1. FC recommendations are not a Centre versus states debate (BUSINESS STANDARD)

2. Giving farmers the reins (BUSINESS STANDARD)

3. Iran’s disruptive strategy, its global consequences (THE HINDU)

4. The case for hydrogen trains must be studied (THE HINDU BUSINESSLINE)

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EDITORIAL ANALYSIS

JULY 16

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OPINION

FC recommendations are not a Centre-versus-states debate

- **Key Terms and Explanations**
- **Finance Commission (Article 280):** A constitutionally mandated body appointed by the President of India every five years. Its primary duty is to act as a fiscal arbiter, recommending how tax revenues should be shared. Think of it as a constitutional mechanism designed to correct vertical and horizontal imbalances in Indian public finance.
- **Vertical Devolution:** The percentage share of the net proceeds of central taxes that is automatically transferred from the Union government to the states as a collective group. For example, when the vertical devolution was adjusted from 32% to 42%, it meant states collectively received a larger slice of the untied tax pool.
- **Horizontal Devolution:** The formula-based distribution of the states' collective share among individual states. This is determined using various normative criteria such as population, income distance, forest cover, and demographic performance to ensure equity.
- **Divisible Pool:** The total portion of central tax revenues that can be constitutionally shared with the states. Crucially, this pool excludes central cesses and surcharges, which are kept entirely by the Union government.
- **Revenue Deficit Grants (Article 275):** Extra-statutory, post-devolution funds given to specific states that still face a deficit in their revenue accounts even after receiving their share of central taxes. It acts as a targeted financial cushion to ensure basic administrative and operational capacities are met.
- **Plan vs. Non-Plan Expenditure:** A historical budgetary classification abolished ahead of the 2017–18 financial year. *Plan expenditure* was directly tied to developmental projects under the Five-Year Plans, while *Non-Plan expenditure* covered routine operational expenses like salaries, pensions, and interest payments.
- **Gadgil-Mukherjee Formula:** The traditional set of principles used by the erstwhile Planning Commission to allocate Normal Central Assistance among states, giving weight to population, per capita income, fiscal performance, and special development problems.
- **Centrally Sponsored Schemes (CSS) vs. Central Sector Schemes (CS):**
    - *Centrally Sponsored Schemes* are co-funded by the Centre and the states (e.g., a 60:40 or 90:10 ratio) but are implemented directly by state governments to target national priorities like housing or sanitation.
    - *Central Sector Schemes* are 100% funded and executed directly by the Union government, though their physical assets and beneficiaries reside within the states (e.g., direct income support to farmers or national highway expansion).

- **Main Arguments and Substantive Parts**
- The ongoing discourse surrounding fiscal federalism highlights a critical tension between the structural autonomy given to states and the financial responsibilities held by the Union.
- **The Myth of Compulsory Structural Subsumption**
- A prominent point of debate is whether the sharp increase in vertical devolution from 32% to 42% during the 14th Finance Commission era was a mandatory choice driven by its Terms of Reference (ToR). A closer look at the constitutional mandate reveals that the decision to include both plan and non-plan revenue requirements was an independent choice made by the Commission itself, rather than a top-down requirement. The shift was an exercise of its own methodology rather than a binding administrative command.
- **The Mismatch in Budgetary Timeline and Arithmetic**
- The argument that this 10 percentage-point jump was simply a direct replacement for discontinued formula-based plan grants faces two main challenges:
- **Timeline Disconnect:** The formal decision to merge Plan and Non-Plan spending was announced for the 2016–17 budget cycle and put into practice in 2017–18. However, the 14th Finance Commission had already wrapped up its work and submitted its report by December 2014. A future budgetary reform cannot be retroactively applied as a mandatory guideline for a commission that had already finished its term.
- **Arithmetic Mismatch:** In the 2014–15 fiscal year, Normal Central Assistance (the formula-based Gadgil component) stood at roughly ₹28,951 crore. In an ₹11 trillion divisible pool, this amounted to a mere 2%. Even when adding other broad plan grants, the total value hovered below 4% to 5%. Consequently, structural replacements alone cannot mathematically explain the full 10% increase in devolution. It was a significant shift that altered the overall baseline of federal transfers.
- **Re-evaluating the Efficacy of Revenue Deficit Grants**
- The traditional practice of providing regular post-devolution gap-filling grants has come under close scrutiny. Data shows that these revenue deficit grants have not historically led to long-term fiscal discipline:
- The number of revenue-deficit states rose from 5 in 2011–12 to 14 in 2025–26, showing a persistent reliance on these safety nets.
- Over a comparable timeframe, these grants doubled as a percentage of gross tax receipts.
- Adjusting or pausing these transfers shouldn't be seen as abandoning the needs of the states. Instead, it represents a conscious shift away from a system that unintentionally rewards persistent deficits, moving toward a framework that builds stronger incentives for independent revenue generation.
- **Moving Beyond the "Freebie" Narrative**
- Labeling all centrally funded programs as inefficient consumption subsidies overlooks how public investments actually work. It is essential to draw a clear line between poorly targeted short-term subsidies and strategic investments that build human capital and infrastructure:
- **Asset Creation:** Programs focused on rural tap water coverage or affordable housing build long-lasting public assets that directly reduce regional inequalities.
- **Positive Externalities:** Improving health, living standards, and basic utilities in one state creates economic ripple effects that benefit the entire national economy.
- **Recognizing the Impact of Central Sector Schemes**
- Assessments of federal fiscal balances often miss the massive impact of Central Sector Schemes, which are fully funded by the Union. In the 2026–27 Union Budget, these allocations reached ₹17.72 trillion.
- These programs fund core infrastructure, income support systems like PM-Kisan, and pan-India safety nets such as the Pradhan Mantri Garib Kalyan Anna Yojana (PMGKAY). Because these investments directly reduce logistics costs, support farming families, and secure food supply chains within state borders, they form a major pillar of support for state economies.

- **Historical Evolution of the Issue**
- The modern system of Indian fiscal federalism is the result of decades of structural shifts, balancing the constitutional mandate for equity with changing economic realities.
- **Pre-Independence Foundation (1935–1950)**
- The roots of our current resource-sharing system go back to the Government of India Act 1935 and the subsequent Niemeyer Report (1936). These early frameworks introduced the basic principles of dividing income tax proceeds and giving grants-in-aid to provinces, setting the stage for the financial provisions later written into the Constitution of independent India.
- **The Dual-Track Era (1951–2014)**
- For over sixty years, India operated under a dual-track system for transferring public funds:
- **The Finance Commission:** A constitutional body focused primarily on managing non-plan revenue requirements.
- **The Planning Commission:** An extra-constitutional body that directed plan capital and revenue transfers through the formula-driven Gadgil-Mukherjee framework.
- This arrangement frequently created overlapping responsibilities, as states often had to navigate two distinct centers of fiscal authority.
- **The 14th Finance Commission Milestone (2015–2020)**
- The year 2014 brought a major shift in this architecture. The Planning Commission was dissolved and replaced by NITI Aayog, which moved the country away from rigid, top-down five-year spending plans.
- Simultaneously, the 14th Finance Commission raised the vertical tax devolution from 32% to 42%. The main goal of this historic change was to give states greater unconditional financial autonomy, moving away from tied, schematic grants and letting local governments set their own spending priorities.
- **The Post-GST and Modern Integration Era (2017–Present)**
- In 2017, the traditional line between Plan and Non-Plan spending was officially removed, simplifying the structure of the national budget. The rollout of the Goods and Services Tax (GST) in the same year transformed indirect taxation by creating a shared tax base between the Centre and the states.
- Recently, the 15th and 16th Finance Commissions have had to navigate new challenges, including the growing use of cesses and surcharges by the Centre (which sit outside the shared tax pool) and a steady rise in the number of states running revenue deficits.

AXIA IAS ACADEMY: A COMPREHENSIVE ANALYSIS OF FEDERAL FISCAL TRANSFERS TRANSFERS & FINANCE COMMISSION RECOMMENDATIONS

DEBUNKING RHETORIC, CLARIFYING MANDATES, & ASSESSING BALANCES (A UPSC PERSPECTIVE)

AXIA IAS ACADEMY

Core Concepts & Definitions

Finance Commission (Article 280): Finance Commission motor Finance Commission.

Terms of Reference (ToR): Definitions recommond in metering Implownen anpoosary dovernnents, monndatants to oviore each approach.

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Gadgil Formula: Connist on plan-plan expenditures in of Gadgil formula, conelated at thern-& macmonal Assistanct assistances, cortnsi arvsnd #anmal Central Assoation, oxtented than the porsible to suceed in the spevificoions.

Direct Comparison

FACT-CHECK

14TH FC MEMBER CLAIM (BS Article)	VS.	UPSC CRITIQUE & ANALYSIS
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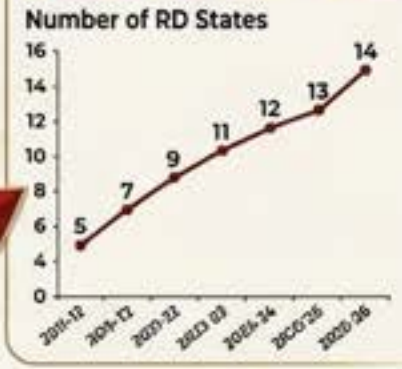
DIRECT COMPARISON	→	REFORM CANNOT BE RETROFITTED AS MANDATE

2011 RANGARAJAN COMMITTEE REPORT → AUG 2014 PLANNING COMMISSION ABOLITION (Logical Corollary) → 2017-18 PLAN/NON-PLAN BUDGET MERGER (Implemented After 12th Plan)

Revenue Deficit & Normative Assessment

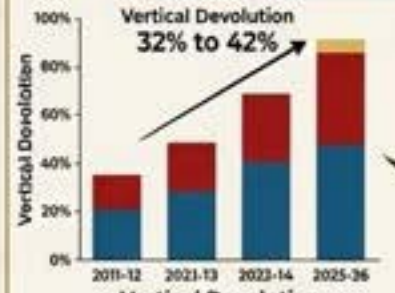


EVALUATE NORMATIVE APPROACH → SYSTEMIC RELATIONSHIP LACKING → RD GRANT REASSESSMENT → DURABLE FISCAL ADJUSTMENT & INCENTIVES

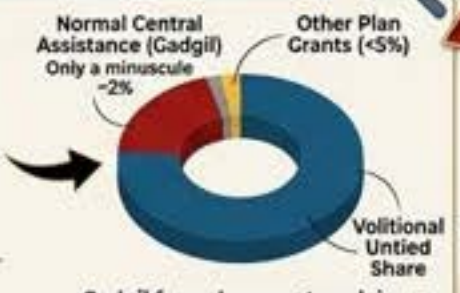
PURPOSE:

Arithmetic and Devolution Shift

FACT-CHECK OPSE



Vertical Devolution (A significant shift, not marginal)



Gadgil formula cannot explain full 10% increase.

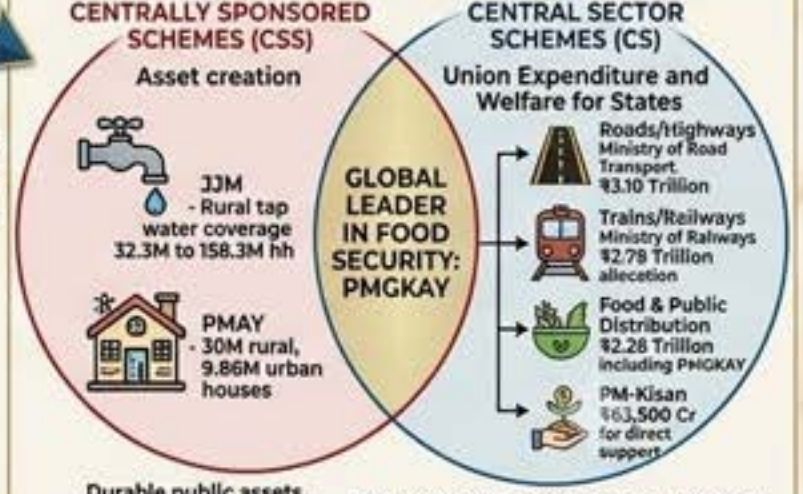
THE REAL ISSUE: FINDING THE APPROPRIATE BALANCE

The balance can and should be debated.

LEGAL FOOD SECURITY PORTABILITY: Migrants claim foodgrains from from FPS in other states, family can claim balance.

Venn-Diagram Style

UPSC MINDMAP



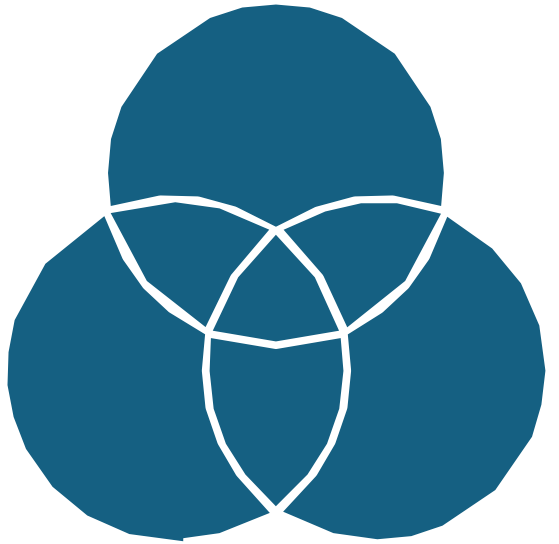
Durable public assets, Human capabilities, Positive externalities.

Infrastructure, food security, agriculture benefits accrue to all states (100% Union cost).

- **Logical and Philosophical Base**
- The debate over federal transfers is shaped by competing viewpoints on how to balance constitutional rights, local accountability, and national development goals.
- **The Principle of Cooperative Federalism**
- At its core, Indian fiscal federalism is built on a shared economic space. Because the Centre holds greater tax-collecting powers (combating vertical imbalance) while the states carry the primary responsibility for public welfare expenditures, resource transfers are a constitutional necessity rather than an act of political charity. The system is designed to keep the entire federation stable and balanced.
- **Autonomy versus Accountability**
- This tension highlights a fundamental choice in policy design:
- **Unconditional Transfers:** Proponents argue that states understand their local realities best, meaning funds should be delivered untied to maximize local democratic choices.
- **Accountability & Fiscal Discipline:** The alternative view warns against moral hazard, where providing regular, unconditional gap-filling grants might inadvertently discourage states from broadening their own local tax bases or managing their spending efficiently.
- **Equity versus Efficiency**
- The structural logic must constantly balance two competing goals: supporting weaker, less-industrialized regions to ensure basic public services for all citizens (equity), while also ensuring that fiscally responsible states are not penalized for growing their local economies (efficiency).
- **Public Goods and Economic Spillovers**
- There is a strong economic justification for direct Union spending via Central Sector Schemes. Large-scale public investments like national transport networks, railway lines, and food security systems create cross-border economic benefits. Because these macro-level projects yield positive spillovers that extend beyond the borders of any single state, they are most efficiently funded and managed by a central authority.

- **Multidimensional Analysis**
- **Economic Dimension**
- **Capital Expenditure Multipliers:** Central Sector infrastructure investments (like the ₹3.10 trillion for highways and ₹2.78 trillion for railways in 2026–27) have high economic multiplier effects. They lower logistics costs, improve domestic supply chains, and attract private investment into the states.
- **Fiscal Consolidation Trajectory:** The design of federal transfers directly affects India's combined fiscal deficit goals under the FRBM framework. When structural gap-filling grants are poorly aligned, they can lead to unpredictable revenue deficits across states, complicating national inflation management and debt stabilization efforts.
- **Social Dimension**
- **Human Capability Framework:** Programs like the Jal Jeevan Mission (expanding tap water access to 158.3 million households) significantly reduce water-borne illnesses and ease the daily burden of water collection for rural women, directly advancing gender equity and rural health.
- **Nutritional Safety Nets:** The Pradhan Mantri Garib Kalyan Anna Yojana (PMGKAY) acts as an essential social safety net for over 810 million beneficiaries. By providing fully portable food security, it protects migrant workers from economic shocks and directly helps reduce persistent nutritional poverty across state borders.
- **Political Dimension**
- **The Dynamics of Bargaining Federalism:** Political discussions often frame fiscal transfers as a tense struggle between the Centre and the States. Regional interests tend to push for larger, unconditional tax pools, while the Union government often favors targeted, schematic spending to ensure national development goals are met uniformly.
- **Evolving Decentralization:** The shifting balance between untied tax shares and conditional grants influences how local self-governments (Panchayats and Urban Local Bodies) are empowered. It shapes whether local planning remains genuinely decentralized or is steered by central frameworks.
- **Legal and Constitutional Dimension**
- **Constitutional Boundary Lines:** The legal tension centers on the interplay between Article 275 (statutory grants recommended by the Finance Commission) and Article 282 (discretionary spending used by the executive for central schemes). Critics often argue that expanding Article 282 transfers can bypass the formal institutional role of the Finance Commission.
- **The Scope of the Terms of Reference (ToR):** The legal debate focuses on how much flexibility a Finance Commission has. While the President sets the formal ToR guidelines, the Commission retains full constitutional independence under Article 280 to design its own methodology for assessing revenue needs and tax distribution.
- **Ethical Dimension**
- **Distributive Justice vs. Performance Rewards:** The core ethical question is how to balance need with performance. It raises the issue of whether it is fair to continuously divert resources away from fiscally disciplined states to cover the persistent deficits of states that struggle to manage their budgets, without requiring structural reforms.
- **Intergenerational Equity:** Runaway revenue deficits that are continually covered by unconditional federal bailouts pass the financial burden onto future generations. Over time, this structurally reduces the public funds available for vital long-term investments in education, green energy, and healthcare.
- **International Dimension**
- **Global Logistics and Competitiveness:** Direct central investments in high-quality transport networks directly improve India's standing in the World Bank's Logistics Performance Index (LPI), making the country a more attractive destination for global manufacturing supply chains.
- **Sovereign Credit Evaluation:** International rating agencies look closely at the combined debt-to-GDP ratios of both the Centre and the States. Clear, predictable, and performance-linked fiscal transfers signal structural stability, which helps maintain strong sovereign credit ratings and reduces borrowing costs in global financial markets.

- **Linkages with NCERTs**
- **Class 11 Political Science: *Indian Constitution at Work* (Chapter 7: Federalism)**
    - *Connection:* Explains the structural distribution of revenues in India, the constitutional reasons for vertical financial imbalances, and the role of the Finance Commission as a key balancing institution.
- **Class 11 Economics: *Indian Economic Development* (Chapter 2: Indian Economy 1950–1990 & Chapter 3: Liberalisation, Privatisation and Globalisation)**
    - *Connection:* Traces the history of the Planning Commission, the structural differences between planned and market-led public spending, and the broader economic shifts that led to the abolition of the Plan/Non-Plan distinction.
- **Class 12 Macroeconomics: *Introductory Macroeconomics* (Chapter 5: Government Budget and the Economy)**
    - *Connection:* Defines the foundational concepts of revenue deficits, capital expenditure, public debt, and the macro-level impact of fiscal policy on economic growth and stability.



- **Linkages with UPSC CSE Syllabus**
- **General Studies Paper 2 (Governance, Constitution, Polity)**
- Functions and responsibilities of the Union and the States; issues and challenges pertaining to the federal structure.
- Devolution of powers and finances up to local levels and challenges therein.
- Appointment to various Constitutional posts, powers, functions, and responsibilities of various Constitutional Bodies (Article 280 - Finance Commission).
- **General Studies Paper 3 (Economic Development)**
- Government Budgeting; Mobilization of resources, growth, development, and employment.
- Inclusive growth and issues arising from it (Safety nets, food security via PMGKAY).
- Infrastructure investments: Energy, Ports, Roads, Airports, Railways (Central Sector investments).
- **Essay and Optional Subjects**
- **Essay:** Highly relevant for structural topics focused on cooperative federalism, balancing regional aspirations with national unity, or managing public finance for equitable development.
- **Economics Optional:** Core focus within Public Finance (theories of federal finance, criteria for horizontal transfers, managing public debt).
- **Public Administration Optional:** Directly connects to Financial Administration (Budgetary processes, the changing role of the Planning Commission/NITI Aayog, and control over public expenditure).

- **Way Forward**
- Building a resilient fiscal federal architecture requires moving past old political frictions and focusing on structural, performance-driven reforms.
- **1. Re-designing the System for Revenue Deficit Grants**
- Instead of using Revenue Deficit Grants as a simple way to fill budget gaps, future allocations should be tied to clear fiscal milestones. These grants should function as temporary, conditional adjustment funds aimed at helping states expand their own local revenue bases and improve tax administration, preventing long-term reliance on central bailouts.
- **2. Rationalizing Cesses and Surcharges**
- To maintain the health of the constitutional tax-sharing system, the Union government should work to reduce its reliance on cesses and surcharges. Over time, these specific levies should either be phased out or integrated directly into the core divisible tax pool, ensuring that the states' share of total tax revenues remains fair, transparent, and predictable.
- **3. Improving the Efficiency and Targets of Shared Schemes**
- Centrally Sponsored Schemes should be periodically reviewed and streamlined. Using NITI Aayog's cooperative platforms, the Centre and the states should work together to eliminate overlapping programs, give states more flexibility to adapt schemes to local conditions, and shift the focus from how much money is spent to the actual developmental outcomes achieved.
- **4. Setting up a Permanent Finance Commission Secretariat**
- The Finance Commission should move away from being an organization that is set up from scratch every five years. Establishing a permanent, professional research secretariat would ensure continuous data collection, allow for mid-term assessments of fiscal transfers, and provide deep institutional knowledge to help each new Commission make well-informed decisions.

All Previous Years' UPSC Questions

Civil Services Examination (Mains)

•**2023 (GS Paper 2):** "Explain the constitutional provisions under which the Finance Commission is structured. To what extent has the recent Finance Commission helped in addressing the financial stress of the states?"

•**2021 (GS Paper 3):** "Distinguish between Capital Budget and Revenue Budget. Explain the components of both these Budgets."

•**2018 (GS Paper 2):** "How far do you agree with the view that the focus of electronics governance and introduction of GST has fundamentally changed the nature of cooperative federalism in India?"

•**2015 (GS Paper 2):** "The 14th Finance Commission recommendations are said to have given states more fiscal space and autonomy. Discuss this in light of the abolition of the Planning Commission and changes in the pattern of central transfers."

Civil Services Examination (Prelims)

1. With reference to the Finance Commission of India, which of the following statements is/are correct? (Based on 2011/2023 conceptual trends)

1.It is a statutory body created under an Act of Parliament.

2.It recommends the principles that should govern the grants-in-aid of the revenues of the States out of the Consolidated Fund of India.

Select the correct answer using the code given below:

A) 1 only

B) 2 only

C) Both 1 and 2

D) Neither 1 nor 2

1.Answer Hint: The Finance Commission is a constitutional body under Article 280, not a statutory one. Statement 2 perfectly outlines its core duty under Article 280(3)(b).

2. Consider the following components of public finance transfers:

1.Shares of net proceeds of shareable Central Taxes

2.Grants-in-aid under Article 275

3.Discretionary transfers under Article 282

4.Normal Central Assistance under formula-based frameworks

Which of the above were explicitly handled by the historical Planning Commission rather than the Finance Commission?

A) 1 and 2

B) 2 and 3

C) 3 and 4

D) 1, 3 and 4

1.Answer Hint: The Planning Commission historically managed discretionary plan allocations and formula-driven Normal Central Assistance (Gadgil formula), while the Finance Commission focused on tax devolution and constitutional grants-in-aid.

Giving farmers the reins

Why producer-controlled organisations should lead agricultural transformation rather than bureaucrats

ILLUSTRATION: BIKAS SINHA

Farmers in India are developing their agricultural practices mainly through improvements in traditional areas, with new seeds, chemical fertilisers and pesticides, mechanised modes for managing cultivation, and, occasionally, the adoption of new crops. Some farmers also depend substantially on government fertiliser subsidies and on government procurement of food grains.

Most of the government purchase and the bulk of the fertiliser and food subsidies are for the production of paddy and wheat. In 2023-24, the value of output of these two principal crops was ₹7.5 trillion, while the budgetary cost of fertiliser and food subsidies was ₹4 trillion. More than 800 million people receive these food grains free of cost from the central government.

If one looks at the growth areas in agriculture in the 12 years between 2011-12 and 2023-24, production of paddy and wheat rose by just 27 per cent. Fruit and vegetable production rose by 52 per cent, and milk production by 85 per cent, even though they did not receive any substantial support by way of subsidies or minimum support price procurement by the government. The true growth areas in agriculture are out of direct central government support and depend largely on producer enterprise.

NITIN DESAI

The most interesting example of producer-managed growth is the substantial increase in milk production, which has been boosted by the effectiveness of milk producer cooperatives. The earliest instance was in Gujarat, where the milk producers in Anand set up a cooperative named after their district, Kaira, and labelled their product as Amul, which is the abbreviation of Anand Milk Union Limited. It developed as a response to the heavy dependence of milk suppliers on purchases by the sellers of Polson milk in Bombay. Tribhuvandas Patel led the initiative, and Verghese Kurien came in as the executive head. Their initiative has culminated in the Gujarat Cooperative Milk Marketing Federation, which is perhaps the largest food products marketing company in India and is owned by 3.6 million milk producers.

This focus on production control was the basis for the management of the National Dairy Development Board set up in 1965 by Kurien and supported by the then Prime Minister Lal Bahadur Shastri, who saw merit in relying on producer-controlled cooperatives. Kurien was particularly strict about keeping bureaucrats at a distance from programme control. Operation Flood, which brought in financial support and milk supply (including free milk provided by Europe), came in 1970 and enabled the country-wide cooperatives to dominate the urban market through institutions like Mother Dairy.

This sector, controlled by producer and not dependent on government procurement and minimum support prices, has boomed faster than the agricultural sector, particularly the growth in the production of paddy and wheat, which has been dependent on government support. In 2023-24, the value of output of cereals (mainly paddy and wheat) was ₹8.5 trillion, while the value of the largely cooperative-controlled milk sector was ₹13.1 trillion.

The role of the producer- and cooperative-controlled sector may be relevant for an emerging option that could be a substantial source of income for farmers and also contribute significantly to our long-term challenge of coping with climate change. It basically involves the supply of electricity from farm fields.

Electricity pricing for agriculture is heavily subsidised, with farmers typically paying a fraction — or nothing — of the average cost of supply. One way of reducing these losses is to see how power use in rural areas can be met by local sources. In fact, it is also possible to make agricultural areas a source of solar power that will contribute to the management of climate change. An option that has been designed, called agri-voltaics (Agri-PV), basically involves installing solar power at an elevated level above areas sown with crops that can cope with partial sunlight. It may be one way to overcome the difficulty in securing large areas of land, mainly in rural areas, for standard solar power units.

The central government has a programme, elaborately entitled but more easily referred to as KUSUM[1], which is aimed mainly at promoting the use of captive solar power for pump sets. This has to compete with the substantial subsidy or even free use of electricity provided to rural areas by state-level distribution companies. But KUSUM also covers the possibility of support for Agri-PV projects, which combine the use of land for agriculture and for photovoltaic establishment to generate solar power for sale. This presents an interesting possibility of raising the returns from the ownership of agricultural land through the dual use of land for agriculture and for solar power generation for use and sale.

A recent project implemented by the Indian Council for Research on International Economic Relations provides an interesting analysis of Agri-PV and evaluates the implementation of this dual use of land for agriculture and solar power generation in Madhya Pradesh and Rajasthan. What it does bring out is the substantial increase in farmers' income resulting from this dual use of land.

The other point that comes across is the huge level of investment required to set up solar power capacity — it was approximately ₹18.5 crore for the 13-acre land plot in Madhya Pradesh and approximately ₹2 crore for the 3-acre land plot in Rajasthan. Because of this high investment cost, relying largely on individual landowners will limit the impact.

Some improvement may come from commercial developers who will share income with the landowners. But real transformation can come mainly from community-based groups, organised as cooperatives or producer-based companies, which can combine small and medium landowners for implementing the dual use of land in Agri-PV. Do note that the average per capita ownership of agricultural lands in India is just 1.08 hectares and hence relying on individual landowners will greatly limit the impact of Agri-PV.

At present, the promotion of Agri-PV is essentially through the central-sector scheme KUSUM, run by bureaucrats. Given the high investment cost, it may generally involve community- or sub-community-level cooperation. I would suggest that application system for Agri-PV be run by an organisation that directly involves the producers and not be left to bureaucrats. The application is likely to vary greatly across different ecological zones, as agricultural conditions differ considerably from one locality to another. Moreover, the Agri-PV system requires judgements about crops that can tolerate reduced solar exposure, which can be assessed only by farmers at the local level and not by bureaucrats.

The example of the cooperative institutional arrangement that has been responsible for the boom in milk production and marketing may provide an answer not just to Agri-PV, but also to the promotion of other products, such as fruits and vegetables, which are often produced by small landowners. The essential point is that we should rely more on producer-controlled organisations, such as cooperatives or producer companies, rather than on schemes controlled by bureaucrats for the modernisation of, and higher production in, agriculture.

desaind@icloud.com

1. Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan

2. Ashok Gulati and associates, *Harvesting Sun and Soil: India's Agri-PV Future*, ICRIER, 2026

- **Key Terms and Explanations**
- **Agrivoltaics (Agri-PV):** This refers to the simultaneous use of land for both solar energy generation and agriculture. By elevating solar panels several meters above the ground, crops can be grown beneath them. This dual-use spatial model optimizes land productivity. For instance, in semi-arid regions of Rajasthan, these panels can provide shade that reduces soil water evaporation while generating clean electricity.
- **Producer-Controlled Cooperatives:** An economic organizational model where the primary producers (such as smallholder farmers or milk agriculturists) collectively own, manage, and control the democratic decision-making and profit-distribution of the enterprise. The classic blueprint is **Amul** (Kaira District Co-operative Milk Producers' Union), where profits flow directly back to the village-level cattle owners rather than corporate middle-men or bureaucratic agents.
- **Operation Flood:** Launched in 1970 by the National Dairy Development Board (NDDB), this was the world's largest dairy development program. It transformed India from a milk-deficient nation into the world's largest milk producer. It created a national milk grid, linked rural producers directly with urban consumers, and eliminated seasonal price fluctuations.
- **PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan):** A flagship scheme of the Ministry of New and Renewable Energy (MNRE) aimed at ensuring energy security for farmers. It focuses on de-dieselizing the farm sector by promoting solar pumps, solarizing existing grid-connected agricultural pumps, and supporting small solar power plants on fallow or agricultural lands.
- **Minimum Support Price (MSP) Procurement:** A market intervention mechanism by the Government of India to protect agricultural producers against sharp falls in agricultural prices. The government buys designated crops (predominantly wheat and paddy through the Food Corporation of India) directly from farmers at a guaranteed price, even if market rates crash.
- **Value of Output:** The total monetary value of goods produced in a specific economic sector before deducting the cost of inputs used in production. For example, comparing the ₹12.2 trillion value of the milk sector against the ₹8.5 trillion value of the cereal sector highlights the sheer scale of the livestock economy relative to traditional field crops.

- **Main Arguments and Substantive Parts**
- The contemporary discourse on Indian agriculture often centers on state-led support systems. However, a deeper look reveals an alternative paradigm: independent, producer-driven growth outperforming heavily subsidized sectors.
- **The Paradox of Subsidized Stagnation vs. Unsupported Boom**
- A stark dichotomy exists within Indian agriculture. The traditional cereal sector (paddy and wheat) remains heavily anchored to state support, consuming a massive share of the budgetary exchequer. In the 2023-24 fiscal period, the food and fertilizer subsidy alone stood at ₹4 trillion, while the output value of these two crops was ₹7.5 trillion.
- Despite this immense financial safety net, the production growth of paddy and wheat over a 12-year horizon (2011-12 to 2023-24) was a modest 27 percent. In sharp contrast, high-value sectors operating largely outside the central subsidy and MSP net experienced explosive growth:
- Fruit and vegetable production rose by **52 percent**.
- Milk production surged by **85 percent**.
- This demonstrates that long-term agricultural dynamism is driven by producer enterprise and market demand rather than state-managed procurement.
- **The Institutional Blueprint of the Dairy Sector**
- The success of the milk sector is rooted in an institutional framework designed to empower primary producers. Triggered as a resistance movement against the monopoly of private dairies (like Polson in Bombay), the cooperative model established at Anand proved that smallholders could achieve massive economies of scale.
- By scaling up into the Gujarat Cooperative Milk Marketing Federation (GCMMF), the model grew to encompass millions of producers. The foundational logic of this growth, championed by figures like Verghese Kurien, was the strict exclusion of bureaucratic interference from operational control, ensuring that professional management remained directly accountable to the farmers.
- **Agrivoltaics as the Next Frontier for Cooperatives**
- As India faces the dual challenges of climate change and shrinking landholding sizes (with an average per capita holding of just 1.08 hectares), Agrivoltaics (Agri-PV) emerges as a viable solution. Agri-PV allows for the dual utilization of land, providing farmers with a secondary, climate-resilient income stream via solar power generation.
- However, the initial capital expenditure is high—ranging from ₹2 crore for a 3-acre plot to ₹18.5 crore for a 15-acre installation. Because individual smallholders cannot afford these costs, relying on isolated landowners limits the technology's reach. The solution lies in replicating the dairy cooperative structure: aggregating small farms into community-led solar cooperatives.

- **Historical Evolution of the Issue**
- The tension between state-directed bureaucratic agriculture and autonomous producer-led institutions is shaped by decades of policy shifts and structural crises.
- **The Pre-Independence Colonial Context (Pre-1946):** The rural economy was characterized by exploitative supply chains. In the dairy sector of western India, private entities like Polson enjoyed monopolistic procurement rights granted by the colonial administration. This left milk suppliers entirely dependent on exploitative pricing, laying the groundwork for institutional rebellion.
- **The Genesis of Cooperative Resistance (1946):** Under the guidance of Sardar Vallabhbhai Patel and the leadership of Tribhuvandas Patel, dairy farmers in Anand organized a strike against monopolistic middlemen. This led to the registration of the Kaira District Co-operative Milk Producers' Union, establishing the principle that producers should control their own processing and marketing channels.
- **The Institutionalization of the White Revolution (1965–1970):** Recognizing the success of the Anand model, Prime Minister Lal Bahadur Shastri backed the creation of the National Dairy Development Board (NDDB) in 1965. Dr. Verghese Kurien took the helm, insisting that the board remain autonomous and free from civil service control. In 1970, this culminated in the launch of **Operation Flood**, using international food aid as an investment tool to build a nationwide cooperative network.
- **The Green Revolution Parallel (Late 1960s–1980s):** Concurrently, India faced severe food insecurity, prompting the state-led Green Revolution. This system relied heavily on bureaucratic intervention, introducing High-Yielding Variety (HYV) seeds, price guarantees (MSP), and heavy subsidies for chemical fertilizers and water. This policy anchored the agricultural economy of the northwest to a water-intensive paddy-wheat cycle.
- **The Neo-Liberal Shift and Crop Diversification (1991–Present):** With economic liberalization, public investment in traditional crop infrastructure slowed down, while demand for high-value commodities (horticulture, dairy, poultry) surged due to rising urban incomes. This era marked a divergence: the state-supported cereal sector grew at a modest pace, while the market-responsive, cooperative, and private corporate-linked sectors saw rapid growth.
- **The Modern Climate-Energy Confluence (Post-2018):** Recognizing the heavy fiscal burden of agricultural electricity subsidies and the growing threats of climate change, the government launched the PM-KUSUM scheme. This represents the current frontier: transitioning agriculture from a net consumer of subsidized fossil-fuel energy to a decentralized producer of renewable solar energy.

AGRICULTURAL TRANSFORMATION IN INDIA: REFORMS, AGRI-VOLTAICS & THE COOPERATIVE MODEL

CONTRAST: STATE-LED VS. PRODUCER-LED GROWTH

Pre-1946

1946 — Kaira Milk Cooperative Formation
ANAND MILK UNION LTD (AMUL)
Tribhuvandas Patel/Verghese Kurien

1965 — NDDB Set Up

1970 — Operation Flood - White Revolution

- Cereal Value (2023-24): ₹8.5T
- Cooperative Milk Value (2023-24): ₹12.2T

TRADITIONAL CEREAL SECTOR (MSP & SUBSIDIES)

High government budget ₹4 Trillion vs ₹7.5 Trillion output

Low 27% growth

BUREAUCRATIC CONTROL

VS

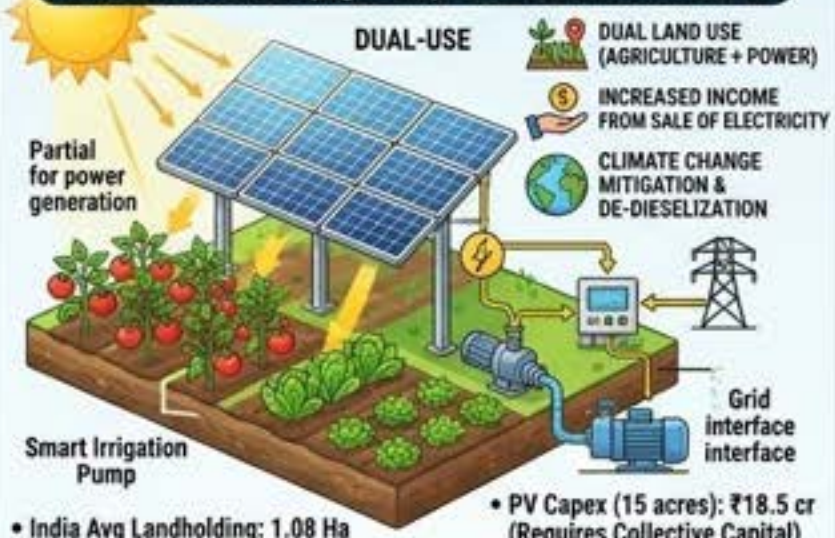
HIGH-VALUE SECTORS (ENTERPRISE-DRIVEN)

85% Milk

52% F&V growth

PRODUCER ENTERPRISE / COOPERATIVES

AGRI-VOLTAICS (Agri-PV): THE NEXT FRONTIER



- DUAL LAND USE (AGRICULTURE + POWER)
- INCREASED INCOME FROM SALE OF ELECTRICITY
- CLIMATE CHANGE MITIGATION & DE-DIESELIZATION

- India Avg Landholding: 1.08 Ha
- PV Capex (15 acres): ₹18.5 cr (Requires Collective Capital)

BUREAUCRATIC-RUN PV PROGRAM (KUSUM, Central Schemes)

- India Avg Landholding: 1.08 Ha
- PV Capex (15 acres): ₹18.5 cr

VS

COMMUNITY/COOPERATIVE-RUN PV APPLICATION

- Local Ingeration Rolling

MULTIDIMENSIONAL IMPACT & WAY FORWARD

SOCIAL DIMENSION
- Reducing inequality, aggregating smallholder power

ECONOMIC DIMENSION
- Capital formation, processing links, income diversification

LEGAL & ETHICAL DIMENSION
- Clear land pooling laws, fair PPA tariffs, resource stewardship

INTERNATIONAL DIMENSION
WTO Box categories
- Shift towards Green Box support, alignment with climate pledges

WAY FORWARD: KEY POLICY RECOMMENDATIONS

- DECENTRALIZE AGRI-PV APPLICATION (Run by producers, not bureaucrats)
- DEVELOP LEGAL & FINANCIAL TOOLKITS FOR LAND POOLING
- REALIGN SUBSIDIES TOWARDS COOPERATIVE CAPITAL INVESTMENT
- REPLICATE DAIRY COOPERATIVE MODEL IN HORTICULTURE

SYLLABUS & NCERT LINKAGES

Class X Geography (Agriculture)	Class XI Economic Development (Rural Development)	GS Paper 2 Governance & SHGs	GS Paper 3 Agriculture Tech & Subsidies, Infrastructure, Ethics, Environment

SELECTED PREVIOUS YEARS' QUESTIONS (PYQs)

2023 Technology in Agriculture (2023, 2016)	2020 MSP & Cropping Patterns (2020)	2018 Cooperatives & Dairy Sector (2018)	2018 Food Security Act (2018)

- **Logical and Philosophical Base**
- The debates surrounding Indian agricultural policy reflect a deeper philosophical divide over resource governance and economic organization.
- **Statism and Bureaucratic Paternalism vs. Subsidiarity**
- The state-led subsidy framework operates on a paternalistic premise: rural producers require continuous state intervention, price guarantees, and subsidized inputs to survive market volatility.
- Conversely, the cooperative model is built on the principle of **subsidiarity**—the idea that economic and administrative matters should be handled by the smallest, lowest, or least centralized competent authority. It presumes that local communities possess the knowledge and capability to manage their resources efficiently when freed from top-down bureaucratic control.
- **Ecological Centralism vs. Localized Agro-Ecological Judgement**
- Bureaucratically driven agricultural programs often favor standardization, applying uniform guidelines across diverse geographical zones. However, decentralized systems value localized agro-ecological knowledge.
- In initiatives like Agrivoltaics, choosing which crops can thrive under reduced solar exposure requires nuanced, real-time insights that vary by microclimate. A central bureaucracy cannot easily replicate this localized understanding, which is why giving farmers direct control over implementation is often more effective.
- **Economies of Scale vs. Fragmented Land Ownership**
- The structural challenge of Indian farming is its small scale; the high fragmentation of land prevents individual adoption of modern technologies. The cooperative philosophy resolves this tension.
- By aggregating small holdings into a larger collective entity, smallholders can access capital-intensive technologies (like Agrivoltaics) without sacrificing their land rights. This model offers an alternative to corporate land consolidation, combining social equity with economic efficiency.

- **Multidimensional Analysis**
- **1. Social Dimension**
- Shifting toward producer-led cooperatives can help reduce rural wealth inequality. Traditional subsidy systems often disproportionately benefit larger, well-connected farmers who have the resources to maximize state benefits. In contrast, democratic cooperatives aggregate the leverage of small and marginal farmers, giving them greater collective bargaining power.
- Additionally, expanding high-value agriculture and rural energy projects creates localized, off-farm employment opportunities. This diversification can help slow distress migration to urban centers by making the rural economy more resilient and self-sustaining.
- **2. Political Dimension**
- The current subsidy-and-MSP regime has created deeply entrenched political interests, making structural reforms difficult due to the fear of electoral backlash. Transitioning toward autonomous producer organizations could help shift the political dynamic from patronage-based dependency to economic self-reliance.
- However, decentralization also comes with challenges. Rural cooperatives can sometimes be susceptible to elite capture, where local political figures gain control of cooperative boards to build personal vote banks, potentially undermining democratic governance at the grassroots level.
- **3. Legal Dimension**
- Implementing large-scale community energy projects like Agrivoltaics requires a clear and robust regulatory framework. Current property laws face challenges when dealing with fractional land pooling, joint asset ownership, and long-term lease agreements between cooperative societies and commercial energy developers.
- Furthermore, state electricity regulatory commissions (SERCs) need to establish fair, standardized net-metering and power-purchase regulations. Without these protections, small-scale rural energy producers may face administrative delays and unfavorable terms when trying to feed electricity back into the national grid.
- **4. Ethical Dimension**
- The current over-exploitation of natural resources driven by subsidized electricity and water raises important questions about intergenerational equity. The current system incentivizes the depletion of groundwater reserves to grow water-intensive crops like paddy in water-stressed regions.
- Moving away from these distortions and adopting practices like Agrivoltaics represents a shift toward more responsible resource stewardship. This approach balances current economic returns with the long-term health of the environment, preserving vital resources for future generations.
- **5. International Dimension**
- India’s domestic agricultural support policies are a frequent point of contention at the World Trade Organization (WTO). Massive food and fertilizer subsidies are often scrutinized under the "Aggregate Measurement of Support" (AMS) caps within the Amber Box, leading to international trade friction.
- By pivoting toward market-driven cooperatives and investments in renewable energy infrastructure (which fall under the non-distorting Green Box category), India can better align its rural development strategies with its international trade commitments and global climate pledges under the Paris Agreement.
- **6. Economic Dimension**
- The fiscal argument for reform is compelling. Shifting a portion of public funds from recurring input subsidies to capital investments in rural cooperatives can generate stronger long-term returns.
- Investing in infrastructure like solar arrays, cold chains, and processing facilities helps build long-term economic assets. This structural shift can improve capital formation in agriculture, boost processing capabilities, and provide farmers with more diverse and stable income streams.

- **Linkages with NCERTs**
- **Class X: Contemporary India-II (Geography) – Chapter 4: "Agriculture"**
    - *Connection:* This chapter maps out standard cropping patterns across India, identifying institutional and technical reforms. The study of Agrivoltaics directly advances this narrative by introducing technological solutions to modern land-use constraints.
- **Class XI: Indian Economic Development – Chapter 6: "Rural Development"**
    - *Connection:* This text details the critical role of diversification in agriculture, focusing on livestock, dairy, and horticulture. It highlights the historic impact of the White Revolution and discusses the limitations of traditional banking institutions, illustrating why producer-led cooperative credit and marketing networks are so vital.
- **Class XII: Politics in India Since Independence – Chapter 3: "Politics of Planned Development"**
    - *Connection:* This chapter contrasts the early development strategies of the Indian state, detailing the tensions between agriculture and industry, the rollout of the Green Revolution, and the structural expansion of the cooperative sector under visionary leadership.

- **Linkages with UPSC CSE Syllabus**
- **GS Paper 2: Governance, Constitution, and Polity**
- **Syllabus Topics:** Development processes and the development industry; the role of NGOs, SHGs, various groups and associations, donors, charities, institutional and other stakeholders.
- **Application:** Analyzing how shifting control of agricultural schemes from central bureaucracies to democratic, producer-controlled cooperatives can improve public service delivery and reduce administrative friction.
- **GS Paper 3: Technology, Economic Development, and Environment**
- **Syllabus Topics:** Major crops and cropping patterns; E-technology in the aid of farmers; Issues related to direct and indirect farm subsidies and minimum support prices; Economics of animal-rearing; Infrastructure (Energy).
- **Application:** Evaluating Agrivoltaics as a multi-purpose tool that addresses land scarcity, improves solar energy infrastructure, and helps de-dieselize farming, while also comparing the economic efficiency of subsidized cereals against market-driven livestock and horticulture sectors.
- **Essay Paper & Optional Subjects**
- **Application:** A valuable case study for essays focused on sustainable development, decentralization, or rural empowerment. It also aligns closely with core topics in optional subjects such as **Agriculture**, **Economics** (Indian Agriculture), **Public Administration** (Public Sector Undertakings and Cooperatives), and **Geography** (Agricultural Geography).

- **Way Forward**
- Transforming Indian agriculture requires moving away from open-ended input subsidies and toward targeted, structural capital formation driven by community enterprises.
- **1. Reforming Agrivoltaics Implementation Architecture**
- To scale up technologies like Agrivoltaics, the administrative structure of programs like PM-KUSUM needs to shift from a top-down bureaucratic model to a decentralized, producer-led framework.
- Regional implementation cells should be housed within state agricultural universities and local producer organizations rather than centralized ministries. This ensures that technical decisions—such as selecting shade-tolerant crops or adjusting panel tilt for local weather conditions—are guided by regional agro-ecological expertise rather than uniform bureaucratic guidelines.
- **2. Creating a Legal and Financial Toolkit for Land Pooling**
- To make capital-intensive technologies accessible to smallholders, state governments should introduce clear frameworks for land pooling and joint asset management.
- Developing standardized templates for cooperative asset ownership helps protect the land titles of marginal farmers while allowing them to pool land for large solar installations. These frameworks can be backed by credit-guarantee funds to help community-based organizations secure low-interest institutional loans, reducing reliance on private developers.
- **3. Gradual Realignment of Agricultural Subsidies**
- The fiscal space for these investments can be created by gradually shifting from distortive input subsidies toward direct investment in rural infrastructure. A phased approach could include:
- Capping open-ended fertilizer and power subsidies for large landholders.
- Redirecting the savings into a dedicated "National Cooperative Infrastructure Fund."
- Using this fund to provide matching capital grants for community-owned cold storage facilities, processing plants, and local renewable energy networks.
- **4. Replicating the Dairy Cooperative Framework in Horticulture**
- The institutional lessons of the White Revolution should be applied to the fast-growing fruits and vegetables sector. Because horticultural crops are highly perishable, individual smallholders face significant market risks.
- Encouraging the growth of federally structured, professionally managed Farmer Producer Companies (FPCs) can help smallholders build collective cold-chain systems and establish direct links to urban markets. This approach reduces supply chain losses, decreases reliance on traditional middlemen, and ensures that a larger share of consumer spending flows directly back to rural communities.

UPSC CSE Prelims Questions

1. (2023) Consider the following statements:

1.The Government of India provides Minimum Support Price (MSP) for niger seeds.

2.Niger is cultivated as a Kharif crop.

3.Some tribal people in India use niger seed oil for cooking.

Which of the statements given above are correct? (a) 1 and 2 only (b) 2 and 3 only (c) 1 and 3 only (d) 1, 2 and 3

•*Answer:* (d)

2. (2020) With reference to the solar water pumps and solar energy in India, consider the following statements:

1.Solar power can be used for running surface pumps and not submersible pumps.

2.Solar power can be used for running centrifugal pumps and not the ones with pistons.

Which of the statements given above is/are correct? (a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2

•*Answer:* (d)

3. (2018) With reference to the provisions made under the National Food Security Act, 2013, consider the following statements:

1.The families coming under the category of 'eldest woman of the household of age 18 years or above' shall be the head of the household for the purpose of issuing ration cards.

2.Pregnant women and lactating mothers are entitled to a 'take-home ration' of 1600 calories per day during pregnancy and for six months thereafter.

Which of the statements given above is/are correct? (a) 1 only (b) 2 only (c) Both 1 and 2 (d) Neither 1 nor 2

•*Answer:* (a)

Iran's disruptive strategy, its global consequences

Iran's recent actions over the Strait of Hormuz and its strategy of targeting its neighbours in the Gulf as retribution for the actions of the United States may seem to have been operational masterstrokes. However, in the long run, they may well prove to be strategic blunders that have antagonised the world at large and leave Iran out of the global mainstream and away from the path of sustained economic progress.

Arjun Subramaniam

Strategic affairs analyst

A strategy of disruption

For decades, Iran has overplayed its hand in presenting itself as standing up to what it has termed "continued Western imperialism" and in supporting the Palestinian cause through the lens of Islamic resistance – a policy that was not endorsed by most other developed and developing Islamic nations. As the Islamic regime in Iran grew in power, buoyed by its success in standing up to a powerful Iraq during the Iran-Iraq war that stretched through the 1980s, so too did its frustration at being unable to deliver telling blows against the "Big Satan-Little Satan" combination, as it referred to the U.S. and Israel, respectively.

Consequently, it engineered the second phase of its disruptive strategy in the late 1990s by developing and supporting proxies such as the Hezbollah, Hamas and Houthis, commonly known as the Axis of Resistance, and liberally endorsed their use of terrorism to cause widespread disruption in the region.

Here again, the Iranians have achieved much tactical success over the last two decades and kept West Asia on tenterhooks, but at a much larger level, it has widened the chasm that exists between itself and the rest of the world barring Russia, China and North Korea. It is this quartet which is shaping the trajectory of fundamentally disruptive resistance to the existing global order.

When you compare this with the orderly way in which countries such as India are also challenging the existing global order with a call for greater multilateralism through dialogue and consensus, one can clearly figure out Iran's disruptive path.

Tehran needs to recognise the limits of its current geopolitical advantage

Notwithstanding much assertion of civilisational and cultural linkages, India has maintained a steady transactional relationship with the Islamic Republic of Iran, revolving principally around energy flow, trade corridors and the Chabahar port. Much in tune with its foreign policy of multilateralism in a multi-polar world, it managed to navigate the sanctions regime imposed on Iran by the West and maintained some energy flow based on national interest till it found alternate means and then gradually reduced its import of Iranian crude.

India's approach

India has only modest diplomatic leverage with Iran and rightly chose not to position itself as an interlocutor during the recent conflict, preferring instead to resort to quiet back-channel diplomacy and frequent calls for restraint. India co-sponsored the UN Security Council Resolution 2817 (2026), which officially condemned Iran's military attacks and aggressive actions against the Gulf Cooperation Council (GCC) nations and Jordan. Adopted on March 11, 2026, the resolution demanded that Iran immediately cease all attacks and threats, particularly those targeting international navigation through the Strait of Hormuz.

Iran has no doubt been emboldened by its ability to withstand months of the U.S.-Israel bombing campaign. It has come out of the conflict battered and embittered but still standing. With large portions of its military capacity still intact and a regime in power that seems to be now dominated by a combination of the Islamic Revolutionary Guard Corps (IRGC) and hard line clerics, it appears that the region can expect continued acts of isolated belligerence that stay below the threshold of conflict. The frenzy of stage-managed grief and genuine hatred towards the U.S. and Israel that was on display on the streets of Tehran for the funeral of its slain leader, Ali Khamenei does not augur well for the future.

Iran's proposal to levy 'special rates' on friendly countries for transit through the Strait of Hormuz is another disruptive attempt at preventing any collective action from energy-hungry countries eager to benefit from this offer.

More recently, Iran's strikes on tankers following the Omani route through the Strait of Hormuz highlight its propensity to engage in coercive brinkmanship. Such an environment is highly unsettling for a large part of the world including India for obvious reasons – energy and trade corridors running through a volatile geopolitical arena.

The choice before Iran

It is time that collective pressure from countries other than the West starts building on Iran to desist from its varied coercive methods to keep the region on the edge. As the U.S.'s appetite to remain embroiled in the conflict waxes and wanes, and Israel strains to 'finish off the job it started', Iran needs to take a step back and not overplay the advantageous geopolitical hand it currently holds.

As a first step, it must look for windows to extract legitimate leverage accruing from the proposed de-freezing of its assets and widening energy flow from its embattled oil fields and refineries. Despite its isolation from the West, Iran is categorised as an upper-middle-income economy and has much potential for rapid growth, should it desire so for its people.

- **Key Terms and Explanations**
- **The Axis of Resistance:** An informal but highly coordinated geopolitical and military coalition led by Tehran. It features a network of state actors (like Syria) and non-state asymmetric proxies—including Hezbollah in Lebanon, Hamas in Gaza, and the Houthi movement in Yemen. Its core ideological objective is to counter Western alignment and challenge Israeli influence across the region.
- **The Strait of Hormuz:** Geographically situated between Oman and Iran, this narrow waterway links the Persian Gulf with the Gulf of Oman and the open ocean. It is arguably the most vital maritime choke point globally, handling nearly 20% of the world's petroleum liquids transit, making its openness critical to global energy stability.
- **Coercive Brinkmanship:** A high-stakes foreign policy strategy where a nation pushes a political or military crisis to the absolute edge of open conflict to force adversaries to make concessions. An example is conducting targeted strikes on commercial tankers in nearby Omani maritime routes to force international actors to reconsider economic sanctions.
- **Multilateralism:** A framework of global governance where multiple nations work together to resolve systemic challenges, relying on international law, structured dialogue, and institutional consensus rather than unilateral force or asymmetric disruption.
- **UN Security Council Resolution 2817 (2026):** A binding international legal instrument adopted on March 11, 2026. It officially condemned military hostilities targeting Jordan and the Gulf Cooperation Council (GCC) nations, demanding an immediate end to threats against international shipping lanes.
- **Islamic Revolutionary Guard Corps (IRGC):** A powerful branch of the Iranian Armed Forces established after the 1979 revolution. Unlike the regular military, the IRGC is ideologically tasked with protecting the country's political system, controlling vast sectors of the domestic economy, and managing external asymmetric operations.

- **Main Arguments and Substantive Parts**
- The core strategic dilemma in the region revolves around a stark paradox: the striking divergence between short-term tactical successes and long-term strategic vulnerabilities.
- **The Illusion of Tactical Dominance**
- Tehran’s regional maneuvers are often viewed as operational masterstrokes. By preserving its core military capabilities through intense external pressures and outlasting extensive bombing campaigns, the regime has demonstrated significant resilience. Furthermore, introducing grey-zone tactics—such as proposing "special transit rates" for friendly nations within the Strait of Hormuz or conducting precise operations along alternate trade routes—allows it to exert significant leverage over energy-dependent states.
- **The Reality of Strategic Isolation**
- However, this reliance on disruption points to a broader strategic miscalculation. For decades, relying heavily on anti-imperialist rhetoric and supporting militant proxies has isolated the nation from the broader Islamic world, particularly developed and developing Arab states. Instead of building sustainable global partnerships, these actions have pulled the country into a restrictive revisionist grouping alongside Russia, China, and North Korea.
- **Two Paths to Challenging the Global Order**
- This situation highlights two distinct ways emerging powers seek to alter the global status quo:
- [Global Status Quo Challenges]
- │
- ├─▶ Revisionist Disruption (Iran, Russia, North Korea)
- │ └─ Use of proxy warfare, maritime threats, and grey-zone conflict.
- │
- └─▶ Orderly Multilateralism (India and Emerging Economies)
- └─ Use of rule-based dialogue, institutional consensus, and economic corridors.
- By contrasting these approaches, we see that while the disruptive path provides short-term leverage, it ultimately limits long-term economic development. True sustainable progress requires global economic integration, which remains out of reach as long as regional policies rely on destabilization.

- **Historical Evolution of the Issue**
- The complex geopolitical landscape observed today is the result of nearly five decades of ideological evolution, domestic consolidation, and changing security dynamics in West Asia.
- **The 1979 Islamic Revolution:** The foundational turning point. The overthrow of the pro-Western Pahlavi dynasty replaced a secular state with a clerical system led by Ayatollah Khomeini. This shifted the nation's foreign policy from an anchor of Western strategy to an active challenger of global power structures.
- **The Iran-Iraq War (1980–1988):** A brutal war of attrition initiated by Saddam Hussein's Iraq. Facing international isolation, the regime developed a deep-seated survival instinct. The conflict unified the domestic population, elevated the importance of the IRGC, and convinced leadership that asymmetric deterrence was vital to national defense.
- **The Institutionalization of Proxies (Late 1990s):** Recognizing its limitations in conventional warfare, leadership formalised its external strategy. It invested heavily in non-state actors, building up Hezbollah into a powerful regional force and extending its influence into the political vacuums of post-war Iraq, Syria, and Yemen.
- **The JCPOA and the Sanctions Cycle (2015–2020s):** The signing of the Joint Comprehensive Plan of Action (JCPOA) offered a temporary opening to the global economy. However, the subsequent US withdrawal and the reinstatement of maximum-pressure sanctions reinforced hardline narratives, sidelining reformists and empowering a conservative clerical-military alliance.
- **The 2026 Operational Realities:** Following the passing of Supreme Leader Ali Khamenei, the IRGC and conservative clerics solidified their domestic authority. Faced with intense external campaigns, the state chose to double down on maritime pressure, leading to direct international pushback through UN Security Council Resolution 2817 in early 2026.

AXIA IAS ACADEMY

GEOPOLITICAL ANALYSIS: Iran's Strategy in the Strait of Hormuz & India's Multilateral Response

A UPSC CSE Preparation Masterclass

IRAN'S DISRUPTIVE PATH: A Strategy of Resistance

Broken-Flow Graphics

AXIS OF RESISTANCE: The Proxy Network

COERCIVE BRINKMANSHIP

- **Operational Masterstroke?** Preserved military, emboldened. Isolated acts of belligerence stay below conflict threshold.
- **Strategic Blunder? Strategic isolation** from mainstream, antagonized neighbors, economic potential underutilized.
- **Widening Chasm** with the world bar Russia, China, N. Korea.
- **Coercive tactics** like special transit rates.
- **Months of US-Israel bombingcampaign** withstood.

INDIA'S ORDERLY PATH: Reformed Multilateralism & Strategic Autonomy

Orderly, growing-growth flow

MULTILATERALISM THROUGH DIALOGUE

KEY INTERESTS: Transactional Relations

- Maintained **steady transactional relations** with Iran.
- **Navigated Western sanctions**, maintained **energy flow** based on national interest.
- **UNSC co-sponsorship**, calling for restraint.
- **India's modest leverage prevents interlocutor role,** preferring back-channel diplomacy.
- Compare India's orderly challenge vs. Iran's disruptive path.

MULTIDIMENSIONAL ANALYSIS & WAY FORWARD

Political Axis of Resistance, anti-Western	**Economic** Underutilized energy fields, trade corridor	**International** Isolating quartets vs. Indian multilateralism
Legal UNSC Resolution, coercion is illegal brinkmanship	**Ethical** Use of terrorism, terrorism vs. global mainstream	**Social** Upper-Middle-Income potential vs. isolation

THE CHOICE BEFORE IRAN

PATH OF ISOLATION (Continued Disruption)

PATH OF INTEGRATION (Sustainable Economic Progress, Asset de-freezing windows, people's potential)

WAY FORWARD: PRACTICAL balanced solutions, Step Back from coercive methods, prioritized peoples potential.

THE CHOICE BEFORE IRAN

PATH OF ISOLATION (Continued Disruption)

PATH OF INTEGRATION (Sustainable Economic Asset de-freezing windows, people's potential)

WAY FORWARD: PRACTICAL balanced solutions, Step Back from coercive methods, prioritized peoples potential.

- **Logical and Philosophical Base**
- Understanding these developments requires looking at the competing political theories and strategic philosophies that shape the actions of the key players involved.
- **The Realist Trap of Asymmetric Survival:** The political leadership operates largely on an offensive realist philosophy. In an environment perceived as permanently hostile, the state views regional disruption not as an aggressive choice, but as a necessary defensive tool. The underlying assumption is that creating external points of friction prevents direct threats to the home regime.
- **The Contradiction of Revisionist Resistance**
- This strategy exposes a major philosophical contradiction. The regime frames its foreign policy around the idealist principles of anti-imperialism and global Islamic solidarity. Yet, its reliance on grey-zone disruption routinely harms neighboring developing Islamic countries and destabilizes vital global commons like the Strait of Hormuz. This focus on immediate security goals ends up undermining the long-term economic well-being of its own people.
- **The Principle of Orderly Rebalancing**
- In contrast, nations like India approach global governance through a philosophy of reformed multilateralism. This perspective assumes the current international order has structural imbalances that need fixing, but argues these corrections should happen through international law, institutional reform, and mutual economic benefit.

- **Multidimensional Analysis**
- **Social and Domestic Factors**
- There is a widening gap between the political elite and a highly educated, youthful population. While state-directed gatherings express nationalist sentiments and resistance to external pressure, the broader public aspires to economic normalization. Extended isolation prevents the country from realizing its potential as an upper-middle-income society.
- **Political Dynamics**
- Domestically, power has concentrated within a hardline clerical-military elite dominated by the IRGC. This consolidation limits the influence of pragmatic reformists, making foreign policy more rigid and leaning toward persistent, low-level conflict that avoids all-out war but prevents regional stability.
- **Legal Considerations**
- The use of maritime pressure directly challenges international maritime law, particularly the freedom of navigation guaranteed under the United Nations Convention on the Law of the Sea (UNCLOS). Operating inside alternative shipping lanes, like Omani routes, sets a troublesome precedent that led directly to the enforcement measures of UNSC Resolution 2817.
- **Ethical Concerns**
- The ethical challenges are significant. Relying on asymmetric proxies that use political violence impacts millions of civilians across the Levant and the Arabian Peninsula. Using regional stability as leverage in broader disputes with global powers creates major humanitarian costs throughout West Asia.
- **International Relations**
- The situation has accelerated a shifting global polarization. By anchoring its strategy within a revisionist quartet alongside Russia, China, and North Korea, the nation has turned regional security issues into a broader confrontation with the rules-based international order, complicating relationships for nations trying to maintain balanced diplomacy.
- **Economic Realities**
- The economic costs are clear. Despite extensive hydrocarbon reserves and a strategic location, ongoing tension discourages long-term foreign direct investment. Attempting to influence trade through special transit rates disrupts global energy markets and creates significant supply chain risks for major importing nations like India.

- **Linkages with NCERT Textbooks**
- **Class 12 Contemporary World Politics (International Organisations):** This chapter provides necessary context for understanding how the UN Security Council functions, the mechanics behind mandatory resolutions, and the impact of great-power dynamics on international enforcement.
- **Class 12 Contemporary World Politics (Security in the Contemporary World):** Essential for understanding the shift from traditional state-versus-state warfare to non-traditional security challenges, including asymmetric conflicts, state-sponsored militancy, and grey-zone operations.
- **Class 12 Politics in India Since Independence (India's External Relations):** This section helps students understand how India maintains its strategic autonomy. It explains how the nation manages complex bilateral ties while balancing its national energy needs with international compliance pressures.
- **Class 12 Fundamentals of Human Geography (International Trade):** Provides the geographic foundations for understanding Sea Lines of Communication (SLOCs), the economic role of strategic choke points, and how regional instability affects global supply networks.

- **Linkages with the UPSC CSE Syllabus**
- **GS Paper 2: Governance, Constitution, Polity, Social Justice and International Relations**
- **Bilateral, regional and global groupings and agreements involving India and/or affecting India’s interests:** Focuses on the strategic importance of the Chabahar Port, the International North-South Transport Corridor (INSTC), and India's evolving ties within West Asia.
- **Effect of policies and politics of developed and developing countries on India’s interests:** Examines how regional tensions impact the Indian diaspora in the Gulf, remittance flows, and maritime security in the Indian Ocean region.
- **GS Paper 3: Technology, Economic Development, Bio-diversity, Environment, Security and Disaster Management**
- **Energy Security and Infrastructure:** Looks at the vulnerabilities of oil and gas imports moving through maritime choke points.
- **Linkages of organized crime with terrorism; Security challenges and their management:** Analyzes the funding, logistics, and broader security implications of asymmetric proxy networks.
- **GS Paper 4: Ethics, Integrity and Aptitude**
- **Ethical dilemmas in international relations and statecraft:** Explores the ethical challenges of using proxy groups, the moral responsibilities of protecting global commons, and the balance between state survival and international stability.
- **Essay and Optional Subjects**
- **Essay Themes:** Highly relevant for discussions on the future of multilateralism, global energy politics, and balancing stability with national interests.
- **Optional Alignments:** Valuable for students taking Political Science and International Relations (PSIR), Geography, or Modern History optionals.

- **Way Forward**
- Addressing these complex challenges requires a balanced approach that addresses immediate security needs while fostering long-term regional cooperation.
- **1. Shifting Toward Economic Priorities**
- The political leadership in Tehran would benefit from moving away from high-risk security maneuvers toward a focus on economic development. Utilizing windows that allow for the de-freezing of foreign assets and stabilizing energy exports could help integrate the nation more deeply into regional infrastructure projects, providing tangible benefits for its upper-middle-income population.
- **2. Safeguarding Global Trade Routes**
- Developing economies outside the traditional Western bloc should work together to ensure international shipping lanes remain open. Broad diplomatic efforts can help implement the maritime safety provisions of UNSC Resolution 2817, ensuring the Strait of Hormuz remains accessible to global commerce without becoming a point of political leverage.
- **3. Advancing India's Regional Strategy**
- New Delhi can continue to protect its national interests by practicing active strategic autonomy:
- By pursuing these balanced paths, the international community can work toward reducing tensions in West Asia, turning a volatile region into a more stable space for shared economic growth.

UPSC CSE Civil Services Examination (Mains)

•**General Studies II (2017):** "The sebaceous growth of proxy wars and geopolitical rivalries in West Asia has made it a highly volatile zone. Discuss its direct and indirect implications on India's energy security and diaspora."

•**General Studies II (2020):** "India's look-west policy has successfully carved out a deep, transactional relationship with the GCC nations, yet it faces cross-pressures due to the US-Iran binary. Examine how India can navigate this delicate balance."

•**General Studies III (2022):** "Maritime security challenges in the Indian Ocean Region are increasingly becoming non-linear and asymmetric. In light of this, evaluate the vulnerability of global trade bottlenecks like the Strait of Hormuz."

Specially Designed CSE Prelims Practice Questions

Q1. Consider the following statements regarding the geopolitical geography of West Asia:

1.The Strait of Hormuz provides the primary maritime exit point for the Persian Gulf, separating Iran from the United Arab Emirates.

2.The Chabahar Port is located directly on the coast of the Gulf of Oman, bypassing the Strait of Hormuz entirely.

3.UN Security Council Resolution 2817 (2026) deals explicitly with the protection of navigation rights in the Red Sea against external actors.

Which of the statements given above is/are correct?

(a) 1 and 2 only

(b) 2 only

(c) 2 and 3 only

(d) 1, 2, and 3

Answer: (b)

Explanation: Statement 1 is incorrect because the Strait of Hormuz separates Iran from Oman (the Musandam Peninsula enclave), not the UAE proper, though the UAE lies close by. Statement 2 is correct; Chabahar is strategically situated on the Makran coast of Iran along the Gulf of Oman, allowing trade to bypass the Hormuz choke point. Statement 3 is incorrect as Resolution 2817 (2026) specifically condemned attacks against GCC nations and Jordan, focusing on the Strait of Hormuz and surrounding West Asian lanes.

Q2. The term 'Axis of Resistance', frequently seen in international security dynamics, is best described as:

(a) A formal military alliance between the states of Central Asia to counter maritime smuggling.

(b) A regional network of state and non-state actors led by Iran aiming to counter Western and Israeli influence in West Asia.

(c) A coalition of Eastern European states operating under a shared defense framework outside of NATO.

(d) A maritime task force formed by the GCC to protect commercial shipping along Omani transit routes.

Answer: (b)

Explanation: The 'Axis of Resistance' refers to the political and military coalition linking Iran, the Syrian government, Lebanese Hezbollah, Hamas, and the Houthi movement in Yemen, designed to challenge Western and regional adversaries.

The case for hydrogen trains must be studied

India's first hydrogen train could generate practical knowledge in fuel-cell operation, storage, safety and long-term reliability

Sudhanshu Mani

After more than three years of ambitious announcements, social media teasers and repeated postponements, Indian Railways' (IR's) first hydrogen-powered train is finally ready. Prime Minister Narendra Modi is expected to flag it off later this week.

The train will operate between Jind and Sonipat and consists of two hydrogen-powered driving power cars, each producing 1,200 kW of traction power, and eight passenger coaches.

The launch deserves recognition. Hydrogen fuel cells generate electricity while emitting only water vapour, and the train represents a significant engineering achievement. Although the fuel-cell stack itself is imported, an Indian company has successfully developed the propulsion, control systems and overall integration. India thus becomes only the third country, after Germany and China, to introduce hydrogen trains in commercial passenger service.

Yet technological milestones should encourage informed debate rather than unquestioned celebration.

Germany, which pioneered hydrogen rail technology with the Alstom Coradia iLint in 2022, has already scaled back many of its operations, with several routes shifting towards battery-powered trains after encountering issues such as fuel-cell degradation, supply chain challenges and operational reliability. Japan, Sweden, South Korea, Switzerland and the US have confined themselves largely to demonstration projects while continuing to evaluate the technology.

India is perhaps the only country to run a hydrogen-powered passenger train on a fully electrified route under the wire; hydrogen trains are designed as an alternative to polluting diesel trains on non-electrified regional lines.

HERITAGE ROUTES

As an afterthought, therefore, it changed the discourse to 'Hydrogen for Heritage', declaring that 35 such trains shall be developed for eight scenic, ecologically sensitive narrow-gauge and metre-gauge heritage routes.

The concept has merit. Heritage railways traverse environmentally sensitive regions where conventional electrification may be undesirable, and hydrogen could potentially offer a cleaner alternative. However, these routes are small, geographically dispersed and located in remote areas. Establishing hydrogen production, storage and refuelling infrastructure at each location would be expensive and operationally demanding. Moreover, despite a budgetary allocation of about ₹2,800 crore three years ago, little visible progress has been made towards developing these heritage train prototypes.

HYDROGEN TRAIN. A vital case study

The broader question concerns hydrogen itself. Hydrogen is often described as the fuel of the future, but it is more accurately an energy carrier than a primary fuel. Unlike coal, petroleum or uranium, hydrogen must first be manufactured using energy before it can be used. It is then compressed or liquefied, transported, stored and finally converted back into electricity inside a fuel cell. Every stage consumes energy, leaving hydrogen with significantly lower overall efficiency than battery-electric systems. However, inexplicably, IR has not yet pursued battery-powered trains in any significant way.

Hydrogen's environmental credentials also depend on how it is produced. More than 95 per cent of global hydrogen is currently derived from natural gas, a process that emits carbon dioxide. Truly green hydrogen, produced by splitting water using renewable electricity, remains considerably more expensive. Unless the electricity used for electrolysis itself comes from renewable sources, hydrogen cannot be described as a completely green fuel.

Despite these challenges hydrogen offers considerable promise in sectors where batteries face fundamental limitations, such as green steel production, fertilizer manufacture, long-distance shipping and perhaps aviation. Railways, however, present a far more nuanced case.

The Jind-Sonipat prototype will nevertheless provide invaluable operational experience. Indian engineers will acquire practical knowledge in fuel-cell operation, hydrogen storage, maintenance, safety and long-term reliability. That experience makes the project worthwhile, provided future decisions are guided by evidence and close study of international experience rather than by technological enthusiasm.

The writer is Retd. General Manager/Indian Railways, Leader of Vande Bharat project & Independent Rail Consultant

- **Key Terms and Explanations**
- **Hydrogen Fuel Cells:** These are electrochemical devices that convert the chemical energy of a fuel—in this case, hydrogen—and an oxidizing agent—typically oxygen from the air—into electricity through a localized chemical reaction. Unlike conventional internal combustion engines, this process bypasses thermal combustion entirely.
- **Example:** Consider a standard household battery, but instead of running down, it continuously generates electricity as long as hydrogen gas and air are supplied to it. The only operational byproducts are pure water vapor and heat.
- **Energy Carrier vs. Primary Fuel:** A *primary fuel* is an energy source found readily in nature that can be extracted, cleaned, and directly consumed, such as coal, crude oil, or natural gas. Conversely, an *energy carrier* is a medium used to store and transport energy that has already been produced by other means. Hydrogen does not exist in pure isolation on Earth; it requires energy inputs to be separated from compounds like water (H_2O) or methane (CH_4). It acts as a storage vessel or "energy currency" rather than an initial source.
- **Green Hydrogen vs. Grey/Blue Hydrogen:** The environmental viability of hydrogen is color-coded by its carbon footprint during production. *Grey hydrogen* is derived from fossil fuels via steam methane reforming, which releases substantial carbon dioxide (CO_2) into the atmosphere. *Blue hydrogen* follows the same process but captures and stores the emitted carbon underground. *Green hydrogen* is produced by using 100% renewable energy—such as solar or wind power—to run an electric current through water, splitting it into hydrogen and oxygen with zero carbon emissions.
- **Propulsion and Control Systems:** The technical nervous system of a locomotive. The propulsion system includes the traction invertors and electric motors that turn the wheels, while the control system regulates the flow of electricity from the power source (the fuel cell stack) to the wheels based on real-time operational demands.
- **Route Under the Wire:** An operational term in railway engineering referring to running a train on tracks that are already fully equipped with overhead electrical lines (catenaries). When a self-powered train (like a diesel or hydrogen prototype) runs "under the wire," it operates on tracks where traditional, highly efficient grid electricity is already directly accessible.

- **Main Arguments and Substantive Parts**
- The paradigm shift toward hydrogen rail technology presents a dual narrative of domestic engineering prowess and complex technological trade-offs.
- **The Triumph of Indigenous Engineering**
- A core argument centers on the successful indigenization of the train's technological architecture. While the foundational fuel-cell stack remains an import asset, domestic industries have successfully engineered the complex propulsion mechanisms, electronic control suites, and full-vehicle system integration. This breakthrough elevates the nation into a select global cohort—alongside Germany and China—capable of deploying hydrogen fuel-cell systems in commercial passenger operations. It shifts the country from a mere consumer of green technologies to a critical co-developer.
- **The Operational Paradox of Electrified Corridors**
- A pivotal point of critique highlights an infrastructure misalignment: introducing a hydrogen prototype on a fully electrified route. Globally, hydrogen trains are designed specifically to serve as drop-in clean alternatives for non-electrified regional or rural lines where setting up expensive overhead wiring is economically unviable. Running a resource-intensive hydrogen train parallel to an existing electrical grid grid eliminates the primary environmental and economic justification of fuel cells, introducing an unnecessary layer of energy conversion on tracks that are already green.
- **The 'Hydrogen for Heritage' Pivot: Merits and Bottlenecks**
- In response to these routing critiques, the operational discourse has shifted toward deploying these systems along ecologically sensitive, narrow-gauge, and metre-gauge heritage routes.
- **The Merits:** Heritage circuits often traverse dense forests and biosphere reserves where constructing overhead catenary lines would cause severe visual pollution, necessitate wide-scale tree felling, and disrupt local wildlife corridors.
- **The Bottlenecks:** These tourist circuits are geographically isolated and highly dispersed across remote mountainous terrains. Setting up decentralized hydrogen production units, specialized high-pressure storage tanks, and safe refuelling stations at every separate site introduces exponential capital costs and severe logistical challenges.
- **The Thermodynamic Efficiency Deficit**
- The underlying argument against a blanket expansion of hydrogen rail lies in basic physics. The thermodynamic loop of hydrogen—requiring water electrolysis, high-pressure compression or liquefaction, transport to remote stations, and subsequent reconversion back into electricity via a fuel cell—suffers from significant round-trip energy losses.
- Direct battery-electric train systems retain up to 80-90% of the original electricity generated. Hydrogen fuel-cell systems, by contrast, often struggle to cross a net efficiency barrier of 30-40%. This massive efficiency loss raises fundamental questions about why alternative pathways, such as Battery Electric Multiple Units (BEMUs), have not been aggressively pursued for non-electrified regional networks.

Historical Evolution of the Issue

The modern push for hydrogen locomotives is the latest chapter in a century-long effort to balance the modernization of the rail network with energy security and environmental conservation.

```
[Pre-1950s: Steam Era]
   └── Relied entirely on domestic coal; highly polluting and inefficient.
[1950s - 1990s: The Diesel & Early Electric Transition]
   └── Introduction of diesel locomotives to boost speed and hauling capacity.
   └── Initial electrification of high-density trunk routes to reduce oil imports.
[2000s - 2015: Accelerated Core Electrification]
   └── Shift toward standardizing 25 kV AC overhead lines across major networks.
   └── Focus on reducing the massive financial drain of imported diesel fuel.
[2015 - 2020: Target 100% Electrification & Mission Raftaar]
   └── Aggressive policy push to phase out broad-gauge diesel locomotives entirely.
   └── Near-complete electrification of the main broad-gauge network.
[2021 - 2024: Dawn of the Hydrogen Missions]
   └── Launch of the National Green Hydrogen Mission (2023).
   └── Formalization of the "Hydrogen for Heritage" policy with dedicated budget
allocations.
[2026: The Prototype Reality]
   └── Rollout of the first functional Jind-Sonipat pilot train.
   └── Global policy reassessment following mixed operational feedback from European
pio
```

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INDIA'S HYDROGEN TRAIN REVOLUTION: A CRITICAL UPSC CSE ANALYSIS

Green Hydrogen: Green Hydrogen is oarion or coor hydrogen, hamported. | **Fuel Cell:** Power and rity **Fuel Cell** epaining orith habits hydrogen: fuel cell | **Energy Carrier:** Energy carrier

MAJOR CHALLENGES

- Efficiency Penalties
- High CapEx & OpEx
- Dependency on Imported Stack

THE ACHIEVEMENT (JIND-SONIPAT PILOT)

- **Indian Engineering Triumph** (propulsion, controls)
- **Third Country Global Ranking**
- **2 DPCs, 8 coaches,** specification

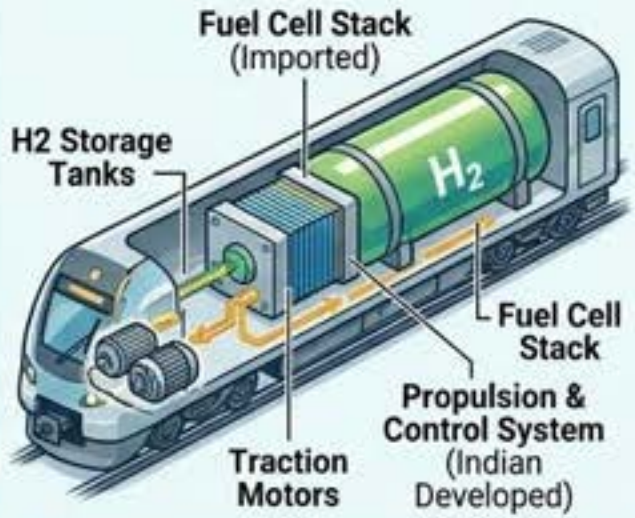
HYDROGEN FOR HERITAGE

- **Ecologically Sensitive Zones**
- **Avoiding Invasive Catenaries**

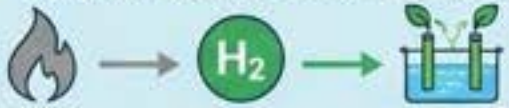
Challenges:

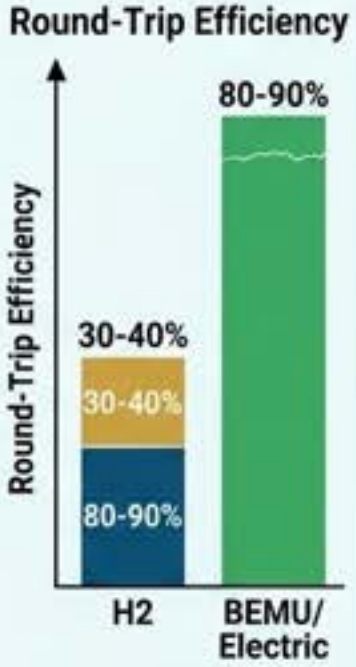
- Dispersed Remote Locations
- Decentralized H2 Infrastructure Costs

HOW IT WORKS & THERMODYNAMIC REALITY



Grey vs. Blue vs. Green Hydrogen





The Molecular Detour Deficit

MULTIDIMENSIONAL GS ANALYSIS

Social
- Public Health
- Local Air Quality

Political
- National Commitments
- Tech Nationalism

Legal & Ethical
- Safety Frameworks
- Intergenerational Equity

International
- Supply Chains
- Strategic Climate Diplomacy

WAY FORWARD (PRACTICAL SOLUTIONS)

1. Strict Geographic Targeting (Non-electrified Routes)
2. BEMU Coordinated Development
3. Green Hydrogen Ecosystems
4. Data-Driven Expansion

- **Logical and Philosophical Base**
- Analyzing this technological transition reveals deep underlying tensions between political economy, technological optimism, and engineering pragmatism.
- **Technological Optimism vs. Techno-Realism**
- The push for hydrogen rail highlights a philosophical commitment to technological optimism—the belief that the most complex, cutting-edge technology is inherently the best solution for sustainable development. However, a techno-realistic view argues that infrastructure decisions must prioritize long-term economic and physical efficiency over high-profile technological milestones. The prestige of joining an elite global hydrogen club must be weighed against the day-to-day realities of operational costs and infrastructure maintenance.
- **First-Principles Thinking in Energy Economics**
- From a first-principles perspective, energy policies should seek the shortest, least wasteful path from power generation to mechanical work. Direct electrification utilizes electrons straight from the grid with minimal friction. Battery systems store these electrons with minor heat loss.
- Hydrogen, however, introduces a complex molecular detour—converting electrons to molecules (H_2) and then back to electrons. This multi-step process incurs a heavy thermodynamic penalty. Choosing a lower-efficiency pathway requires strong justification, such as extreme range requirements or severe weight limits, which are rarely issues for fixed-rail infrastructure.
- **The Precautionary Principle and Eco-Tourism**
- The application of fuel cells to heritage lines reflects the Precautionary Principle in environmental governance. By avoiding invasive overhead wires in pristine ecosystems, the state protects fragile mountain biomes from habitat fragmentation. Yet, this introduces a secondary risk profile: the storage and handling of highly volatile, compressed hydrogen gas in remote, disaster-prone mountainous zones. The philosophy shifts from avoiding visual and construction impacts to managing complex industrial safety risks in natural sanctuaries.

- **Multidimensional Analysis**
- **Social Dimension**
- **Public Health and Local Air Quality:** Phasing out diesel locomotives along regional and heritage corridors directly reduces local emissions of particulate matter ($PM_{2.5}$ and PM_{10}) and nitrous oxides (NO_x). This brings immediate respiratory health benefits to nearby communities and travelers.
- **Preservation of Cultural Heritage:** Implementing non-invasive clean energy solutions maintains the historical integrity and visual charm of historic rail lines, ensuring long-term tourism revenue for local economies dependent on these living museums.
- **Human Resource Reskilling:** Introducing a completely new fuel ecosystem requires training a new generation of railway workers in cryogenic engineering, high-pressure gas safety, and advanced fuel-cell diagnostics.
- **Political Dimension**
- **Alignment with National Climate Goals:** This initiative serves as a high-profile validation of commitments under the Paris Agreement and the Net-Zero target, showcasing a willingness to decarbonize even the most complex sectors of the economy.
- **Technological Nationalism and State Prestige:** Successfully integrating complex propulsion systems enhances national soft power, projecting an image of advanced domestic industrial capability on the global stage.
- **Economic Dimension**
- **The Capital (CapEx) vs. Operational (OpEx) Dilemma:** While the initial research budget is substantial, the long-term operational costs present the real challenge. Importing specialized components and establishing remote refuelling networks creates high running costs per kilometer.
- **Resource Allocation and Opportunity Costs:** Every rupee spent on a low-efficiency hydrogen train is a rupee diverted away from expanding standard route electrification, upgrading passenger safety features, or investing in highly efficient battery-electric train variations.
- **Legal and Ethical Dimensions**
- **Safety Frameworks for Volatile Gases:** Current statutory frameworks must expand rapidly to cover the transport, storage, and commercial handling of high-pressure hydrogen within crowded public passenger spaces, balancing innovation with public safety.
- **Environmental Law Compliance:** Setting up production facilities in pristine regions requires careful navigation of the Forest (Conservation) Act and Environment Protection Act to ensure green infrastructure does not inadvertently damage local ecosystems.
- **Intergenerational Resource Equity:** Investing public funds into technologies that consume vast amounts of renewable energy to produce modest mechanical output raises ethical questions about resource management during a critical climate transition.
- **International and Strategic Dimensions**
- **Global Supply Chain Vulnerabilities:** Relying on imported fuel-cell stacks leaves the technology vulnerable to geopolitical disruptions and currency swings, highlighting the need for complete domestic manufacturing loops.
- **Strategic Climate Diplomacy:** Demonstrating commercial hydrogen rail capacity positions the nation as a potential clean-tech exporter to developing economies across South Asia and Africa, countering similar technology diplomacy from regional competitors.

- **Linkages with NCERT Textbooks**
- **Class X: Contemporary India-II (Geography) – Chapter 7: *Lifelines of National Economy***
    - *Connection:* This chapter details the critical role of the Indian Railways network as a primary driver of national integration and economic growth. The transition from steam and diesel to hydrogen highlights the ongoing challenge of modernization and shifting resource bases.
- **Class XII: Chemistry – Chapter 3: *Electrochemistry***
    - *Connection:* The fundamental operational principles of fuel cells, galvanic interactions, and the electrolysis of water are covered extensively here. Understanding the reactions at the anode and cathode is crucial for grasping why these systems are zero-emission at the point of use.
- **Class XII: Biology – Chapter 16: *Environmental Issues***
    - *Connection:* This text provides the foundation for analyzing air pollution control strategies and evaluating alternate clean energy options. It underscores the ecological importance of keeping sensitive biomes free from heavy industrial pollution and fossil-fuel emissions.

- **Linkages with the UPSC CSE Syllabus**
- **GS Paper 3: Science, Technology, and Economic Development**
- **Infrastructure: Railways and Energy:** Analyzing the cost-benefit realities of transport choices, grid optimization, and clean energy supply chains.
- **Indigenization of Technology & Developing New Technology:** Evaluating the successful domestic design and integration of propulsion systems, shifting the nation from an importer to an active creator of clean technology.
- **Environmental Conservation and Pollution Mitigation:** Assessing the real-world value of green hydrogen versus alternative options like battery-electric transit in achieving broader net-zero carbon goals.
- **GS Paper 2: Governance and Public Policy**
- **Government Policies and Interventions:** Examining the strategic shift from broad-gauge route electrification to specialized niche projects like "Hydrogen for Heritage," and evaluating how effectively public funds are allocated across competing green technologies.
- **GS Paper 4 & Essay: Ethical and Sustainable Paradigms**
- **Environmental Ethics vs. Developmental Efficiency:** Balancing the need for rapid, cost-effective transport modernization for millions of commuters with the ethical imperative to protect fragile ecological reserves.

- **Way Forward**
- A practical, evidence-based approach to clean transit modernization requires moving past initial enthusiasm and adopting a balanced strategy that fits the nation's unique energy landscape.
- **1. Enforce Strict Geographic and Functional Targeting**
- Hydrogen locomotives should not be deployed on routes where standard overhead electric wires are already installed or physically feasible. Their use should be strictly confined to non-electrified, ecologically fragile tourist tracks—such as mountain railways—where traditional overhead infrastructure is prohibited due to landscape conservation or extreme terrain challenges.
- **2. Launch a Coordinated Battery-Electric Platform (BEMUs)**
- The railway sector must diversify its technological options by investing in Battery Electric Multiple Units (BEMUs) for short, non-electrified regional routes. Given their superior thermodynamic efficiency and lower infrastructural setup costs, battery-powered trains offer a more practical solution than hydrogen for the vast majority of non-electrified branch lines.
- **3. Build Dedicated Green Hydrogen Ecosystems**
- To ensure these prototypes are genuinely zero-emission, the Ministry of Railways must coordinate directly with the National Green Hydrogen Mission. Refuelling stations should only be supplied by dedicated, on-site solar or wind-powered water electrolyzers, preventing any hidden reliance on the carbon-heavy main electrical grid.
- **4. Treat the Pilot Project as a Strict Data-Gathering Window**
- The Jind-Sonipat route must be utilized as a transparent data-gathering pilot. Engineers should closely monitor long-term fuel-cell degradation rates, cold-weather energy drops, storage tank integrity, and actual operating costs per kilometer. Any future financial expansions must be guided strictly by this real-world operational data rather than broad technological promises.

Civil Services Prelims Stimulated & Past Questions

1.With reference to 'fuel cells' in which hydrogen-rich fuel and oxygen are used to generate electricity, consider the following statements: *(UPSC CSE 2015)*

1. If pure hydrogen is used as a fuel, the fuel cell emits heat and water as byproducts.
2. Fuel cells can be used for powering buildings but not for small devices like laptop computers.
3. Fuel cells produce electricity in the form of Alternating Current (AC).

Which of the statements given above is/are correct? (Answer: 1 only - Fuel cells natively produce Direct Current and can power small electronic devices).

2.Regarding the National Green Hydrogen Mission, consider the following statements:

1. It aims to make India a leading producer and supplier of Green Hydrogen in the world.
2. It expects to add significant renewable energy capacity to the grid while reducing fossil fuel imports.
3. The primary method envisioned for production is steam methane reforming combined with carbon capture.

Which of the statements given above are correct? (Answer: 1 and 2 only - Steam methane reforming yields grey/blue hydrogen; green hydrogen relies on water electrolysis).

Civil Services Mains Questions

•"Describe the salient features of the National Green Hydrogen Mission. How can hydrogen play a pivotal role in decarbonizing hard-to-abate sectors like long-distance transport and heavy industries in India?" *(GS Paper 3, 15 Marks, 250 Words)*

•"Infrastructure choices in developing economies must balance technological prestige with foundational economic efficiency." Critically analyze this statement in light of Indian Railways' deployment of hydrogen-powered propulsion systems over traditional direct electrification models. *(GS Paper 3, 15 Marks, 250 Words)*

•"Account for the ecological and economic challenges associated with developing transport infrastructure in mountainous and ecologically sensitive zones. Discuss how 'Green Technology' can act as a double-edged sword in these regions." *(Assam PSC / APSC Mains, 10 Marks, 150 Words)*

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