Building a Semiconductor Ecosystem in India

This editorial is based on "India, US semicon partnership on good wicket" which was published in The Hindu Business Line on 26/11/2024. The article brings into picture the intensifying global semiconductor race, highlighting strategic US-India collaborations like iCET to counter China's dominance. It underscores India's semiconductor mission as a pivotal step toward building a robust ecosystem, bridging talent gaps, and emerging as a trusted global technology partner.

For Prelims: Global semiconductor industry, India Semiconductor Mission, Semicon India Programme, Make in India, Atma Nirbhar Bharat, MSMEs, Quantum computing, Digital India RISC-V program, Solar panels, Electric vehicles, Renewable energy

For Mains: Current Status of India's Semiconductor Sector, Key Issues Hindering the Progress of India's Semiconductor Sector.

The **global semiconductor industry** stands at a critical geopolitical crossroads, with the **United States and India** forging strategic partnerships to challenge China's technological dominance. Through initiatives like **iCET and the CHIPS**, both nations are investing billions to develop robust semiconductor ecosystems, focusing on critical technologies, talent development, and supply chain resilience. India's semiconductor mission represents a transformative opportunity to **indigenize electronic manufacturing, overcome talent shortages, and emerge as a trusted global partner in high-tech innovation.**

What is the Current Status of India's Semiconductor Sector?

- **Market Size:**
  - In 2022, the Indian semiconductor market was valued at $26.3 billion and is projected to grow at a CAGR of **26.3% to reach $271.9 billion by 2032.**
- **Import-Export Trends:**
  - Semiconductor imports significantly outpace exports; however, exports have grown from **$0.21 billion (2017)** to **$0.52 billion (2022)**.
    - The pandemic disrupted global trade, but a strong recovery in 2021 reflected India's push towards establishing itself in the semiconductor value chain.
- **Government Initiatives:**
  - **India Semiconductor Mission (ISM):** Aims to build a robust semiconductor ecosystem with fiscal incentives of **50% project cost** for fabs and display units.
  - **Semicon India Programme (2021):** Allocated **₹76,000 crore ($9.2 billion)** to accelerate manufacturing and R&D.
  - **International MoUs:** Partnerships with the **European Commission** and **Japan** to strengthen supply chains and ecosystem collaboration

Why Investing in Semiconductors is Crucial for India?

- **Strategic Importance in Geopolitics:** India's geopolitical positioning and its aspirations for **self-reliance make domestic semiconductor production** crucial.
    - For instance, the **US-China tech war highlights the need for semiconductor independence.**
    - According to WSTS, the global semiconductor market is expected to **grow to $1 trillion by 2030**, and India's semiconductor consumption is projected to exceed **$100 billion by 2026,** driven by the electronics and automotive sectors.
- **Boost to Domestic Manufacturing under Atma Nirbhar Bharat:** Semiconductors are the backbone of electronics manufacturing, a sector targeted by the Indian government under the **"Make in India" and "Atma Nirbhar Bharat" initiatives.**
    - India aims to achieve a 10% share in the global semiconductor market by 2030.
    - Local production can reduce import dependency, which currently costs **India $24 billion annually on semiconductor imports**
    - The **Semiconductor Mission, with a $10 billion outlay for manufacturing incentives**, aims to establish India as a global hub for chip production, supporting industries like mobile manufacturing and 5G.
    - Tata Electronics has completed the Definitive Agreement with Powerchip Semiconductor Manufacturing Corporation (PSMC) of Taiwan to launch **India's first AI-enabled semiconductor Fab in Gujarat.**
- **Economic Growth and Job Creation:** Investing in semiconductor manufacturing can significantly boost **India's GDP and create millions of jobs across sectors.**
    - With plants like **Vedanta-Foxconn planning to set up fabs in India,** these projects are expected to generate **1 lakh direct jobs in the coming years.**
    - A robust semiconductor ecosystem can boost India's startup ecosystem, particularly in hardware development. **MSMEs, which contribute 30% to India's GDP**, can benefit from affordable chips for consumer electronics, boosting their competitiveness.
    - For example, startups like **Saankhya Labs are already innovating in the semiconductor space**, showcasing India's potential for indigenous chip design.
- **Ensuring Supply Chain Resilience:** The global chip shortage during the **Covid-19 pandemic** exposed vulnerabilities in India's electronics and automotive sectors.
    - By investing in domestic semiconductor production, India can shield its industries from external disruptions.
    - For example, the **automotive industry lost $110 billion globally in 2021 due to chip shortages,** with Indian carmakers facing delayed production cycles.
- **Strengthening Technological Sovereignty:** Semiconductors are essential for technological innovation in **AI, IoT, and quantum computing**, all critical for maintaining technological sovereignty.
    - Countries like the **US and EU are heavily investing in chip productio**n to reduce reliance on Chinese supply chains.
    - India has launched the **Digital India RISC-V program** and partnerships with entities like **Micron Technology**, which has committed to a $2.75 billion facility in Gujarat.
- **Promoting Green Technology and Renewable Energy:** Semiconductors are key components in green technologies like **solar panels, electric vehicles (EVs), and smart grids.**
    - Domestic semiconductor production can accelerate India's renewable energy goals.
    - For instance**, India aims to achieve 500 GW of non-fossil fuel capacity by 2030,** and chips are essential for solar inverters and EV batteries.
    - The number of power semiconductors used in the global renewable energy markets is expected to grow with a compound annual growth rate (CAGR) of **8% to 10% from now to 2027.**
- **Enhancing National Security and Cybersecurity:** Semiconductors are critical for advanced **defense technologies, including missile systems, drones, and secure communication networks.**
    - Dependence on foreign chips poses risks of espionage and cyber vulnerabilities. India has launched **DRDO-led initiatives to develop indigenous chips for strategic sectors**,

ensuring self-reliance in defense electronics.
    - DRDO has recently commissioned a **Bangalore-based firm to indigenously develop a receiver chip** to acquire and disseminate **Indian time for Navigation.**

What are the Key Issues Hindering the Progress of India's Semiconductor Sector?

- **High Capital Costs and Limited Financial Backing:** Semiconductor manufacturing requires massive capital investments, with **fabs costing upwards of $10 billion each,** creating significant barriers for India.
    - For instance, Micron Technology's facility in Gujarat received $2.75 billion in funding but **requires consistent financial commitment** over the next decade to sustain operations.
    - Globally, countries like the **US have allocated $53 billion under the CHIPS Act, dwarfing India's budget.**
- **Lack of Skilled Workforce:** Semiconductor fabrication demands highly specialized expertise in areas like **nanotechnology, material science, and process engineering,** which India currently lacks at scale.
    - While India has a **strong semiconductor design workforce (20% of global share), fabrication and packaging talent remains minimal**.
    - Also, the semiconductor industry faces a potential skill gap of **250,000 to 300,000 professionals by 2027,** that is a cause of concern.
- **Weak Infrastructure and High Energy Demand:** Semiconductor fabs require advanced infrastructure, including **uninterrupted power, water, and cleanroom environments,** which are limited in India.
    - **A single fab can consume as much electricity annually as a small city** and up to **10 million gallons of ultrapure water daily.**
    - For example, the **Vedanta-Foxconn project faced delays due to inadequate water and power supply chains.**
        - In contrast, **Taiwan provides renewable energy support to its semiconductor** hubs, ensuring operational efficiency.
- **Insufficient R&D Ecosystem:** India's semiconductor ambitions are hindered by the lack of a robust R&D ecosystem to develop indigenous chip technology.
    - Most of India's semiconductor capabilities are focused on **chip design, leaving manufacturing and material research** reliant on imports.
    - According to a McKinsey report (2023), **India invests only 0.65% of its GDP in R&D compared to South Korea's 4.8%**.
    - The absence of foundational research partnerships and university-industry collaboration further slows innovation.
- **Geopolitical Dependencies on Imports:** India is heavily dependent on imports for semiconductor equipment and raw materials like **silicon wafers, making its supply chain vulnerable to global disruptions.**
    - Over 75% of the world's semiconductor production is concentrated in East Asia, with **China being a dominant supplier of raw materials.**
    - The ongoing **US-China tech war** exposed these vulnerabilities, with India's electronics manufacturing suffering delays and increased costs.
    - In 2022, India imported semiconductors worth **$24 billion**, highlighting its import dependence.
- **Long Gestation Period and Low ROI:** The semiconductor industry operates on **a long gestation cycle**, with fabs taking **4–5 years** to become operational and even longer to achieve profitability.
    - Investors often hesitate due to the high initial costs and slow returns. For instance, the US-based Intel took nearly a decade to recover its fab investments, even with government support.
    - In India, **startups and MSMEs find it particularly challenging to invest in such long-term projects** without sustained subsidies and market guarantees..
- **Limited Role of Private Sector in Fabrication:** While India's **private sector is strong in software and design,** its role in semiconductor fabrication is minimal due to high costs and technical barriers.

    - **Most semiconductor initiatives are government-led**, with limited private investment in fab infrastructure.
    - For instance, companies like **Infosys and Wipro dominate chip design but have no presence in fabrication**.
    - In contrast, **Taiwan's semiconductor success stems from private giants like TSMC,** which have driven the industry with government support.
- **Fragmented Approach Across States:** India's federal structure leads to fragmented policies, with states competing rather than collaborating on semiconductor investments. States like **Gujarat, Karnataka, and Tamil Nadu** offer competing incentives, overshadowing other states and hindering **unified semiconductor hubs**.
    - In contrast, **China coordinates semiconductor development at a national level,** ensuring seamless integration of resources across regions.
- **Low Focus on Advanced Nodes:** India's semiconductor ambitions currently focus on **legacy and mature nodes (28nm and above),** which are insufficient for advanced technologies like **AI, quantum computing, and 5G.**
    - **Global demand is shifting toward advanced nodes like 5nm and 3nm,** with TSMC and Samsung leading this market.
    - Without investments in advanced node capabilities, India risks being limited to low-value segments of the semiconductor market.

What Measures can India Adopt to Strengthen its Semiconductor Ecosystem?

- **Enhancing Financial Incentives and De-risking Investments:** India should provide enhanced financial incentives, such as **tax breaks, subsidies, and low-interest loans, to attract semiconductor investors** while ensuring long-term viability.
    - A **dedicated Semiconductor Development Fund** could reduce risks associated with the long gestation period of fabs.
    - The US CHIPS Act ($52 billion) is a model India can emulate to offer a similar level of financial assurance.
- **Building a Skilled Workforce through Specialized Training:** Developing a skilled workforce for semiconductor design and fabrication is crucial. India can **establish specialized training centers** in collaboration with global leaders like **Taiwan Semiconductor Manufacturing Company (TSMC)** and **Samsung**.
    - Programs like the India Semiconductor Mission's aim to train 85,000 professionals should be expanded and linked to industry needs.
    - Offering scholarships in **nanotechnology and VLSI design through IITs and NITs** could address immediate skill gaps.
- **Fostering Public-Private Partnerships:** Strengthening PPPs can drive innovation and scale in India's semiconductor sector.
    - Private players can **focus on chip design and innovation** while the government handles large-scale fabrication facilities.
    - For instance**, a model similar to TSMC's public-private synergy** could be implemented to streamline investments and operations.
    - Collaborations like **Vedanta-Foxconn show promise** but need clearer frameworks to avoid delays in execution.
- **Investing in Semiconductor R&D Ecosystem:** India must establish semiconductor **R&D centers to foster innovation in materials, designs, and advanced nodes.**
    - Government grants and private funding should be allocated to create semiconductor-focused research hubs in collaboration with academic institutions.
    - For example, the **Digital India RISC-V (DIR-V) program** can serve as a platform for designing India's indigenous chips.
- **Improving Infrastructure for Fabs:** India must address infrastructure challenges such as **uninterrupted power supply, ultra-pure water availability, and cleanroom environments for fabs**.
    - Industrial clusters should be developed near semiconductor hubs, with states like **Gujarat and Karnataka** leading the way.
    - **Fast-tracking renewable energy projects for fabs,** akin to TSMC's solar-powered facilities, would reduce operational costs.
    - Government-supported infrastructure projects, such as **dedicated semiconductor parks,**

should be prioritized.

- **Strengthening the Supply Chain for Raw Materials:** India should develop an indigenous supply chain for essential semiconductor materials like **silicon wafers and rare earth elements.**
    - Establishing tie-ups with countries like **Australia and Japan** for rare earth sourcing would reduce dependency on China.
    - **Investing in local production facilities for silicon wafers** and chemicals would strengthen resilience.
    - For example, **India's recent MoU with IEA on critical minerals** could focus especially on semiconductor raw materials.
- **Promoting Advanced Node Development:** India should invest in developing advanced **nodes (below 10nm)** to remain competitive in cutting-edge technologies like AI, quantum computing, and 5G.
    - Establishing advanced research labs **dedicated to smaller nodes**, supported by government funding, will ensure India's entry into high-value markets.
- **Creating a Semiconductor Export Hub:** India should position itself as an **export hub for semiconductors by leveraging its strategic location and cost-effective labor.**
    - Incentives should be provided to attract global companies to establish chip packaging, testing, and design facilities.
    - A **free trade agreement with technology-importing countries** could ensure preferential access to markets. .
- **Simplifying Regulatory Approvals and Bureaucratic Processes:** India needs to streamline its regulatory framework to **attract global semiconductor investments.** Setting up a single-window clearance system for semiconductor projects would reduce delays and improve investor confidence.
    - For example, the Vedanta-Foxconn project faced delays due to bureaucratic inefficiencies; **such issues must be resolved through transparent processes.**
    - Creating **National Semiconductor Task Force** to harmonize state and central efforts
- **Encouraging Domestic IP Development:** India must encourage the development of indigenous semiconductor intellectual property (IP) by **funding local startups and research institutions**.
    - Initiatives like the **"Chip-to-Startup" program can be expanded to focus on IP creation** for specific industries like automotive and IoT. Incentivizing patents through subsidies or grants can boost India's rank in global semiconductor IP filings.
- **Promoting Green and Sustainable Fabs:** To address environmental concerns, India must encourage semiconductor fabs to adopt green technologies**. Incentives should be provided for fabs using renewable energy** and advanced water recycling methods, similar to TSMC's approach.
    - Dedicated sustainability goals for semiconductor projects would align with India's net-zero emissions target by 2070. .
- **Encouraging State and Regional Collaboration:** Rather than competing for semiconductor investments, Indian states should collaborate to create a unified national semiconductor strategy.
    - Regional clusters like the **Bengaluru-Mysuru corridor or the Gujarat-Maharashtra cluster can specialize in design, packaging, and fabrication**.
    - Federal support through the Semiconductor Mission can harmonize state-level policies, avoiding duplication of efforts.
- **Leveraging India's Software Expertise:** India can integrate its global leadership in software with semiconductor hardware development to create a **comprehensive tech ecosystem**.
    - Combining chip design with AI and software solutions can drive demand for indigenous semiconductors.

Conclusion:

India's semiconductor mission holds **immense potential to transform the country into a global tech hub.** The government's continued support, coupled with private sector investment and technological innovation, will be crucial in realizing this ambitious goal. A successful **semiconductor ecosystem will not only strengthen India's digital economy but also elevate its strategic position in the global tech landscape.**

Drishti Mains Question:

Why is investing in the semiconductor sector crucial for India's economic and technological growth? Discuss the challenges involved in building a self-reliant semiconductor ecosystem in India.

UPSC Civil Services Examination, Previous Year Question (PYQ)

Prelims:

Q. Which one of the following laser types is used in a laser printer? (2008)

(a) Dye laser

(b) Gas laser

(c) Semiconductor laser

(d) Excimer laser

Ans: (c)