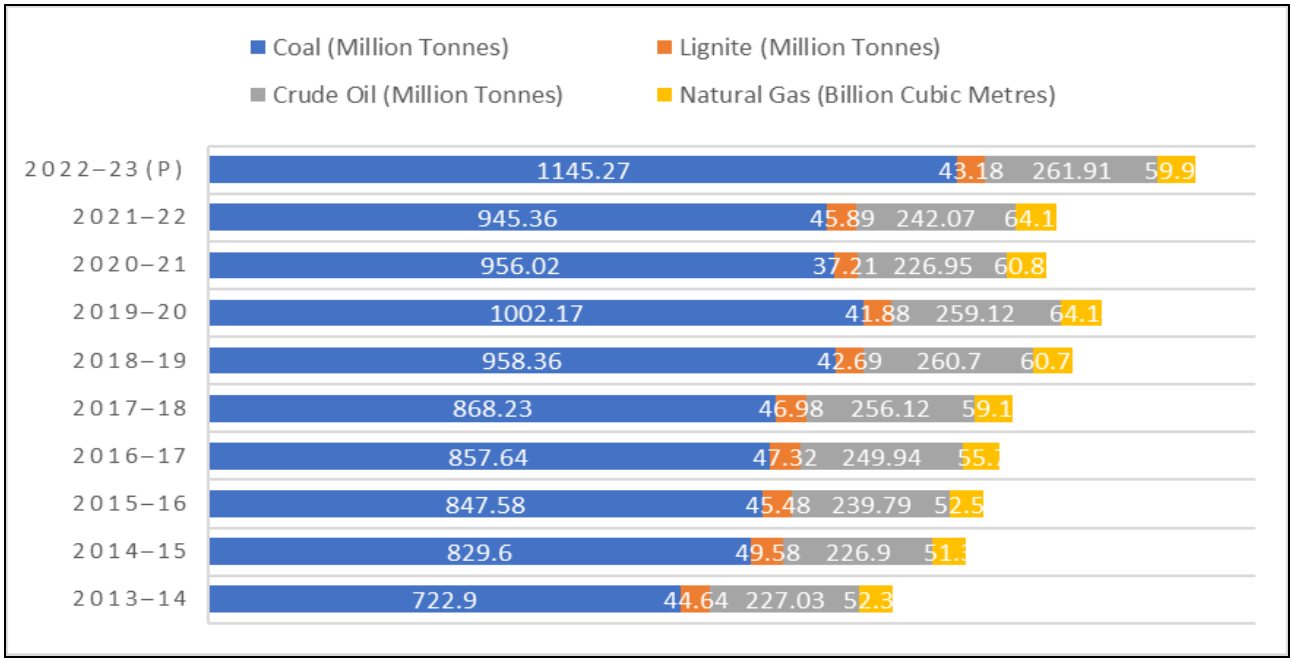

Source: Energy Statistics India - 2024, Note*p - Provisional

Fig 1: Availability of Energy Resources (2013-2023)

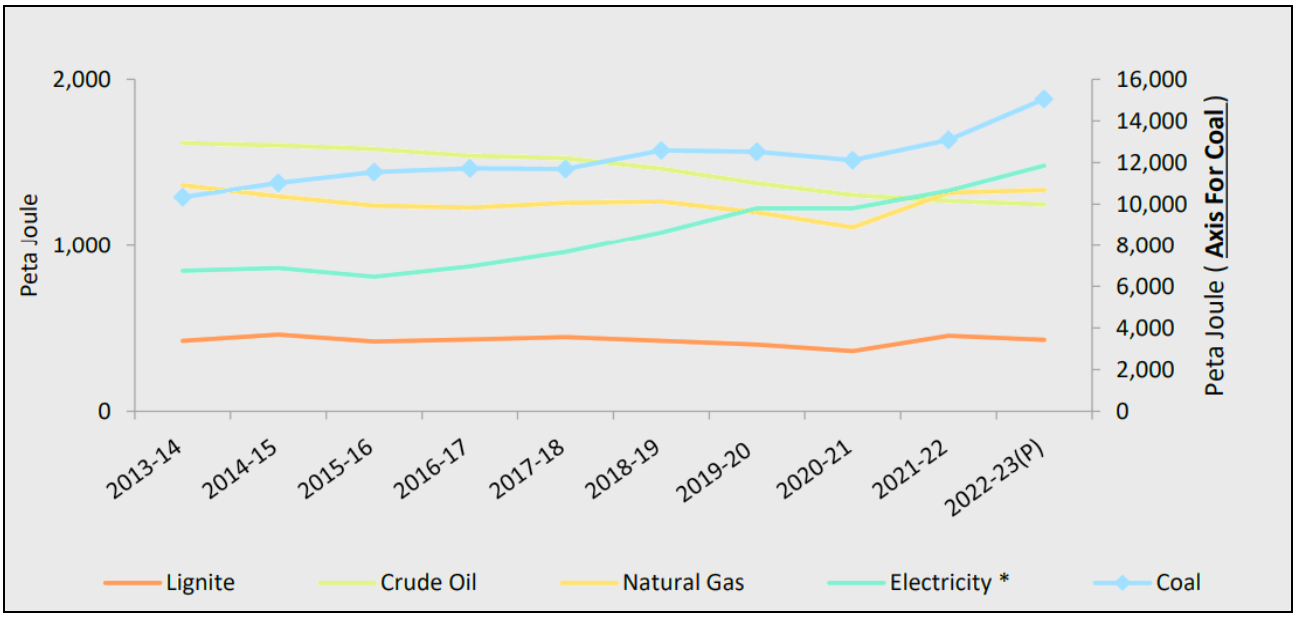

Fig 2: Trends in Production of Energy (in petajoules) by Commercial Sources in India from 2013-14 to 2022-23 (P), Note*p - Provisional

Energy Reserves and Economic Potential in India

India possesses one of the most extensive energy resource bases in the world [7], encompassing fossil fuels-coal, lignite, crude oil, and natural gas-as well as diverse and regionally distributed renewable energy sources such as solar, wind, biomass, and hydroelectric power. These reserves form the foundation of India's energy security and macroeconomic planning. The reserves are classified as per the United Nations Framework Classification (UNFC 2009) into three categories-Class A (commercially recoverable), Class B (potentially recoverable), and Class C (non-commercial/other deposits)-based on their economic, technical, and geological viability. The estimated energy reserves are as follows:

Table 2: Estimated Reserves of Coal (in Million Tonnes)

State	Proved	Indicated	Inferred	Total
Odisha	45,426	34,683	16,314	96,423
Jharkhand	46,328	30,893	6,117	83,338
Chhattisgarh	24,121	32,871	2,993	59,985
West Bengal	14,394	12,643	4,574	31,611
Madhya Pradesh	13,124	12,482	3,196	28,802
Telangana	10,060	9,418	4,770	24,248
Others	-	-	-	37,003
India Total	153,453	133,990	73,967	361,410

(Source: Energy Statistics India - 2024)

Coal forms the largest share of India's domestic energy reserves. Odisha, Jharkhand, and Chhattisgarh alone contribute nearly 69% of the national total. Over 42% of the total is already in the 'proved' category, ensuring commercial availability

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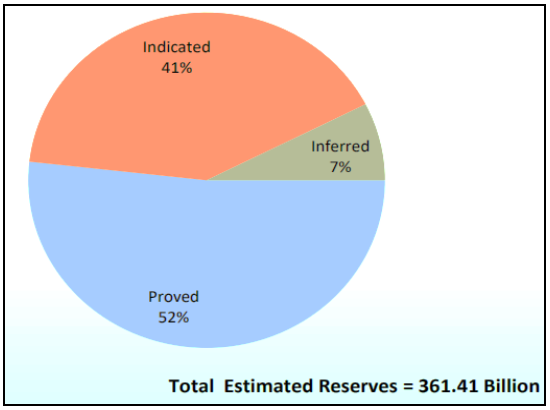


Source: (Source: Energy Statistics India - 2024)

Fig 3: Estimated Reserves of Coal in India as on 01.04.2022

Table 3: Estimated Lignite Reserves in India (as on 01.04.2022)

Category	Quantity (in Billion Tonnes)
Proved	13.17
Indicated	23.40
Inferred	13.63
Total	46.20

Source: Energy Statistics India - 2024)

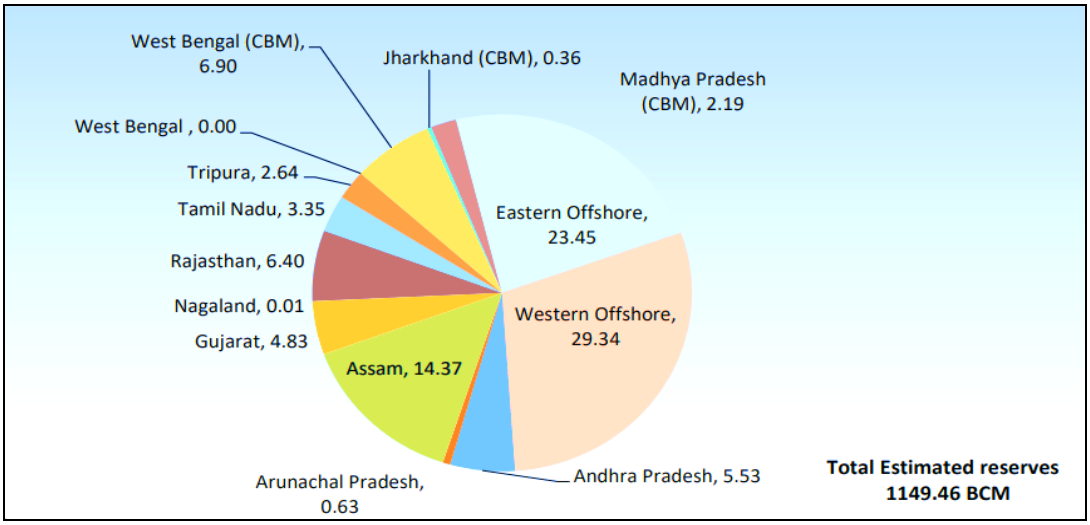
Lignite, although lower in calorific value than coal, is regionally important. Tamil Nadu dominates with over 79% of total reserves, most of which fall under the 'indicated' category, requiring further development before full-scale commercial use.

Table 4: Estimated Crude Oil Reserves in India (as on 01.04.2022)

Region	Quantity (in Million Tonnes)
Western Offshore	217.15
Assam	151.54
Rajasthan	41.76
Gujarat	38.49
Eastern Offshore	41.58
Others	162.50
Total	653.02

Source: Energy Statistics India - 2024)

Crude oil reserves remain limited, with the Western Offshore region contributing 33.3% of total reserves. Assam and Rajasthan are the main onshore sources. High concentration in select basins increases import dependency and investment risk.



Source: Energy Statistics India - 2024)

Fig 4: Estimated Reserves of Natural Gas in India as on 01.04.2022

Natural gas reserves are higher than crude oil in volumetric terms. The Western and Eastern Offshore basins collectively hold over 600 BCM, making them the most promising zones for domestic gas expansion.

Table 5: Source-wise Estimated Renewable Power Potential in India (as on 31.03.2023)

Source	Potential (MW)	Share (%)
Wind (150m height)	11,63,856	55.17
Solar	7,48,990	35.50
Large Hydro	1,33,410	6.32
Biomass	28,447	1.35
Small Hydro	21,134	1.00
Bagasse Cogeneration	13,818	0.66
Total	21,09,654	100.00

Source: Energy Statistics India - 2024)

India has over 2.1 million MW of renewable energy potential. Wind contributes the highest share (55.17%) followed by solar (35.5%), offering significant scope for sustainable energy transition and emission reduction.

Infrastructure and Capacity Utilization in the Energy Sector

India's energy infrastructure continues to expand to meet the increasing electricity and petroleum demand of a growing economy [8]. Two vital areas that determine the efficiency and preparedness of this infrastructure are the installed generation capacity and the refining throughput of crude oil. Their performance reflects how effectively India is building and utilizing its capital-intensive energy assets to ensure long-term energy security, reduced import dependency, and improved service delivery.

Table 6: Year-wise Installed Capacity of Electricity Generation (Utilities + Non-utilities) (in MW)

Year	Thermal	Hydro	Nuclear	RES*	Total
2013-14	1,68,255	40,531	4,780	34,988	2,48,554
2015-16	2,10,675	42,783	5,780	45,924	3,05,162
2017-18	2,18,330	44,478	6,780	57,244	3,26,833
2019-20	2,30,600	45,699	6,780	87,028	3,70,106
2021-22	2,34,728	46,209	6,780	94,434	3,82,151
2022-23(P)	2,37,269	46,850	6,780	1,25,160	4,16,059

(**Source:** Energy Statistics India - 2024), *RES includes Renewable Energy Sources excluding large hydro. Note*p - Provisional

The installed electricity generation capacity in India has shown steady growth, rising from 2,48,554 MW in 2013-14 to 4,16,059 MW in 2022-23. The major portion of this capacity still lies with thermal generation, which accounted for 2,37,269 MW in 2022-23. However, its share is gradually reducing as renewable energy capacity (RES) increased sharply, reaching 1,25,160 MW in 2022-23-a growth of 13.9% over the previous year. This growth in RES highlights the country's transition toward cleaner energy sources. While hydro and nuclear have remained largely stable, thermal energy saw a modest growth of 0.49%. Utilities contributed over 84.02% to the total capacity, showing public dominance in the generation infrastructure.

Table 7: Installed Capacity and Utilization of Refineries of Crude Oil (in TMTPA/TMT)

Sector	Capacity (TMTPA)	Crude Processed (TMT)	Utilization (%)
Public Sector	1,54,416	1,61,500	106.45
Private & JV Sector	99,500	93,733	94.20
Total (India)	2,53,916	2,55,233	101.60

(Source: Energy Statistics India - 2024)

India had 23 operating refineries as of March 31, 2023, with a combined installed capacity of 253.92 million tonnes per annum. Public sector units owned over 61% of this capacity and showed remarkable operational efficiency by processing 1,61,500 TMT, achieving a utilization rate of 106.45%. The private sector, despite modern infrastructure, showed a lower utilization rate of 94.20%, processing 93,733 TMT. Nationally, the average refinery utilization stood at 101.60%, up from 96.99% in 2021-22. This indicates stronger domestic fuel demand and improved operational throughput across plants.

Production Patterns and Economic Efficiency of Energy Resources

India's energy production landscape is shaped by the contribution of multiple fuel types-coal, crude oil, natural gas, lignite, and electricity from hydro, nuclear, and renewable sources [9].

Coal production in India has steadily increased over the past decade, reaching 893.19 million tonnes in 2022-23, with a CAGR of 5.20%. This growth reaffirms India's dependency on coal, which still accounts for nearly 77% of total energy generation. Lignite production, in contrast, shows stagnation with a very marginal CAGR of 0.18%, and a 5.27% decline recorded in the latest year.

Crude oil production has shown a persistent decline, falling from 37.79 MT in 2013-14 to 29.18 MT in 2022-23, translating into a negative CAGR of -2.83%. This highlights India's increasing vulnerability to global oil price shocks and the need for import dependency management. Natural gas production also declined over the period with a CAGR of -0.30%, although a slight recovery was seen with a 1.25% increase from 2021-22 to 2022-23. Electricity generation witnessed the highest overall growth, increasing from 2,34,595 GWh in 2013-14 to 4,11,512 GWh in 2022-23, recording a CAGR of 6.44%, largely driven by the integration of renewable sources.

The total energy production in India in terms of energy units (Petajoules) has grown from 14,583 PJ in 2013-14 to 19,549 PJ in 2022-23, an increase of 34%. Coal continues to dominate with 15,055 PJ, while electricity contributes 1,481 PJ, showing increased generation efficiency. Crude oil and gas remained stagnant or declined in energy terms, affirming the urgent need to restructure the national energy mix away from liquid fossil fuels.

Foreign Trade and Price Movements in Energy Commodities

India's position in the global energy trade continues to be marked by a substantial reliance on imports, particularly in the domains of crude oil, coal, and natural gas [10]. In contrast, petroleum products and electricity show notable export strength.

Coal imports in 2022-23 stood at 237.67 million tonnes, rising by 13.92% over the previous year. The net coal imports were 236.51 million tonnes, maintaining India's position as one of the world's top coal importers. Crude oil imports rose to 232.73 million tonnes, reflecting a 9.58% year-on-year growth. India exported 61.04 million tonnes of petroleum products during the same year, and despite the slight decline of 2.73% compared to the previous year, it remained a net exporter in this segment. Natural gas imports dropped sharply to 26.30 BCM, showing a 15.22% decline, primarily

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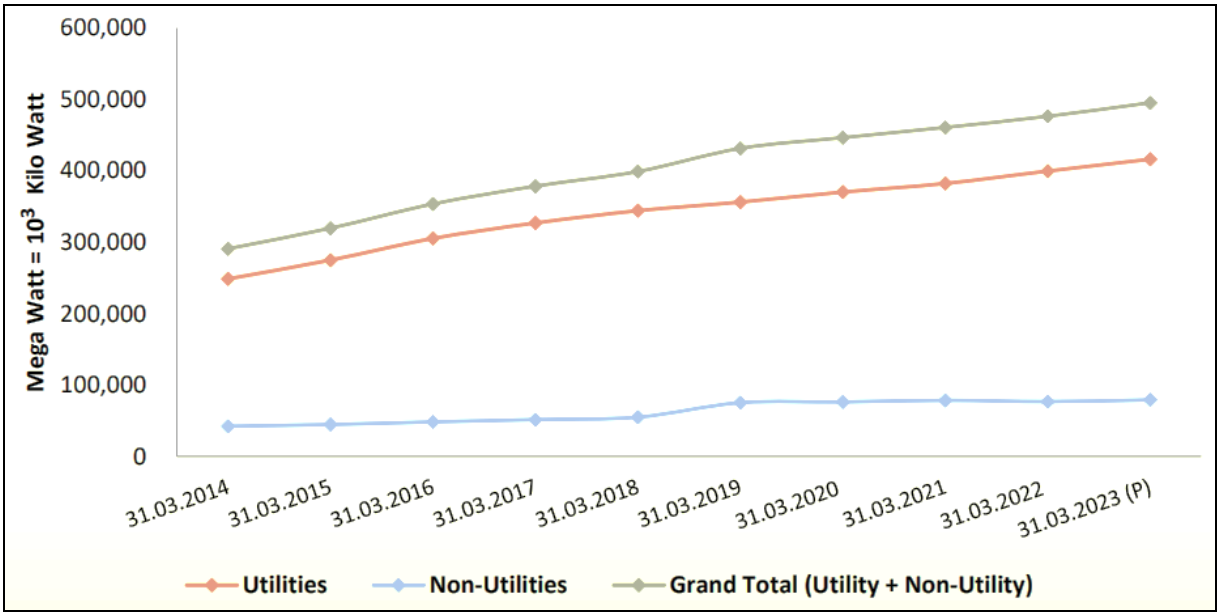
due to high international prices. Electricity trade flipped to a positive net export balance, with India exporting 2,410 GWh in 2022-23, after multiple years of deficit.



(Source: Energy Statistics India - 2024)

Fig 5: Trends in Installed Electricity Generation Capacity (MW), Note*p - Provisional

Table 8: Year-wise Production of Major Energy Resources (in Physical Units)

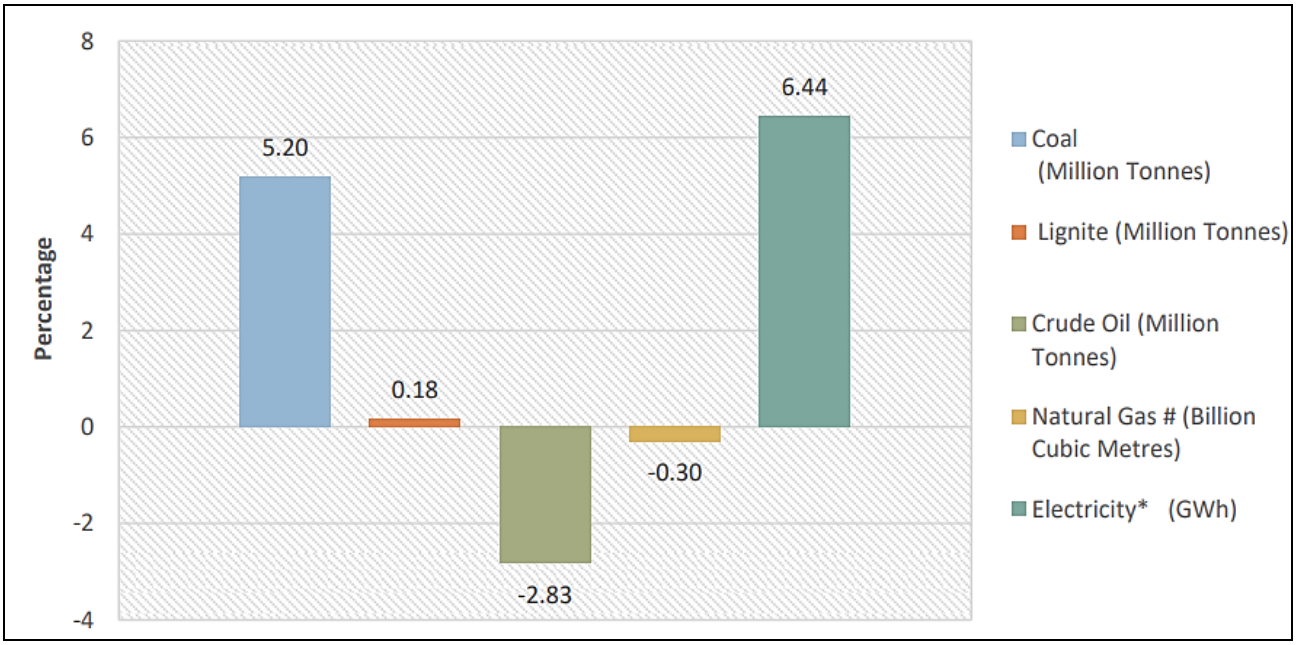
Year	Coal (MT)	Lignite (MT)	Crude Oil (MT)	Natural Gas (BCM)	Electricity* (GWh)
2013-14	565.77	44.27	37.79	35.41	2,34,595
2014-15	609.18	48.27	37.46	33.66	2,38,908
2015-16	639.23	43.84	36.94	32.25	2,24,571
2016-17	657.87	45.23	36.01	31.90	2,41,842
2017-18	675.40	46.64	35.68	32.65	2,66,308
2018-19	728.72	44.28	34.20	32.87	2,99,465
2019-20	730.87	42.10	32.17	31.18	3,40,579
2020-21	716.08	37.90	30.49	28.67	3,40,576
2021-22	778.21	47.49	29.69	34.02	3,69,652
2022-23(P)	893.19	44.99	29.18	34.45	4,11,512
Growth (%)	14.77	-5.27	-1.72	+1.25	+11.32
CAGR (%)	5.20	0.18	-2.83	-0.30	6.44

(Source: Energy Statistics India - 2024) *Electricity includes generation from hydro, nuclear, and renewable sources. Note*p - Provisional

Table 9: Production of Energy in Commercial Units (Petajoules)

Year	Coal	Lignite	Crude Oil	Natural Gas	Electricity	Total
2013-14	10,335	423	1,617	1,364	845	14,583
2016-17	11,722	432	1,541	1,229	871	15,794
2019-20	12,521	402	1,377	1,201	1,226	16,726
2021-22	13,091	453	1,270	1,318	1,331	17,464
2022-23(P)	15,055	429	1,249	1,334	1,481	19,549

(Source: Energy Statistics India - 2024), Note*p - Provisional



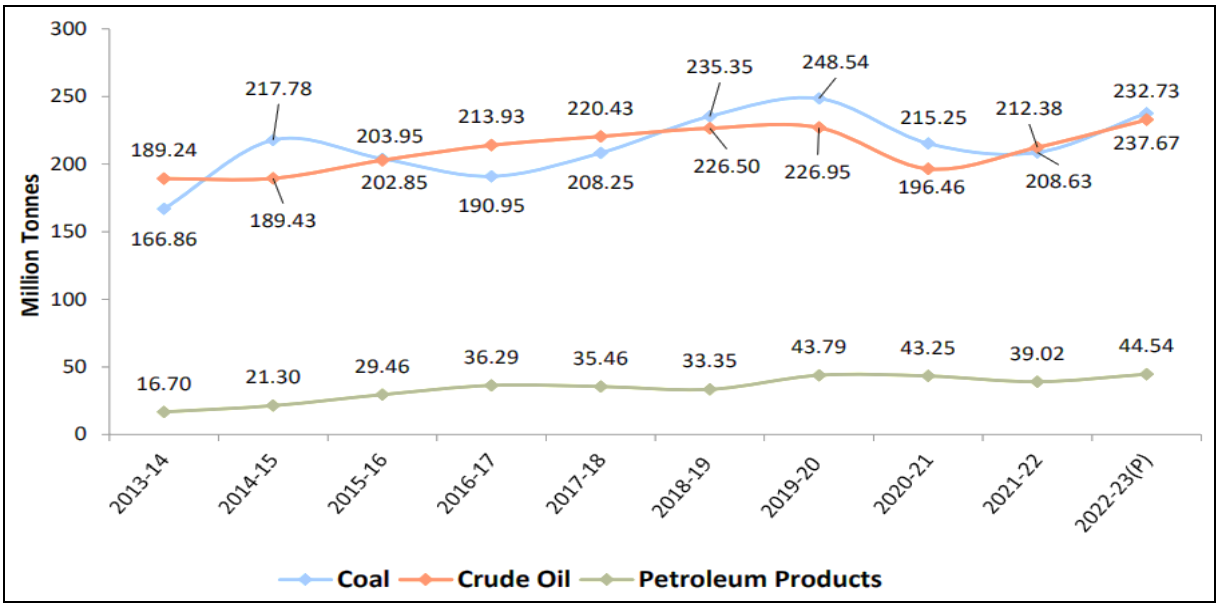
(Source: Energy Statistics India - 2024)

Fig 6: Compound Annual Growth Rate of Energy Resources (2013-14 to 2022-23P), Note*p - Provisional

Table 10: Year-wise Foreign Trade in Energy Commodities (2013-14 to 2022-23)
(Figures in Million Tonnes for solid/liquid fuels and in BCM/GWh for gas and electricity)

Year	Coal Import	Net Import (Coal)	Crude Oil	Net Import (Crude)	Petroleum Product Export	Net Import (Petrol. Prod.)	Natural Gas Import (BCM)	Electricity Net Export (GWh)
2013-14	166.86	165.35	189.24	189.24	62.50	-15.20	17.80	3,946.90
2016-17	208.25	206.75	226.50	226.50	43.79	-21.90	24.85	-1,092.89
2019-20	248.54	247.51	226.95	226.95	43.79	-21.90	33.89	-3,140.31
2021-22	208.63	207.31	212.38	212.38	39.02	-23.74	33.03	-25.85
2022-23(P)	237.67	236.51	232.73	232.73	61.04	-16.50	26.30	2,410.24

(Source: Energy Statistics India - 2024), Note*p - Provisional



(Source: Energy Statistics India - 2024), Note*p - Provisional

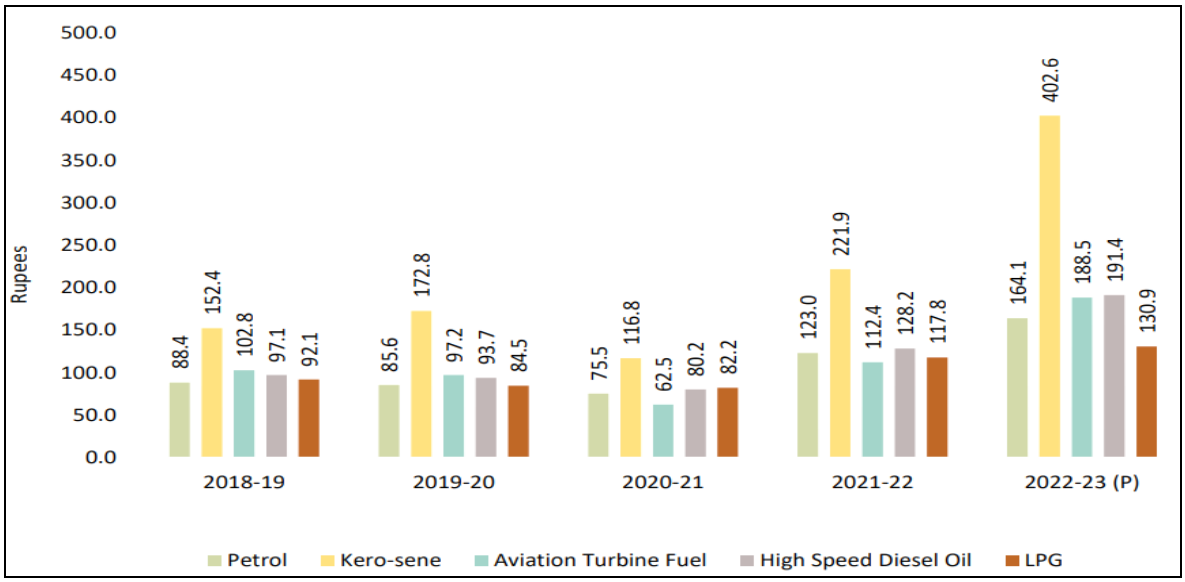
Fig 7: Trends in Import of Coal, Crud e Oil, and Petroleum Products in India

Table 11: Wholesale Price Indices (WPI) of main Energy Commodities (Base: 2011-12 = 100)

Commodity	2021-22	2022-23(P)	Change (%)
Petrol	170.5	271.1	+59.0%
High Speed Diesel	117.4	143.3	+22.0%
Aviation Turbine Fuel	130.9	170.5	+30.2%
LPG	109.6	112.4	+2.6%
Coking Coal	188.5	191.4	+1.5%
Lignite	84.5	82.2	-2.7%
Electricity	117.8	130.9	+11.1%

(Source: Energy Statistics India - 2024)

Petrol prices surged significantly, as reflected in the WPI rising from 170.5 to 271.1, a year-on-year inflation of 59%, driven by international crude volatility and tax pass-throughs. Diesel recorded a 22% price hike, followed by ATF at 30.2%, all of which directly impact industrial and transportation inflation. In contrast, LPG registered only a marginal increase of 2.6%, suggesting effective price cushioning through subsidy control. Coking coal and lignite saw minimal movement, with lignite even declining by 2.7%, possibly due to cost efficiencies in domestic production. The WPI for electricity rose from 117.8 to 130.9, indicating an 11.1% inflation in grid supply costs, often passed on to industrial and commercial consumers.



(Source: Energy Statistics India - 2024,)

Fig 8: Year-wise WPI Trends of Petrol, Diesel, LPG, and ATF (2018-19 to 2022-23P), Note*p - Provisional

National Availability and Sector-wise Distribution of Energy Resources

The total availability of energy resources in India reflects the backbone of the supply-side infrastructure required to support industrial expansion, rural electrification, urbanization, and energy security [11].

Consumption Trends and Energy Demand Elasticity

India's economic growth and demographic expansion continue to intensify demand for energy across sectors [12].

Table 12: Final Energy Consumption by Sector and Fuel Type, 2022-23 (Provisional)

Sector	Coal	Crude Oil	Petroleum Products	Natural Gas	Electricity	Total (ktoe)
Industry	1,59,700	2,355	45,286	767	47,857	2,55,964
Transport	0	0	1,08,000	0	2,000*	1,10,000+
Residential + Others	25,502	308	36,200	490	3,62,000	4,24,500+
Agriculture/ Forestry	22	312	154	-	2,40,800	2,41,300+

(Source: Energy Statistics India - 2024,)

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Industrial sector remained the largest consumer of energy in 2022-23, accounting for 49% of final energy use, dominated by coal, petroleum products, and electricity. The transport sector was entirely reliant on petroleum products, especially high-speed diesel, accounting for about 11.7% of total energy consumption. Agriculture and forestry were heavily dependent on electricity, mainly for irrigation, representing one of the highest uses of grid power outside industry. Residential and public services consumed over 39% of total final energy, driven largely by electricity and LPG, reflecting energy use in cooking, lighting, and appliances.

Table 13: Energy Intensity (MJ/₹1,000 of GVA) by Sector (2013-14 to 2022-23)

Year	Industry	Agriculture	Transport
2013-14	349.80	36.00	322.35
2015-16	335.33	40.88	346.76
2017-18	306.57	40.99	376.60
2019-20	319.72	40.11	399.66
2021-22	263.71	39.48	395.01
2022-23(P)	273.97	39.16	410.13

(Source: Energy Statistics India - 2024), Note*p - Provisional

Over the past decade, the energy intensity of the industrial sector (MJ per ₹1,000 of GVA) has declined steadily, indicating improving efficiency. In contrast, the transport sector's intensity increased from 322.35 MJ in 2013-14 to 410.13 MJ in 2022-23, largely due to rising freight traffic and private vehicle ownership. Agriculture's energy intensity has remained relatively stable, with minor fluctuations based on monsoon patterns and irrigation demand.

Energy Balance, Conversion Losses, and Input-Output Flow Analysis

Table 14: Energy Balance of India for 2022-23 (Provisional)

Flow / Stage	Coal	Oil Products	Natural Gas	Electricity	Total (KToe)
Production	3,59,590	0	31,866	0	4,75,732
Imports	1,26,343	2,82,497	24,331	674	4,33,851
Exports	-783	-63,684	0	-882	-65,349
Primary Energy Supply	4,91,683	2,67,673	56,197	-207	8,50,349
Transformation Losses	-3,17,124	-893	-7,541	+1,39,132	-2,38,707
Refinery Gain (Oil Refining)	0	+11,121	0	0	+11,121
Energy Industry Own Use + T&D	-25,458	-16,607	0	-24,041	-66,106
Final Consumption (All Sectors)	3,17,982	2,06,293	13,240	1,13,242	6,50,757

(**Source:** Energy Statistics India - 2024) *All values in Kilo

Tonnes of Oil Equivalent (KToe), transformation includes energy lost in converting fuels into electricity or other forms.

Policy Findings and Recommendations

Policy Findings

Between 2013 and 2023, India's energy economy underwent a complex transformation marked by sharp increases in energy demand, uneven domestic production trends, and rising sustainability concerns. Coal production surged with a CAGR of 5.20%, reinforcing its dominance in electricity generation, yet this came at the cost of escalating environmental and carbon intensity challenges. Crude oil and natural gas production declined (CAGR: -2.83% and -0.30% respectively), deepening energy import dependency and trade imbalance. Renewable energy capacity witnessed a substantial rise, from 34,988 MW in 2013-14 to 1,25,160 MW in 2022-23, reflecting policy momentum. However, its integration remains limited by grid constraints and land acquisition issues. Energy consumption intensified across sectors, with industrial use comprising 49% of the total, and transport's energy intensity rising sharply. The refining sector demonstrated efficiency, with an overall utilization of 101.6%, yet heavy reliance on imported crude and the volatility of fuel prices (e.g., 59% WPI increase in petrol) created inflationary stress. Electricity output nearly doubled, but regional inequalities and distribution losses persist.

Policy Recommendations

1. **Accelerate Renewable Integration and Grid Modernization:** Promote decentralized solar, hybrid wind-solar projects, and battery storage systems under a national-level integrated grid development plan. Mandate Renewable Purchase Obligations (RPOs) across states with penalties for non-compliance to fast-track India's 500 GW non-fossil goal by 2030.
2. **Reform Fossil Fuel Dependence:** Introduce a phased coal retirement policy, supported by Just Transition Funds for coal-dependent regions like Odisha and Chhattisgarh. Simultaneously, reduce crude oil import vulnerability through domestic E&P (exploration and production) incentives, tax neutrality on biofuels, and blending mandates for ethanol and green hydrogen.
3. **Transport Sector Overhaul:** Implement stricter fuel efficiency norms, promote electric vehicle (EV) penetration via FAME-III (Faster Adoption and Manufacturing of Hybrid and EVs) expansion, and shift freight logistics to electrified rail and inland waterways to reduce rising transport energy intensity (410.13 MJ/₹1,000 GVA in 2022-23).
4. **Refining and Industrial Efficiency:** Provide fiscal and R&D incentives for advanced refinery technologies including petrochemical integration and carbon capture systems. Industrial sectors should be encouraged to adopt high-efficiency equipment under revamped PAT (Perform Achieve Trade) schemes and mandatory

energy audits for MSMEs.

5. **Rationalize Energy Pricing and Inflation Controls:** Establish dynamic fuel pricing linked to a moderated tax structure to cushion consumers from volatile WPI shocks (e.g., +59% in petrol). Direct benefit transfers should be expanded for LPG and electricity subsidies, focusing on rural and low-income segments.
6. **Strengthen Energy Security and Resilience:** Develop strategic petroleum reserves (SPRs) at multiple locations, along with state-level natural gas storage frameworks. Mandate diversification of energy sourcing, both regionally and internationally, to prevent overdependence on a few countries or basins.
7. **Data-Driven Planning and Inter-Ministerial Coordination:** Institutionalize real-time energy data dashboards at the national level. Launch an Integrated Energy and Climate Governance Platform (IECGP) combining efforts of the Ministry of Power, MNRE, and MoPNG to ensure coordinated planning and monitoring of energy goals across ministries.
8. **Support Regional Equity in Energy Resource Allocation:** Introduce inter-state energy equalization grants for coal-poor but energy-deficient states. Incentivize investments in renewables in high-insolation and wind-rich states like Rajasthan, Gujarat, and Tamil Nadu while ensuring equitable grid support.

Conclusion

India's energy economy from 2013 to 2023 unfolds as a narrative of paradoxes-of abundant coal yet constrained energy security, of rapid capacity growth yet uneven access, and of renewable ambition contending with fossil-fuel realities. The decade witnessed a robust rise in coal production (CAGR: 5.20%) and electricity generation (CAGR: 6.44%), highlighting the foundational role of thermal power, even as crude oil (-2.83%) and natural gas (-0.30%) production steadily declined (Sharma *et al*., 2019; Singh & Jana, 2024a). This decline deepened India's reliance on volatile energy imports, resulting in trade vulnerabilities and inflationary stress, as visible in the 59% rise in the Wholesale Price Index for petrol between 2021-23 (Energy Statistics India, 2024).

Amidst this, India also emerged as a frontrunner in clean energy deployment-raising renewable installed capacity from 34,988 MW in 2013-14 to 1,25,160 MW in 2022-23 (Muneer *et al*., 2005). Yet, this transformation remains structurally incomplete. Grid instability, uneven regional energy allocation, and entrenched fossil-fuel subsidies slow the momentum of energy transition. Encouragingly, the decoupling of industrial energy intensity-falling from 349.80 MJ/₹1,000 GVA in 2013-14 to 273.97 MJ in 2022-23-shows early results of energy efficiency interventions like PAT (Sharma *et al*., 2020).

What stands out is the multidimensional nature of India's energy challenge. While it has demonstrated policy innovation and investment in green technologies, its fundamental dilemma lies in balancing affordability, access, and environmental stewardship across a highly diverse population and economy. The rising electricity exports, steady refining sector utilization (101.6%), and behavioral shifts toward sustainable consumption (Bansal *et al*., 2021) reveal a system on the edge of transformative possibility. India now faces a moment of critical opportunity. The task ahead is not merely technical-it is a socio-economic and ecological re-imagination of how energy fuels a nation.

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