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GS Paper II: Current Affairs

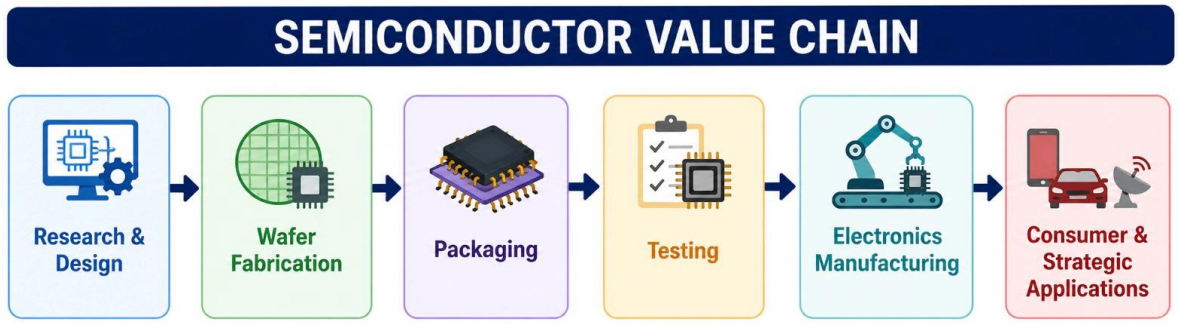
1. Future of India's Semiconductor Industry

a. Introduction

Semiconductors have become the foundation of the modern digital and strategic economy. They are used in mobile phones, computers, automobiles, telecom networks, artificial intelligence systems, defence platforms, aerospace equipment, medical devices, renewable energy systems and critical infrastructure. In this sense, semiconductor capability is no longer only an industrial objective. It is closely linked with economic resilience, technological sovereignty and national security.

A recent NITI Aayog Frontier Tech Hub report, *Future of India's Semiconductor Industry*, has underlined that India's semiconductor ecosystem is not yet ready to fully meet domestic demand. The report stresses the need for local manufacturing, sovereign design capability, research and development excellence and trusted international partnerships to reduce supply-chain vulnerabilities.

Thus, India's semiconductor ambition should be understood not merely as a manufacturing policy, but as a strategic national capability linked with economic security and technological sovereignty.



b. Present Status of India's Semiconductor Ecosystem

- **Early Stage of Manufacturing:** India's semiconductor ambitions have grown rapidly in recent years, but the country is still at an early stage in manufacturing. India does not yet have an operational semiconductor fabrication unit. The first fabrication unit is expected at Dholera in Gujarat by 2028.
- **India Semiconductor Mission:** The India Semiconductor Mission, with a corpus of 76,000 crore rupees, has been designed to support fabrication units, packaging, testing and design-linked incentives. However, most chips used in Indian electronics assembly are still imported. This means that even when electronics are assembled in India, their most critical components often come from foreign supply chains.
- **Strategic Vulnerability:** This dependence creates strategic vulnerability. Chips are essential for sectors such as electronics, telecom, automobiles, defence, aerospace, renewable energy and industrial automation. Any disruption in global semiconductor supply chains can therefore affect India's economic growth, industrial production and security preparedness.
- **Investment Requirement and Strategic Focus:** The NITI Aayog report estimates that India may require 45 to 60 billion dollars in public capital expenditure over the next decade to build a credible semiconductor ecosystem. It also recommends that India should focus on mature, advanced-aligned and compound semiconductor nodes rather than concentrating only on the most advanced 3 to 7 nanometre frontier chips.

This present status shows that India has begun building the policy foundation, but it still needs sustained execution and realistic prioritisation.

c. Why Semiconductors Matter for India

- **Semiconductors as the Brain of Modern Devices:** Semiconductors are often described as the "brains" of modern devices because they control, process and store information. Their importance has expanded beyond consumer electronics. Today, they are essential for electric vehicles, 5G networks, artificial intelligence, smart grids, drones, missiles, satellites, medical equipment and industrial robotics.
- **Link with Economic Security:** This makes semiconductor capability a core requirement for economic security. A country that depends completely on imported chips remains vulnerable to export controls, geopolitical tensions, supply-chain shocks and technology denial.
- **Lessons from Global Chip Shortages:** The experience of global chip shortages during the COVID-19 period showed how deeply industries such as automobiles, electronics and healthcare depend on semiconductor supply chains. For India, the risk is even greater because its electronics manufacturing ambitions, defence modernisation and digital economy depend on reliable chip availability.
- **Strategic Industry Status:** Therefore, the semiconductor industry must be treated as a strategic industry, not merely as another manufacturing sector.

This importance explains why semiconductor policy lies at the intersection of industrial growth, national security and technological self-reliance.

d. Import Dependence and Supply-Chain Vulnerability

- **Dependence on Imported Chips:** India's main weakness lies in its dependence on imported semiconductor components. Many electronics products are assembled domestically, but the chips used in them are sourced from global suppliers.
- **Exposure to External Shocks:** This exposes India to several risks. Geopolitical tensions in Taiwan, export controls by advanced economies, natural disasters in semiconductor hubs, supply-chain concentration in East Asia and technology restrictions can all affect India's access to chips.
- **Sensitive Sector Risks:** The vulnerability is especially serious in sensitive sectors such as defence, aerospace, telecom and critical infrastructure. Dependence on foreign chips in these sectors can create risks of supply disruption, hidden vulnerabilities and limited technological control.
- **Need for Strategic Autonomy:** Therefore, India needs to build domestic capability not only for commercial reasons but also for strategic autonomy.

This makes semiconductor resilience a core component of India's wider supply-chain and national-security strategy.

e. Pragmatic Strategy Suggested by the NITI Aayog Report

- **Selective Depth:** The NITI Aayog report takes a practical view of India's semiconductor future. It suggests that India should not attempt to immediately replicate the full global semiconductor manufacturing spectrum. Instead, it should focus on selective depth, capital efficiency and system-level differentiation. Selective depth means choosing specific areas where India can realistically develop competitiveness.
- **Capital Efficiency:** Capital efficiency means using public funds in segments where the investment can create durable industrial capability. This is important because semiconductor manufacturing is extremely capital-intensive and requires long-term policy commitment.
- **System-Level Differentiation:** System-level differentiation means building strength not only in chip fabrication but also in design, packaging, testing, integration and application-specific semiconductor solutions.
- **Ambitious but Realistic Strategy:** This approach is important because semiconductor manufacturing is technologically complex. Competing directly with the most advanced global players in frontier nodes would require huge investment, deep experience and highly specialised ecosystems. India's strategy must therefore be ambitious but realistic.

Thus, the report encourages India to build depth where it can create durable value rather than chase prestige-driven targets alone.

f. Importance of Packaging and Testing

- **Packaging as a Production Pillar:** One of the important recommendations of the report is to treat semiconductor packaging and testing as a core production pillar. Packaging and testing are often seen as downstream activities, but this view is outdated.
- **Role of Packaging:** Packaging protects the semiconductor chip, connects it with the external circuit and helps improve performance, reliability and energy efficiency. Advanced packaging is becoming increasingly important as chip performance now depends not only on smaller nodes but also on better integration, thermal management and system-level design.
- **Faster Entry Point for India:** For India, packaging and testing offer a faster entry point into the semiconductor value chain. They are less complex and less expensive than full-scale fabrication, but they still create high-value manufacturing capability. They can also help India build skills, supplier networks, quality systems and industry confidence.
- **Independent Value Creation:** Therefore, India should not treat packaging as a secondary activity. It should be developed as an independent area of value creation.

This makes packaging and testing an important bridge between India's current design strengths and its future manufacturing ambitions.

g. Focus on Mature and Compound Semiconductor Nodes

- **Importance of Mature Nodes:** The report's emphasis on mature and compound semiconductor nodes is highly relevant. Mature nodes may not be the most advanced globally, but they are widely used in automobiles, consumer appliances, industrial electronics, defence systems, power devices and telecom equipment.
- **Commercial and Strategic Usefulness:** This makes mature nodes commercially useful and strategically important for India. Many sectors do not require the most advanced chips. They require reliable, affordable and durable chips that can perform specific functions under different operating conditions.
- **Role of Compound Semiconductors:** Compound semiconductors are also important because they are useful in power electronics, electric vehicles, renewable energy systems, defence technologies, radar, communication systems and high-frequency devices. These can support India's energy transition and defence preparedness.
- **Manageable Entry Barriers:** A focus on mature and compound semiconductors allows India to build capability where demand is strong and entry barriers are relatively more manageable.

This strategy aligns semiconductor policy with India's actual industrial demand and strategic requirements.

h. Long Gestation and Execution Challenge

- **Time Required for Fabrication:** Semiconductor manufacturing has a long gestation period. A fabrication unit may take four to five years before production begins. Even after production starts, yield optimisation and reliability testing take time.
- **Meaning of Yield:** Yield refers to the percentage of usable chips produced from a wafer. In semiconductor manufacturing, small defects can reduce yield and affect commercial viability. Therefore, achieving stable production requires process control, skilled engineers, cleanroom discipline, high-quality materials and reliable equipment.
- **Equipment Dependence:** Fabrication units also need more than 50 categories of specialised equipment from global suppliers. This creates dependence on foreign toolmakers, maintenance systems and process know-how.

- **Need for Industrial Discipline:** Thus, India's semiconductor success will depend not only on announcing projects but also on sustained execution, policy continuity and long-term industrial discipline.

This execution challenge makes semiconductor development a decade-long mission rather than a short-term manufacturing push.

i. Talent and Skill Constraints

- **India's Existing Design Strength:** India has a strong base in chip design services. Many Indian engineers work in design, verification and software-linked semiconductor services. However, manufacturing requires a different set of skills.
- **Manufacturing Skill Requirements:** Semiconductor fabrication needs expertise in materials science, process engineering, cleanroom operations, equipment maintenance, chemical handling, metrology, lithography, quality control and reliability testing. These capabilities cannot be built overnight.
- **Need for Sovereign Design Capability:** The report's emphasis on sovereign design and research capabilities is therefore important. India must move from being largely a services-led design base to becoming a creator of intellectual property, architectures and integrated semiconductor solutions.
- **Education and Training Ecosystem:** This requires specialised education programmes, industry-linked training, research centres, faculty development and collaboration between universities, start-ups and global firms.

Therefore, human capital development is as important as financial incentives in building India's semiconductor ecosystem.

j. Role of Research and Development

- **Centrality of R&D:** Research and development is central to building a durable semiconductor ecosystem. Without research depth, India may remain dependent on imported technologies even if some manufacturing activity begins domestically.
- **Priority Research Areas:** India needs research in chip design, materials science, compound semiconductors, advanced packaging, power electronics, semiconductor equipment, process technology and system integration. Public research institutions, private companies, start-ups and academic institutions must work together.
- **Use of Artificial Intelligence:** The use of artificial intelligence can also support faster design optimisation, simulation, defect detection, process control and research cycles. Agentic artificial intelligence systems, which can assist in complex design and engineering workflows, may become important tools in future semiconductor development.
- **AI as an Enabler:** However, artificial intelligence should be seen as an enabler, not a substitute for deep engineering capability.

This shows that India's semiconductor ambitions must be supported by a strong research ecosystem rather than only production-linked incentives.

k. Geopolitical Dimension and Trusted Partnerships

- **Global Nature of Semiconductor Supply Chains:** Semiconductor supply chains are highly globalised but politically sensitive. The United States, Japan, the European Union, South Korea and Taiwan occupy major positions in chip design, equipment, fabrication, materials and manufacturing know-how.
- **Priority Partners:** The NITI Aayog report identifies the United States, Japan, the European Union and South Korea as priority partners for critical tools, equipment servicing, lifecycle support and technology collaboration. This shows that India's semiconductor strategy must combine domestic capability-building with trusted international partnerships.

- **Benefits of Partnerships:** Such partnerships can help India access equipment, standards, training, research collaboration and supply-chain support. However, India must ensure that external partnerships strengthen domestic capability rather than create new dependencies.
- **Strategic Interdependence:** The aim should be to build strategic interdependence, where India becomes a reliable and valuable node in the global semiconductor ecosystem.

Thus, trusted partnerships are essential, but they must be designed to deepen India's own capabilities over time.

l. Major Challenges

- **High Capital Intensity:** India faces several challenges in building a semiconductor industry. The first is high capital intensity. Semiconductor fabrication requires massive upfront investment and long payback periods.
- **Technology Dependence:** The second challenge is technology dependence. India relies on foreign suppliers for equipment, materials, design tools, process technology and specialised know-how.
- **Talent Shortage:** The third challenge is talent shortage. Skilled manpower for fabrication, packaging, testing, cleanroom operations and equipment maintenance remains limited.
- **Long Gestation:** The fourth challenge is long gestation. Fabrication units may take several years to begin production and even longer to achieve stable yields.
- **Global Competition:** The fifth challenge is global competition. Countries such as the United States, China, South Korea, Japan and Taiwan are heavily subsidising their semiconductor ecosystems.
- **Demand Aggregation:** The sixth challenge is demand aggregation. India must ensure that domestic and export demand is sufficient to make fabrication units commercially viable.
- **Ecosystem Complexity:** The seventh challenge is ecosystem complexity. Semiconductor manufacturing requires chemicals, gases, wafers, equipment, design tools, testing systems, logistics, utilities and highly reliable power and water supply.

These challenges show that India's semiconductor mission requires an ecosystem approach rather than isolated project approvals.

m. Way Forward

- **Prioritise Realistic Segments:** India should focus on mature nodes, compound semiconductors, packaging, testing and chips required for high-volume domestic applications. This will allow India to build capability in commercially relevant areas without being trapped by prestige-driven targets.
- **Build Sovereign Design Capability:** India must strengthen research and development in chip design, materials science, architectures, embedded systems and integration technologies. The aim should be to move from design services to ownership of intellectual property.
- **Develop a Skilled Talent Pipeline:** Specialised programmes should be created in semiconductor engineering, cleanroom operations, process technology, equipment servicing and quality control. Universities, industrial training institutes, research centres and industry should work together.
- **Use Trusted International Partnerships:** India should collaborate with the United States, Japan, the European Union and South Korea for technology access, equipment support, standards, training and supply-chain integration. Partnerships should be structured to build domestic capability over time.
- **Ensure Policy Continuity:** Semiconductor policy must remain mission-oriented and stable for at least a decade. Investors need certainty in subsidies, taxation, infrastructure support, customs rules and power and water availability.
- **Link Production with Domestic Demand:** Semiconductor manufacturing should be connected with India's electronics, electric vehicle, telecom, defence, renewable energy and industrial automation sectors. Demand linkage will improve commercial viability.

- **Treat Packaging as a Strategic Pillar:** Advanced packaging and testing should be supported as independent areas of value creation. India can use this segment to build industry capability, improve supply-chain participation and prepare for higher-end manufacturing.
- **Use Artificial Intelligence in Semiconductor Engineering:** Artificial intelligence should be used for design optimisation, simulation, defect detection, process monitoring and faster research cycles. This can improve efficiency and reduce development timelines.

A strong way forward must therefore combine realistic priorities, design depth, skilled manpower, trusted partnerships, demand linkage and long-term policy stability.

Conclusion

India's semiconductor ambition is strategically necessary but industrially demanding. The NITI Aayog report correctly shifts the focus from prestige-driven frontier fabrication to a more practical strategy based on mature nodes, compound semiconductors, packaging, testing, sovereign design capability, research depth and trusted partnerships.

For India, success will not depend on subsidies alone. It will require sustained execution, skilled talent, long-term financing, research excellence, reliable infrastructure and integration with domestic electronics demand.

If pursued with patience and discipline, India can move from being a large consumer of chips to becoming a credible and strategically important participant in the global semiconductor ecosystem.

Reader's Note — About This Current Affairs Compilation

Dear Aspirant,

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While every effort has been made to balance depth with brevity, please keep the following in mind:

1. Orientation & Purpose

This compilation is curated primarily from the UPSC Mains perspective — with emphasis on conceptual clarity, analytical depth, and interlinkages across GS papers.

However, the PrepAlpine team is simultaneously developing a dedicated Prelims-focused Current Affairs Series, designed for:

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