Indian Electronic System Design & Manufacturing (ESDM) Industry

Dreaming Big For A Semiconductor Hub

LSI FINANCIAL SERVICES
PRIVATE LIMITED

OUR PROFILE

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LSI Financial Services Pvt. Ltd. was established in 1997 and is a SEBI registered Category 1 Merchant Banker. The vision of the company is to provide services relating to Project Finance Advisory, Techno Economic Feasibility Study, Financial Restructuring and Asset & Equity Valuation to esteemed Financial Institutions and corporate houses. With senior bankers and eminent industry experts, who are supported by 150 professionals in the team, the company has gathered vast experiences in almost all the sectors in the last two decades.

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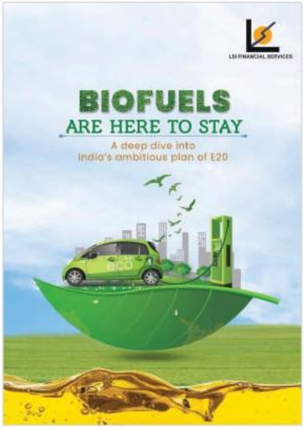
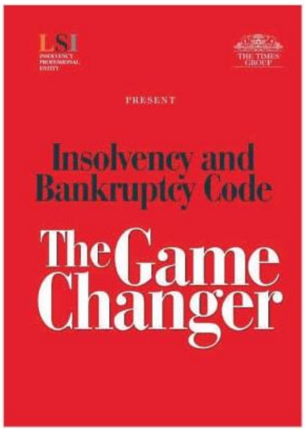
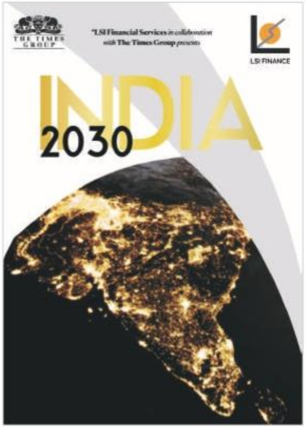
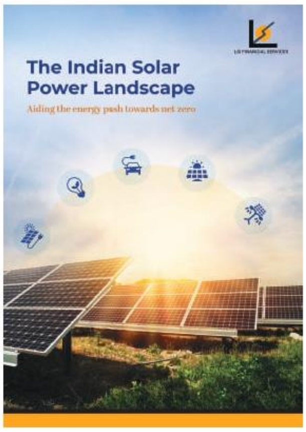
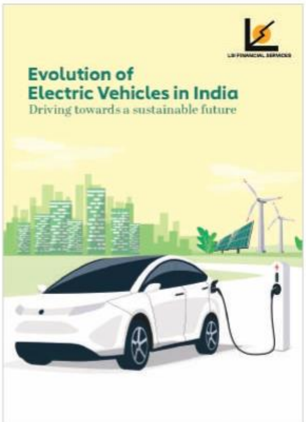
OUR PUBLICATION

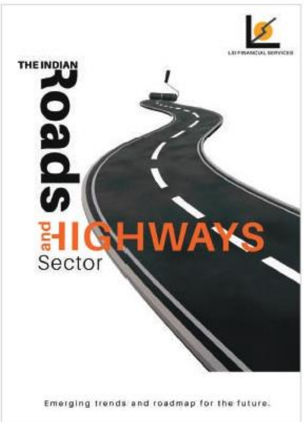


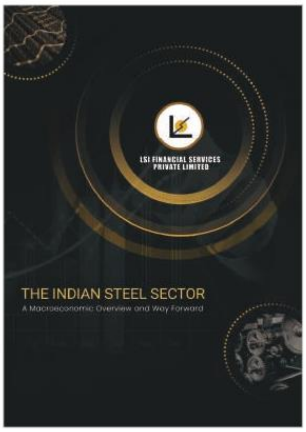












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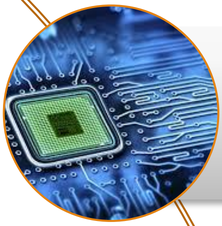
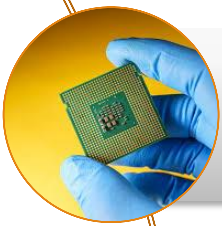
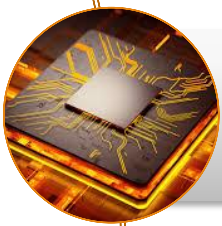
EXECUTIVE SUMMARY



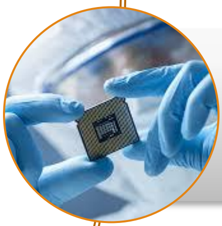
Chips are as important as the oil reserves. In 2022, the global market for semiconductors stood at $591.8 billion. It is expected to reach $1.8 trillion by 2032, with a compound annual growth rate of 12.28%.



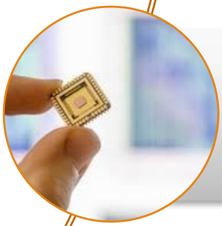
The crunch in chip availability during the pandemic has led companies and the Indian government to ramp up domestic manufacturing and preserve the supply of chips.



The components of the electronics market are electronic design market, electronic manufacturing services maret and electronic component market.



The Electronic System Design and Manufacturing (ESDM) includes design-related activities such as product designing, chip designing, very large-scale integration (VLSI), board designing and embedded systems.

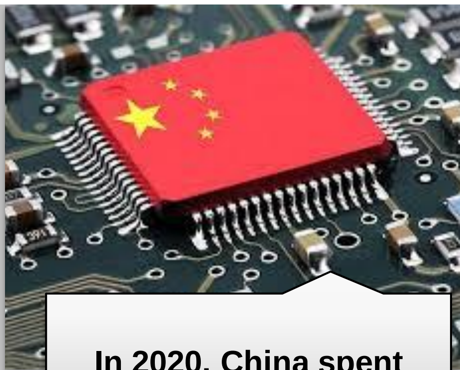


In India, the electronic design market is expected to reach $60 billion by FY25 with a projected CAGR of 20.90% from FY19. The electronics system market will reach $160 billion taking the total ESDM market to $220 billion by FY25.

The Indian government approved the establishment of three new semiconductor manufacturing facilities on February 29, 2024 at Dholera, Gujarat, Morigaon, Assam and Sanand, Gujarat. Prominent American chip company Micron has committed to invest up to US$ 825 million to build a facility in India, also at the Sanand Gujarat in early 2025.

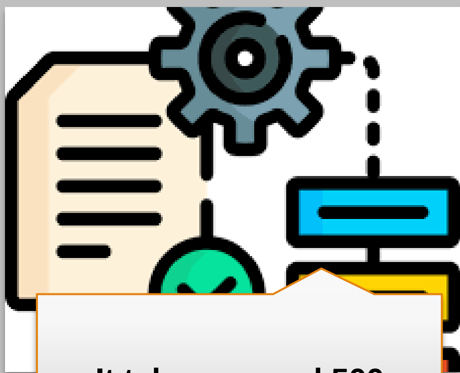
DID YOU KNOW??

The world's biggest importer of semiconductors is China, followed by the United States

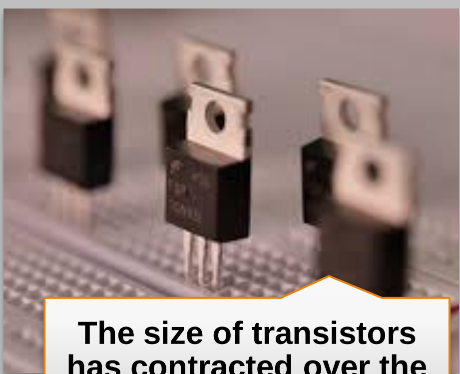


In 2020, China spent more on semiconductors than it did on oil imports.

Average time taken to build one semiconductor microchip wafer can be anywhere between 11 to 16 weeks.



It takes around 500 processes to make just one microchip



The size of transistors has contracted over the years, from an initial 10,000 nanometers (nm) in 1971 to 5nm in 2020.

In 2021, IBM unveiled a 2 nm chip that is smaller than the width of a single strand of human DNA.

Chapter: 1 Microchip – The Building Block of Technology

It is hard to imagine a world without microchips. They are at the heart of the devices that we use to work, travel, stay fit and entertain ourselves – from cars to smartphones and from MRI scanners to industrial robots and data centers.

Microchips are everywhere. In 2021, semiconductor unit sales reached a record 1.15 trillion-unit shipments, and in 2022, the global market for semiconductors stood at $591.8 billion. It is expected to reach $1.8 trillion by 2032, with a compound annual growth rate of 12.28%. By delivering new functionalities, better performance and lower cost with each generation, advances in chips have spawned new products and transformed industries.

What's in a name? – Microchip, Semiconductor, Integrated Circuit (IC)

There is clear difference between the three terms even though they are often used interchangeably. The figure below states the difference between a microchip, a semiconductor and an integrated circuit.

Exhibit 1: Difference Between Microchip, Semiconductor and Integrated Circuit

MICROCHIP	SEMICONDUCTOR	INTEGRATED CIRCUIT
• A microchip is a set of electronic circuits on a small flat piece of silicon. • On the chip, transistors act as miniature electrical switches that can turn a current on or off. The pattern of tiny switches is created on the silicon wafer by adding and removing materials to form a multilayered latticework of interconnected shapes.	• Semiconductor refers to a material whose conductivity is between a conductor and an insulator at room temperature • Common semiconductor materials include silicon, germanium, gallium arsenide, etc., and silicon is the most influential in commercial applications among various semiconductor materials.	• Integrated circuit is a kind of miniature electronic device or component. A certain process is adopted to interconnect the transistors, resistors, capacitors and inductors and other components and wiring required in a circuit together, fabricate on a small or several small semiconductor wafers or dielectric substrates. and then package them in a package.

Silicon – The Digital Gold

Silicon is the material of choice in the chip industry. Unlike the metals normally used to conduct electrical currents, silicon is a 'semiconductor, meaning that its conductive properties can be increased by mixing it with other materials such as phosphorus or boron. This makes it possible to turn an electrical current on or off.

The good news is that it is everywhere. Silicon is made from sand, and it is the second most abundant element on earth after oxygen. Silicon wafers are made using a type of sand called silica sand, which is made of silicon dioxide. The sand is melted and cast in the form of a large cylinder called an ‘ingot. This ingot is then sliced into thin wafers.

Measuring a Chip - The Nano Scale

A microchip the size of human fingernail and contains billions of transistors. Hence, it is understandable that how small the features on a chip need to be. Chip features are measured in nanometers. A nanometer is one billionth of a meter, or a millionth of a millimeter.

For comparison, a human red blood cell is 7,000 nanometers in diameter, and the flu virus is around 100 nanometers. The most advanced microchips contain features that are just a few dozen nanometers in size. The smaller the features in the patterns that our systems can create, the more transistors manufacturers can fit on a chip, thus uplifting the performance of the chip.

Types of Chips

There are two major ways to categorize microchips: by functionality and by type of integrated circuitry. In terms of circuitry, a chip can be analogue, digital, or mixed. The difference between analogue and digital function has to do with the electric signals they process. In digital chips, the signals are binary. In analogue chips, the signals are continuous, meaning they can take on any value within a given range, and they use more traditional circuit elements (resistors, capacitors and occasionally inductors).

In terms of functionality, there are four main categories:

- Logic chips
- Memory chips
- Application-specific Integrated Chips (ASICs)
- System-on-a-chip devices (SoCs)

The two most common types of chips, Logic chips and Memory chips, are digital: they manipulate and store bits and bytes using transistors. ASICs and SoCs are mainly a mix of analogue and digital.

The table below explains the components of the above four functionality of the chips.

Exhibit 2: The Main Categories of Chips by Their Functionality

Long Chips	• They are 'brains' of electronic devices – they process information to complete a task. Among Logic chips, CPUs (central processing units) are the 'original' chips, first designed in the 1960s. • There are also processors with specific functionality in mind, such as GPUs (graphical processing units, which are optimized for visual display) and NPUs (neural processing units, designed for deep and machine learning applications).
Memory Chips	• They store information. There are two types of Memory: volatile and non-volatile. Volatile Memory chips, such as DRAM (Dynamic Random Access Memory), are the 'working memory' chips that save data only while the device's power is turned on. • Non-volatile Memory chips such as NAND Flash save data even after the device is turned off. For example, DRAM helps to run programs on your device, whereas NAND stores your photos. Whereas DRAM is fast, NAND is slow to read and write data.
Application-specific Integrated Chips (ASICs)	• These are simple, single-purpose chips used for performing repetitive processing routines such as scanning a barcode.
System-on-a-chip devices (SoCs).	• These are essentially integrator chips. They are a relatively new type of chip that combines many chips and circuits in a single chip and may integrate things such as graphics, audio, camera, video, and Wi-Fi.

The Power of a Chip

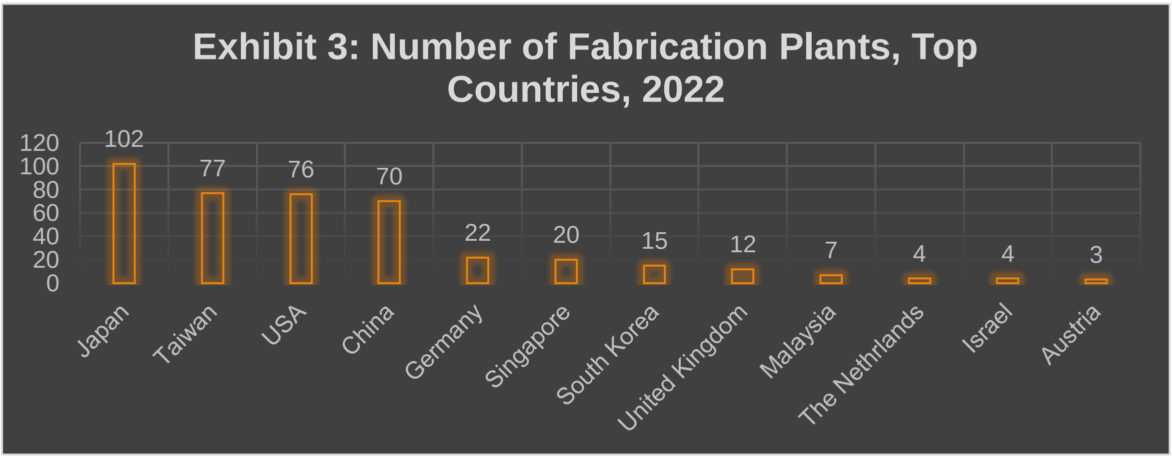
Chip improvements are behind the incredible increase in computing power and memory function that has allowed technology to advance to where it is today. 1956 to 2015, computing power increased one trillion-fold, thanks to chips. Think about this: the computer that navigated the Apollo missions to the moon was about twice as powerful as a Nintendo console. It had

32.768 bits of Random Access Memory (RAM) and 589.824 bits of Read Only Memory (ROM). A modern smartphone has around 100,000 times as much processing power, with about a million times more RAM and seven million times more ROM.

Chips enable applications such as virtual reality and on-device artificial intelligence (AI) as well as gains in data transfer such as 5G connectivity and they are also behind algorithms such as those used in deep learning. All this computing produces a lot of data. By 2025, the world will be producing 175 zettabytes (ZB) of data per year, or roughly the equivalent of one billion terabytes (TB).

The Global Scenario of the Chip Industry

In 2022, the global market for semiconductors stood at $591.8 billion. Among regions, Asia Pacific dominated the global semiconductor market, with its value reaching $230.5 billion in 2022. Significant consumer base, heightened demand for consumer electronics and swift industrial development are among the factors that have boosted the consumption of semiconductors in the region.



Source: Yahoo Finance

China witnessed sales worth $180.4 billion, making it the largest individual market in the world. However, the sales dropped 6.2% compared to 2021. On the contrary, America, Europe and Japan were among the ones with increased yearly sales. In terms of product types, analogue semiconductors witnessed the highest annual growth rate of 7.5%, reaching $89 billion, whereas logic and memory type had the highest sales volume, valued $176.6 billion and $130 billion, respectively. However, the semiconductor industry is still struggling to recover from the after-effects of the pandemic.

Although the Covid 19 pandemic was responsible for the initial trigger for chip shortages, some structural factors also added to it. The auto industry is shifting gears towards automation and electric vehicles which in turn is creating more demand for chips and adding to the supply shortage issues in the industry. Currently, the industry seems to move out of this supply crunch crisis and there are more numbers of chips in the market.

Chapter: 2 The Indian Electronic System Design & Manufacturing (ESDM) Sector – Market Overview

The United States drafted the first semiconductor amplifies in 1947 when India newly attained its independence. Fast-forward to today, global industry players are chipping in to push India closer to its semiconductor dream. But it will be all about keeping the momentum going because the road to make an end-to-end chip in India is at least two decades long, according to experts.

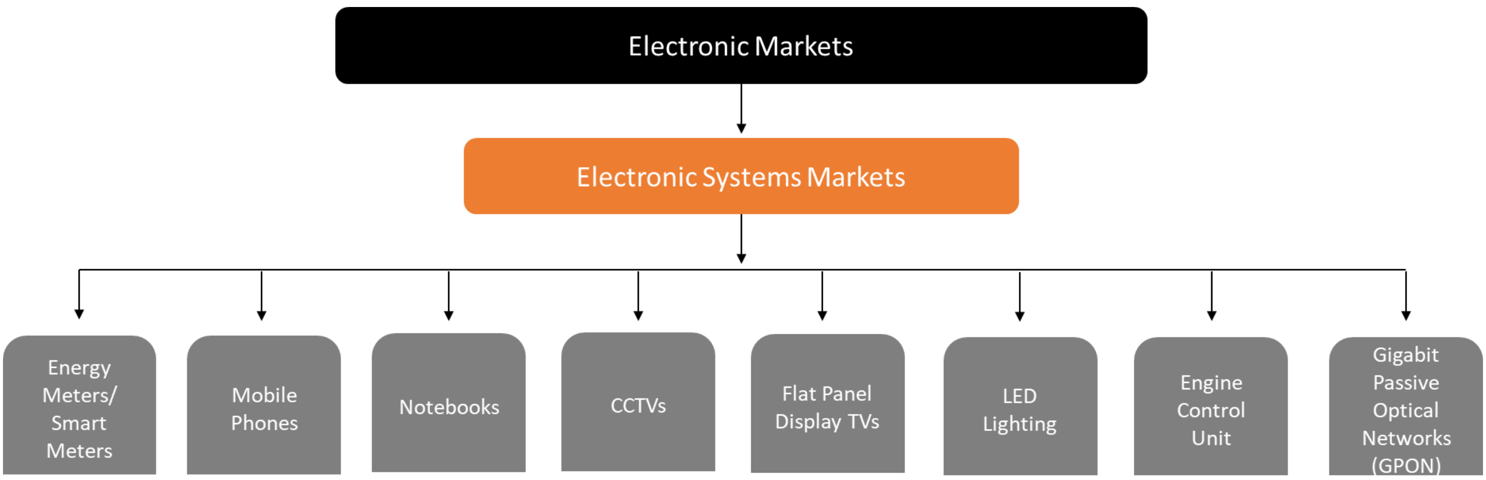
Chips have become as essential as the oil reserves, which have defined geopolitics for the past many decades. This crunch in chip availability during the pandemic has led companies and the Indian government to ramp up domestic manufacturing and preserve the supply of chips. More than 60 percent of the world's semiconductors are currently produced in Taiwan, which, in a way, poses a threat to the US with the potential of China invading it.

Exhibit 4: The Timeline of India's Semiconductor Attempts

Year	Initiatives
1960s	• Fairchild Semiconductor considers building a fab in India, but it does work out, and they move to Malaysia. • Bharat Electronics Ltd (BEL), a public sector undertaking under the Ministry of Defence, acquires germanium and silicon technology for producing semiconductor devices • In 964, Gurpreet Singh launches the semiconductor manufacturing company Continental Device India Pvt.Ltd. (CDIL) in collaboration with Continental Device Corp. of Hawthorne, California
1974	• The Department of Electronics (DoE) realises the need to develop semiconductor design and fabrication
1976	• Cabinet approves the idea of setting up Semiconductor Complex Limited (SCL)
1978	• India's first semiconductor fab, is set up • In Mohali with a project cost of Rs 15 crore.
1980s	• IISc professor AR Vasudeva Murthy helps establish Metkem Silicon Ltd which, in partnership with Bharat Electronics Limited, produces polysilicon wafers for solar cells and electronics. Due to a lack of government support, it doesn't work out.
1983	• Mohali plant is inaugurated, manufacturing chips using technology procured from American Microsystems Inc.
1985	• IIT Kanpur alumnus Prabhakar Goel launches his startup, Gateway Design Automation • (GDA), specialising in making a testing tool Verilog, for chips
1989	• Mohali plant is devastated by fire causing significant damage US-based Cadence Design Systems acquires GDA

Year	Initiatives
Mid-2005	• Major multinational semiconductor Companies attempt to set up their base in India, but move away to China after facing roadblocks
2007	• The government announces India's first semiconductor policy with the objective of attracting Rs 24,000 crore of investment over three years. • AMD and Intel consider setting up fabrication units. Both projects do not come to fruition
2012-13	• Government allocates Rs 39,000 crore to build two fabs; the plan does not work out
2013-2019	• The government issues Letters of Intent (LOIs) to Hindustan Semiconductor Manufacturing Corporation (ST Microelectronics and Silterra Malaysia Sdn. Bhd) and Jaiprakash Associates Ltd. (IBM, Tower Semiconductor Ltd).
In 2016	• Jaiprakash Associates Ltd withdraws its proposal due to capital outlay issues
In 2019	• The government cancels the permit for HSMC after years of paperwork delays on HSMC's part
2021	• The India Semiconductor Mission is launched by the government as it approves a $10 billion (Rs 76,000 crore) incentive to build a semiconductor ecosystem, and invites applications from semiconductor companies
2023	• In June, the government reopened the applications as it did not receive enough applications in the first round due to the 45-day window, which is now removed. • Silicon Valley semiconductor giants Micron Technology, Applied Materials and AMD announce investing money to setup base in India • Taiwan's Foxconn and India's Vedanta individually announced investments to boost semiconductor manufacturing

Major Product Segmentation of the Electronics Market



The components of the Electronics Market including total domestic consumption and exports are:

- Electronics Design Market
- Electronics Manufacturing Services Market
- Electronics Component Market

The Electronics System Design & Manufacturing (ESDM) industry includes electronic hardware products and components relating to:

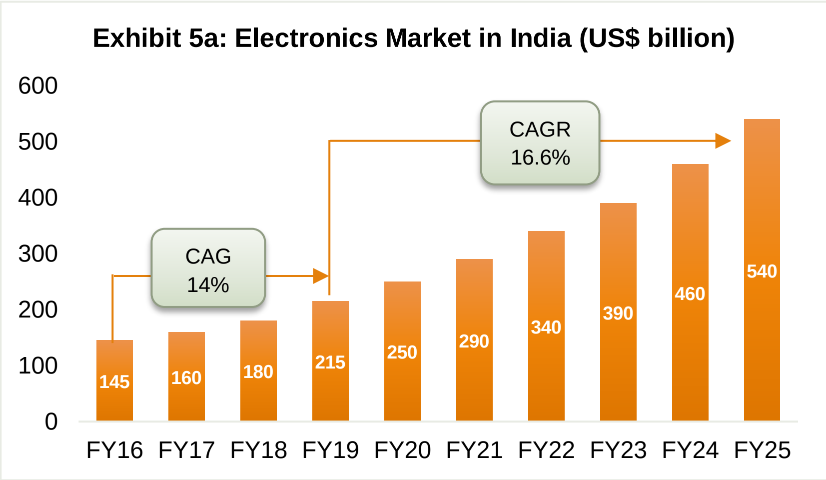
- Information technology (IT)
- Office automation
- Telecom
- Consumer electronics
- Aviation, aerospace, defence
- Solar photovoltaic
- Nano electronics
- Medical electronics.

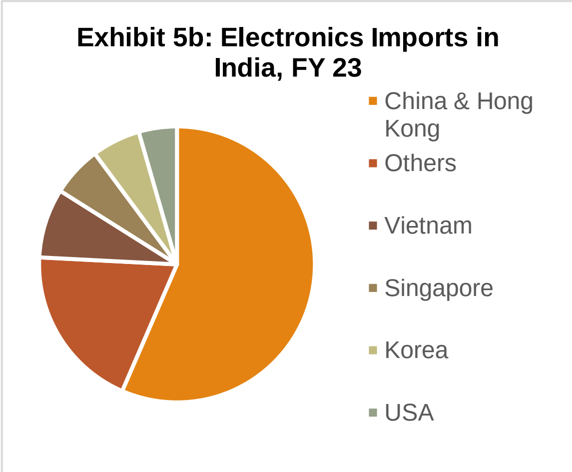
The industry also includes design-related activities such as product designing, chip designing, very large-scale integration (VLSI), board designing and embedded systems.

Overview of the Electronics Market in India

The electronics market has grown at a CAGR of 14% from 2016-19 and is expected to accelerate at a CAGR of 16.6% in 2020-25, with the total demand likely to account for US$ 540 billion in FY25.

- In FY23, the imports of electronics goods stood at US$ 73.46 billion, whereas exports stood at US$ 22.68 billion.
- During April-June 2023, the imports of electronics goods stood at US$ 18.76 billion and exports stood at US$ 6.75 billion.
- Imports of electronics goods stood at US$ 7.14 billion in September 2022.
- The ESDM sector is likely to generate US$ 100-130 billion in economic value by 2025.
- The Government of India aims to make electronics goods amongst India's 2-3 top-ranking exports by 2026.
- Electronics goods exports are expected to increase from the projected US$ 15 billion in 2021-22 to US$ 120 billion by 2026.
- PLI scheme for large scale electronics manufacturing launched by Ministry of Electronics and Information Technology (MeitY) in April 2020 has been extended from existing five years band (FY21-FY25) to six years (FY21-FY26).

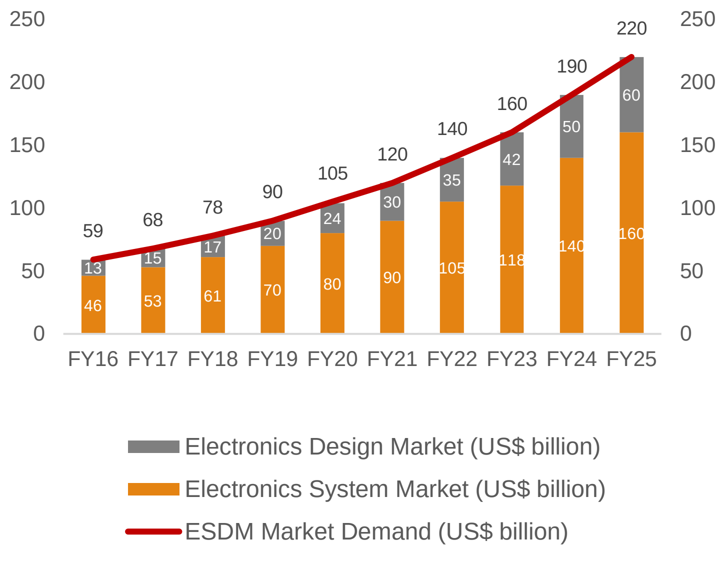




Source: India Electronics & Semiconductor Association (IESA)

- For FY25, the budget estimate for the ministry of electronics and information technology (Meity) increased 48.29% from ₹14,421.25 crore to ₹21,385.15 crore.
- The Indian electronics manufacturing industry is projected to reach US$ 540 billion by 2025.
- India has been one of the largest consumers of electronic products specifically in Asia-Pacific due to factors such as rising per capita disposable incomes and consumption in the past decade.
- US chip design major Advanced Micro Devices (AMD) will invest up to US$ 400 million in India over the next five years and will set up its biggest design facility in the country.
- India has strong design and R&D capabilities in auto electronics and industrial economics. The Government is promoting the development of Electronics Manufacturing Clusters (EMCs) throughout the country to provide world-class infrastructure and facilities.
- Post COVID, the Government of India aims to increase India's contribution by around US$ 400 billion worth of electronics goods including exports worth US$ 120 billion, which would account for 9-10% of the overall global value chains, from the current supply potential of 1-2%.
- India's exports are set to increase rapidly from US$ 10 billion in FY21 to US$ 120 billion in FY26.
- The consumer electronics and appliances industry in India is expected to become the fifth-largest in the world by 2025.
- As global companies are leveraging the well-developed manufacturing system in the State, Tamil Nadu has emerged as one of the major electronics hardware manufacturing and exporting States in the country. The state is well positioned to achieve a US$ 100 billion ESDM industry in the next five years.

Exhibit 6a: The ESDM Market and its Components (US$ Billion)



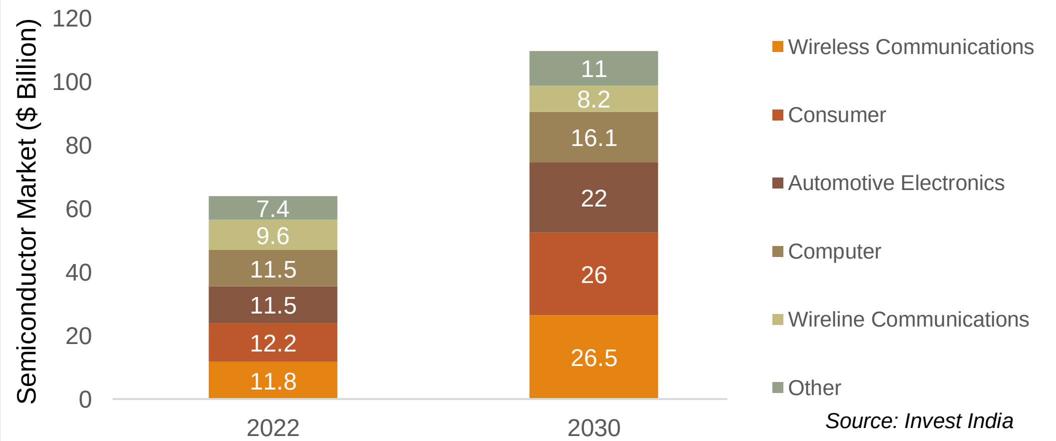
Source: India Electronics & Semiconductor Association (IESA)

Exhibit 6b: Segmentain of EDMS Market

Segments of EDMS Market	**CAGR**	
	FY16 - FY19	**FY19 - FY25**
Electronics System Market	15%	14.80%
Electronics Design Market	15.40%	20.90%

- India's semiconductor marketplace is rapidly growing. The electronic design market is expected to reach $60 billion by FY25 with a projected CAGR of 20.90% from FY19. The electronics system market will reach $160 billion taking the total ESDM market to $220 billion by FY25.
- That market demand for semiconductors in India is expected to nearly double from $64 billion in 2022 to $110 billion by 2030, at which point it is anticipated that India will account for an approximately 10% share of direct global semiconductor consumption.
- By 2030, it is predicted that wireless communications ($26.5 billion), consumer goods ($26 billion), and automotives ($22 billion) will be the largest components of India's semiconductor market.
- In 2021, only 9% of India's semiconductor components were locally sourced. India intends to increase its local sourcing of semiconductors to 17% by 2026, which would translate into a six-fold increase in locally sourced semiconductor revenue between 2019 and 2026.

Exhibit 7:India's Semiconductor Market ($ Billion), 2022 and 2030



Source: Invest India

Demand and Supply Scenario of Semiconductors in India

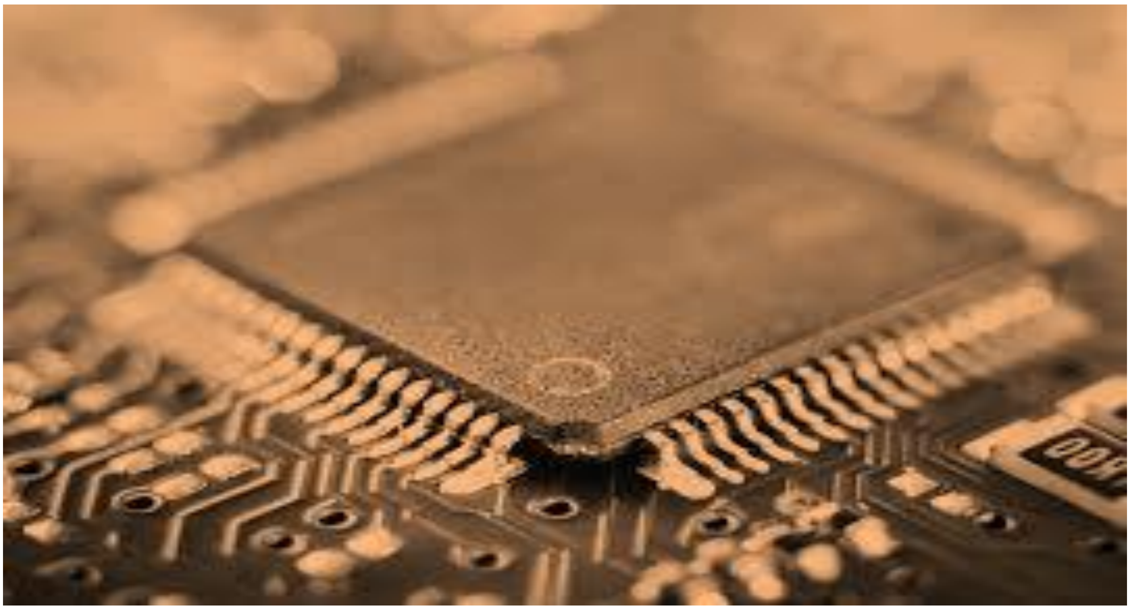
On the demand side the growth of semiconductors is expected to be driven by the by the increasing semiconductor content across consumer electronics and automobiles including EVs and, increasing demand for smartphones as the number of smartphones in India is projected to reach 1 billion by 2026. Further, the roll out of 5G and increasing adoption of IoT devices would accelerate the adoption of smart devices.

The current demand of semiconductors in India is around $24 Billion which is majorly met by imports. By 2025, this demand is expected to reach $100 billion. Setting up semiconductor manufacturing plants in India will require significant infrastructure investments in power, water, and transportation facilities.

While other countries like China, Taiwan, and South Korea have already established themselves as semiconductor manufacturing hubs, India faces stiff competition on a global stage. Building a complete domestic value chain for semiconductors may take considerable time and investment, as a significant portion of the value chain is currently based outside India.

To reduce dependence on imports, efforts should be made to develop a local value chain for semiconductor manufacturing. This could involve incentivising the production of raw materials, such as silicon wafers, or promoting the development of semiconductor equipment suppliers and contract manufacturers. This industry is constantly evolving, with new materials, processes, and technologies emerging all the time.

At present, globally the technology required to produce advanced semiconductors has very limited players in the world, with one being a dominant player. There is no natural advantage for them to invest in India. The challenge is primarily finding the right human capital, supporting a vendor base in India, building strong infrastructure for exports, and forming partnerships that can ensure continued investments with strong technical capabilities.



Chapter: 3 The Manufacturing Process of Semiconductors & The Cost Structure

The capability of a country to produce semiconductors is a way to estimate its manufacturing sector. So far, only 10 countries are manufacturing semiconductors that empower the entire world. Major semiconductor companies are expanding their operations even more in the top production countries. Malaysia, Israel, and The Netherlands have the lowest numbers but a huge potential for semiconductor manufacturing. Moreover, companies like FOXCONN and Intel plan to expand their operations in newer countries like India, Vietnam, etc.

The process of producing semiconductor devices from wafers is called semiconductor manufacturing. Semiconductor manufacturing is often termed as semiconductor fabrication. “Semiconductor microfabrication” is another process that enables the production of extremely small semiconductors at microscopic and nanoscale levels. The goal of semiconductor manufacturing is to produce highly reliable, low-cost cost, and high-quality semiconducting devices or chips.

Experts divide semiconductor manufacturing processes into 6, 7, 8, 10, or 12 steps. However, similar processes add up to a broader category. A manufacturing unit, referred to as a “foundry”, is the place where semiconductors are produced. It must be noted that not all foundries do follow the listed steps rigidly in the sequence. Each company may have its own procedures and regulators.

The Major Steps in Chip Manufacturing

Step 1: Wafer Manufacturing

The first step in semiconductor manufacturing is to produce wafers. A semiconductor wafer is made from semiconducting materials such as silicon, silicon carbide, gallium arsenide, etc. The impure material is melted to form a high-purity liquid that is crystallized through processes such as Czochralsk[1] and various others. The cylindrical-shaped ingot is sent for slicing, polishing, and further procedures.

Step 2: Oxidation

The process of oxidation develops an oxide layer that provides insulation inside semiconductor devices. The insulating layer of oxide protects the wafer and prevents unwanted connections inside the device. Such insulation is required to define the junction area and isolate the gate terminal in Field Effect Transistors (FETs)[2]. Two methods include dry and wet oxidation to form an oxidized thin layer.

Step 3: Photolithography

A photoresist is a UV light-sensitive material that is coated over the wafer. Depending upon the manufacturing process, positive and negative photoresist can be used. A desired

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[1] *The Czochralski (CZ) method is a crystal growth technology that starts with insertion of a small seed crystal into a melt in a crucible, pulling the seed upwards to obtain a single crystal. The method is named after the Polish scientist Jan Czochralski, who developed it in 1916. The method is nowadays used for production of various single crystals such as Silicon and Germanium.*

[2] *A Field Effect Transistor (FET) is a three-terminal active semiconductor device, where the output current is controlled by an electric field generated by the input voltage.*

patterned mask, a circuit designed through an EDA tool, is placed over the wafer as it is exposed to UV light. In simple words, photolithography is the process of placing thin-film circuits on the semiconductor to define precise patterns (or circuits).

Step 4: Etching

After the photolithographic stage, the etching process removes the unwanted material from the wafer. The etching process ensures the correct geometry of the circuit pattern for the semiconductor. The wafer undergoes the etching process many times while the desired part is protected through a mask. Two types of etching processes are used in the industry- dry etching and wet etching.

Step 5: Doping

The doping process involves adding pentavalent or trivalent impurities to enhance the conductivity of the semiconductor device. A common doping method used in the semiconductor manufacturing process is ion implantation. Impurities are accelerated and ions are introduced in the wafer during the process. Post ion-implantation process, the wafer goes through the process of annealing to check the quality of dopants and repair any possible structural damage at the crystal level.

Step 6: Metallization

The process of metallization in semiconductor manufacturing allows electricity to flow inside the device. Various components like transistors, resistors, capacitors, etc., are connected for the semiconductor to function as predicted. In simple words, metallization is the metal wiring to make interconnects and ohmic contacts in the semiconductor. Thin films are engineered inside the small semiconductor to provide a path for the current to flow.

Step 7: Quality control and packaging

The electrical die sorting (EDS) process performs quality checks and tests the manufactured semiconductor for reliability. The process is a final check to eliminate faults inside the wafer. Packaging semiconductors is the last step of the manufacturing process. Semiconductors are cut from the wafers separately and are put in different shapes and packages. The foundry sends the packaged device to the selling unit, finally reaching the consumers.

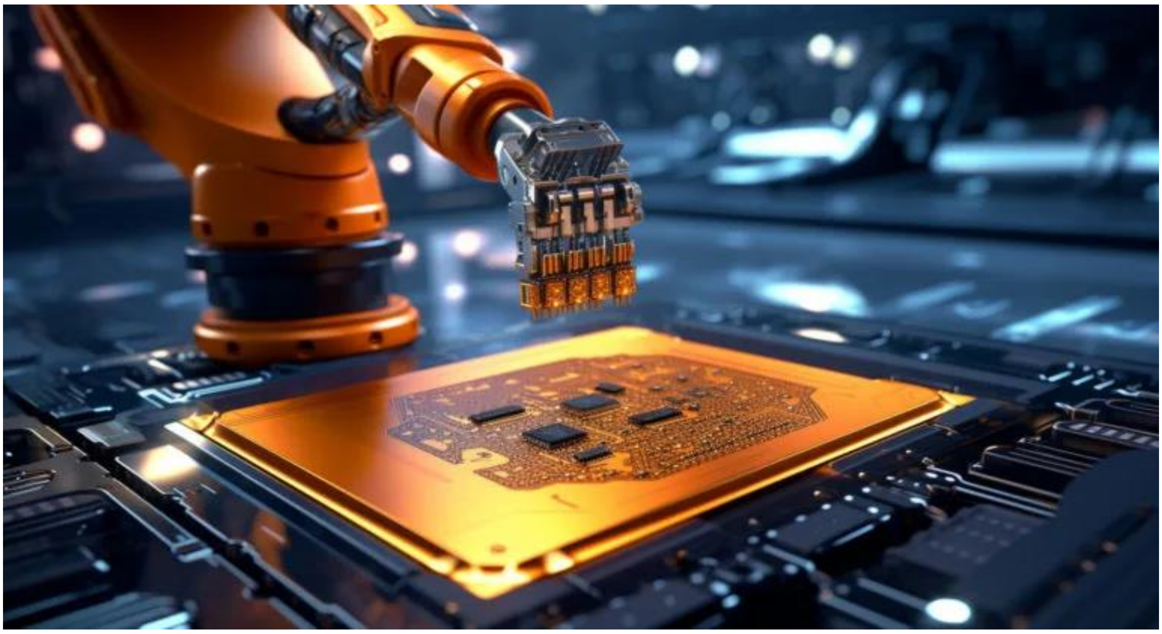
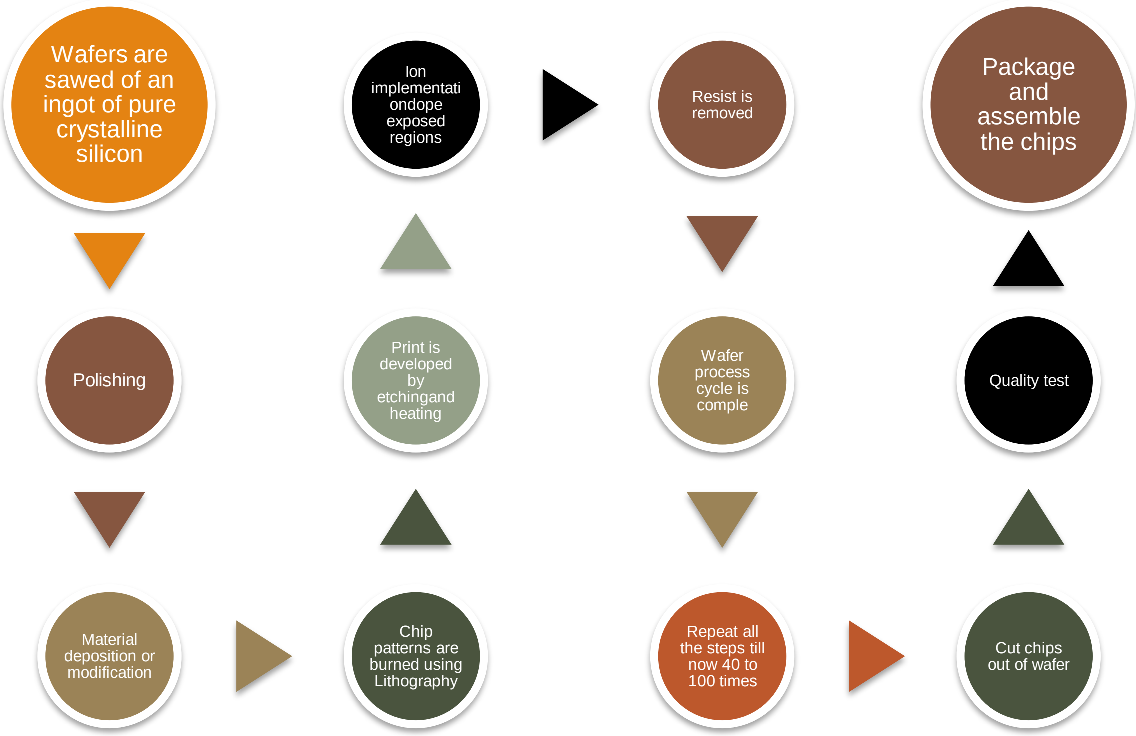


Exhibit 8: A simplified diagram on chip manufacturing



Facts About Semiconductor Value Chain

Semiconductors—the world's fourth-most-traded product—have perhaps the most complex and geographically dispersed value chain of any industry in the world. When all production phases are considered, the entire semiconductor production process extends from material procurement to end-product manufacturing. However, the focus areas are mainly on the following facets of the semiconductor production process:

- Semiconductor R&D and chip design
- Semiconductor Fabrication
- Semiconductor Assembly, Test and Packaging (ATP)

The semiconductor design process includes important additions of core intellectual property (IP)—which consists of reusable modular portions of designs, allowing firms to license and incorporate them in their designs—as well as electronic design automation (EDA) software tools.

Distinctive business models characterize the industry. Integrated device manufacturers (IDMs) represent firms that conduct all key facets of semiconductor manufacturing, especially design and fabrication, internally. Infineon, Intel, Micron, Renesas, Samsung, SK Hynix, and Texas Instruments are leading IDMs. Meanwhile, many semiconductor design firms (such as AMD, NVIDIA, and Qualcomm) are "fabless," meaning they have no production capability, but outsource production to "foundries" such as TSMC or Global Foundries. The most-sophisticated semiconductors operateat the smallest process node sizes (measured in nanometers). The most-sophisticated leading edge logic chips operate at 2–3 nm, while older-process-generation legacy chips may be designed above 28 nm.

Exhibit 9: Participants in Semiconductor Industry Ecosystem

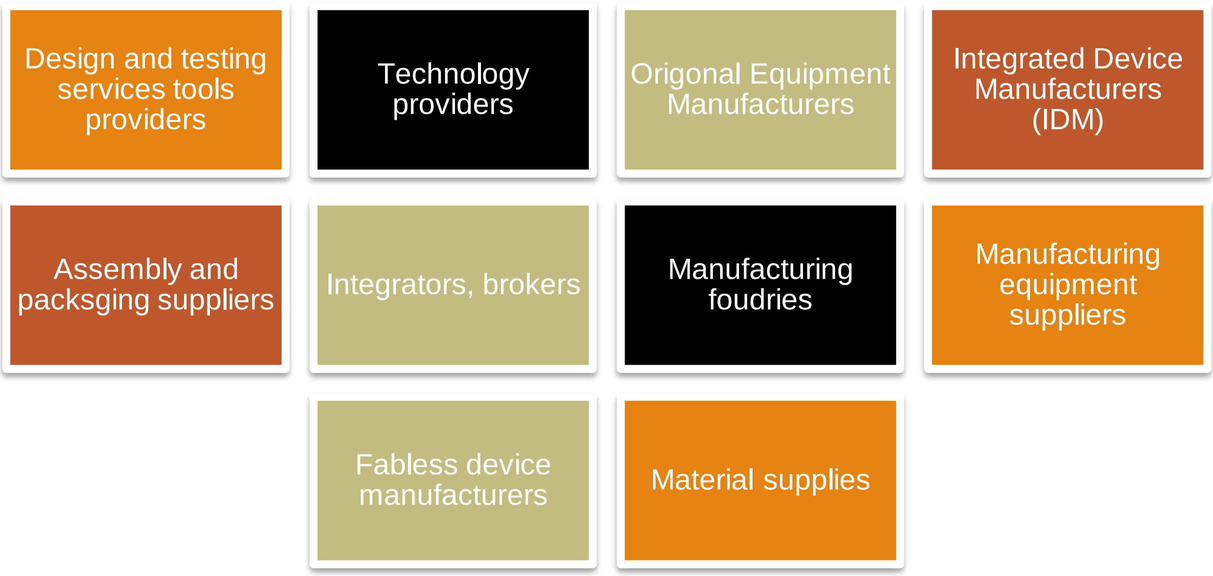
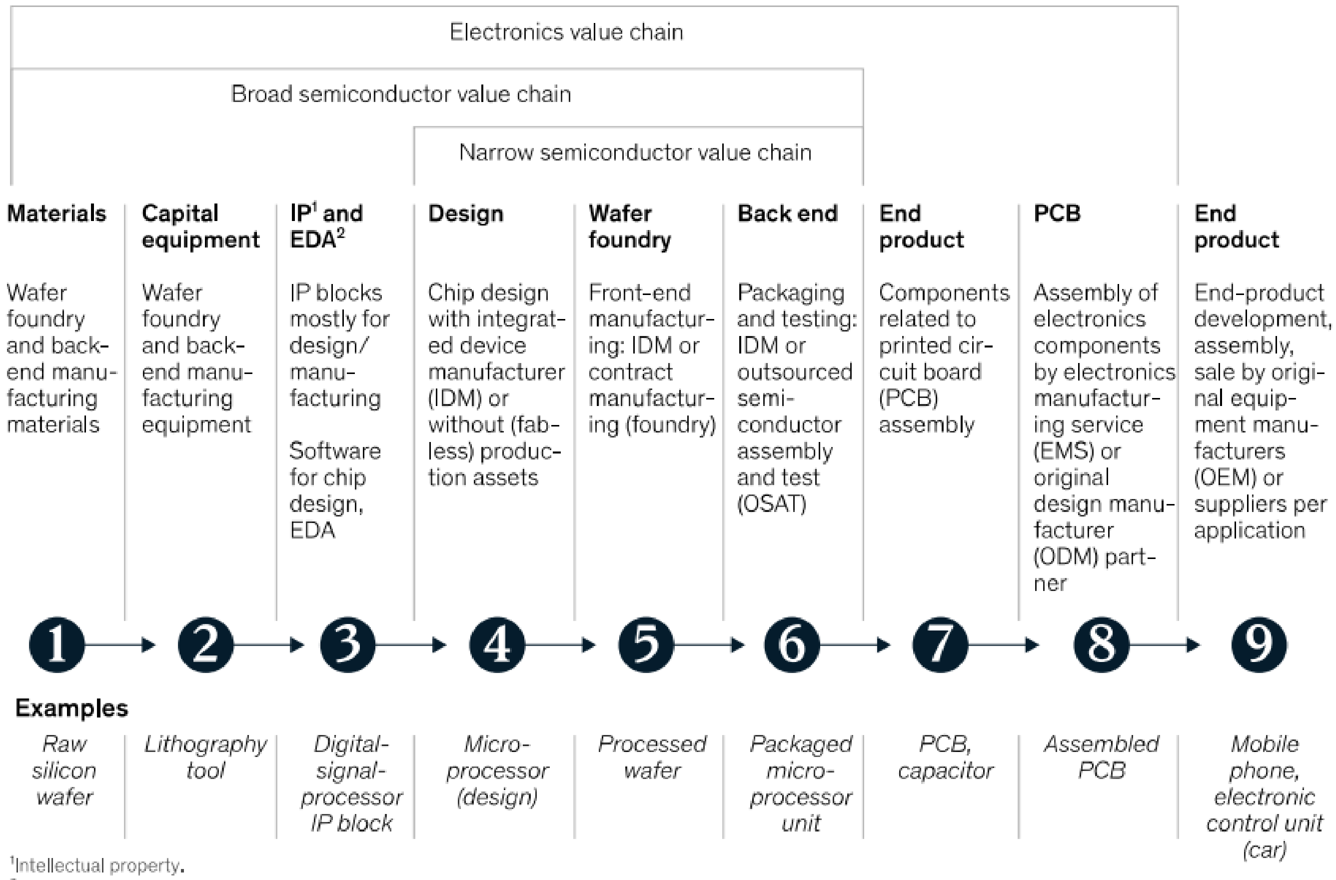


Exhibit 9a: Elements of Semiconductor Value Chain

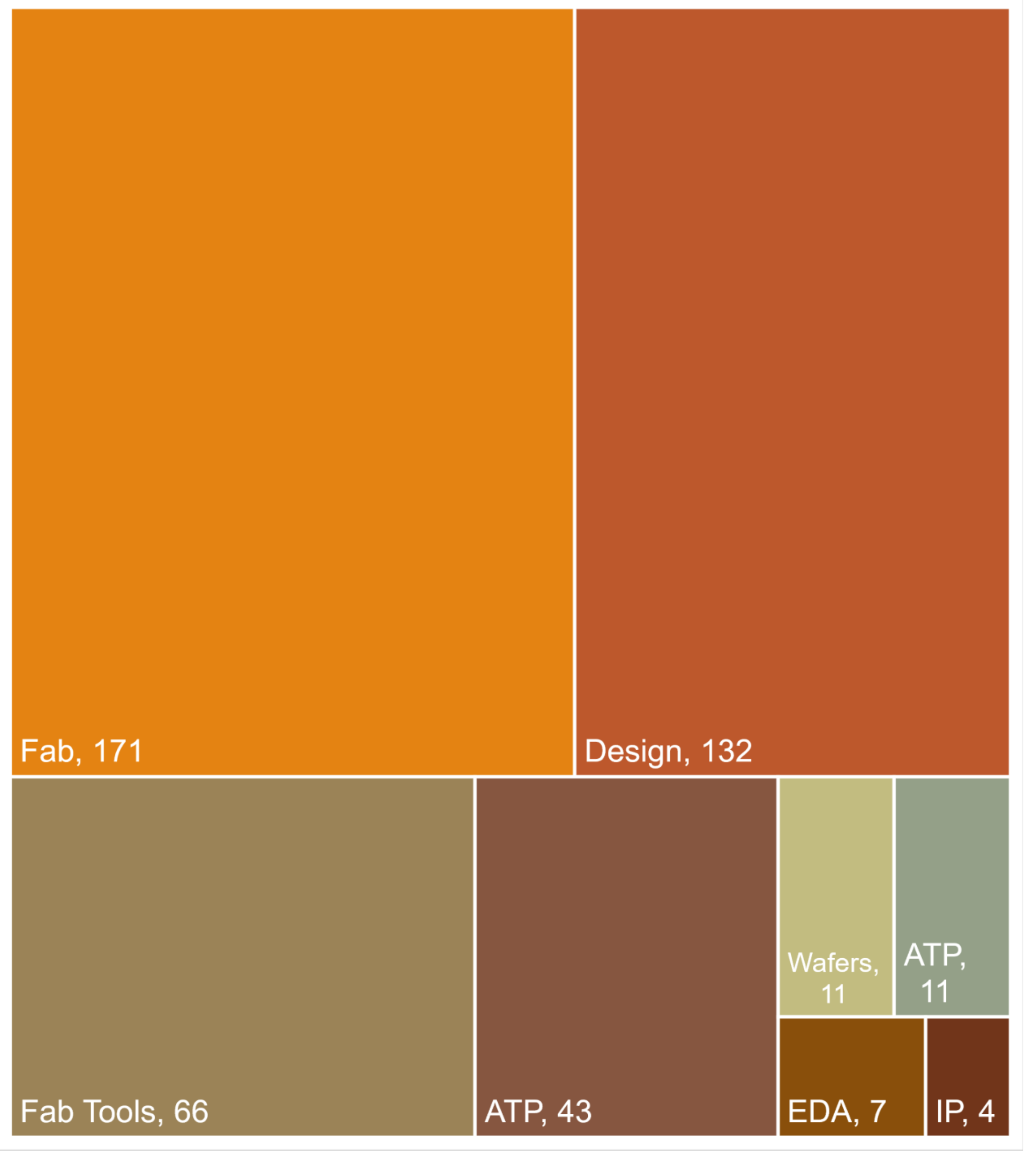


[1]Intellectual property.
[2]Electronic-design automation.

Source: McKinsey Global Institute

In considering the value added by the various facets of semiconductor manufacturing globally— $445 billion in total output as of 2019—analysts estimate that fabrication adds 38.4 percent of global value to the industry ($171 billion), followed by design activities at 29.8 percent ($132 billion), production of fab tooling at 14.9 percent ($66 billion), and ATP at 9.6 percent ($43 billion). That is rounded out by wafers (2.5 percent), ATP tools (2.4 percent), EDA (1.5 percent), and core IP (0.9 percent). In figure 9b, the percentages still reflect the relative value addition contributed by various core activities in the semiconductor supply chain.

Exhibit 9b: Value added by segments of the semiconductor production process, 2019 ($445 billion, total)



Source: Center for Security and Emerging Technology

The Cost of Setting Up a Fabrication Plant

Setting up a semiconductor fab is easier said than done. There are a lot of aspects to investigate. This includes, sourcing lithography tools from global manufacturers, having suitable infrastructure such as a vast area of land, copious amounts of water, water recycling system, electricity lines, and labour power, among other things.

A compound semiconductor or silicon photonics fabrication, for instance, is a smaller investment. A compound semiconductor fabrication will typically consist of three phases—growing wafers, making chips, and packaging—and would total up to **$40 million**.

However, more than 80 percent of the world's semiconductors are still made of silicon substrate. Hence, silicon fabrication becomes a crucial area to discuss, with regard to the government's semiconductor mission. The cost of setting up a silicon fabrication plant is hugely contingent on the technology node the buyers will aim for. This is because one needs lithography equipment for manufacturing semiconductor chips, and the kind of tool used decides the range of technology nodes that one can work with.

Currently, there are three applications in the race for silicon fabrication. They are targeting the following technology node:

1. IGSS Ventures, which is looking to set up a fabrication unit in Tamil Nadu, is aiming at the range of 28nm, 45nm, and 65nm technology.
2. ISMC has proposed a fabrication unit designing 65nm technology.
3. Lastly, the Foxconn-Vedanta joint venture will be looking at a 12-inch (300mm) wafer carrying 28nm technology.

It is important to set the background straight with what the applicants are looking for to determine the cost of the lithography tool that will be needed for the process. The industry typically uses a 200mm wafer for more than 90nm process, whereas less than 90nm process generally requires a 300mm wafer. Considering the requirements of the buyers, a process technology is etched on a 300mm wafer size.

But, within the 300mm wafer size as well, there is a cost bifurcation. Up to 65nm or 55nm technology can be made with 193 Argon Flouride (ArF) Laser, which will cost about $40 million a piece. And if we go further below to the 45nm, 28nm all the way up to 16nm range, a 93-nanometer immersion will be required which will cost about $100 million a piece.

The current policy requires the manufacturers to build a 40,000 per month wafer capacity. To get that kind of production running, 15 to 20 of these lithography tools are required. This means that the lithography tool one uses impacts the overall cost by a huge difference. 65nm to 55nm technology is currently the sweet spot, since one could fully utilise the resources with the best technology available. Hence, 15-20 of 193 ArF lasers would take the cost tally up to **$2 billion**.

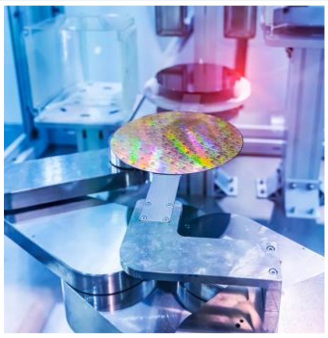
One of the ways the cost could be controlled is by using refurbished equipment. However, the government of India is not supportive of this because they are afraid that India will become a dumping ground of old equipment. Besides, there could also be instances where the applicant might quote an overpriced number for the refurbished tool, and get the subsidy for the same.

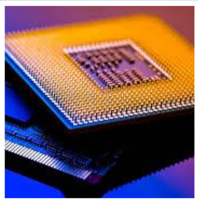
The **$2-billion** figure is however just the equipment cost. Following costs get added to the equipment cost:

- ✓ the infrastructural cost of setting up a fab will be about **$200 million to $300 million**.

- ✓ There will also be a technology transfer fee levied by the companies issuing the lithographic tools to the fabrication plants. The 65nm-55nm range will have a licensing fee of about **$300million to $400million**.
- ✓ As we go to the narrower range, the transfer cost increases to about **$1 billion** for a 28nm range and more if we go further down.

Together, the three components, will add up to **$3 billion** for the 65nm range. Likewise, we can estimate the total cost at the lower end of the spectrum.





Chapter: 4 Drivers & Challenges of the ESDM Industry

The Indian ESDM sector is one of the fastest growing sectors in the economy and is witnessing a strong expansion in the country. The ESDM market in India is well known internationally for its potential for consumption and has experienced constant growth.

Indian manufacturers are attracting the attention of multinational corporations due to shifting global landscapes in electronics design and manufacturing capabilities, as well as cost structures. Companies from all over the world are striving to develop local capacities in India not only to serve the domestic market but also to cater to international markets.

India witnessed a substantial spike in demand for electronic products in the last few years; this is mainly attributed to India's position as second-largest mobile phone manufacturer worldwide and surge in internet penetration rate. The Government of India attributes high priority to electronics hardware manufacturing, as it is one of the crucial pillars of Make in India, Digital India and Start-up India programmes.

Growth Drivers

The global demand for semiconductors is envisaged to grow exponentially with advancement of technology. The establishment of a strong manufacturing and design base for semiconductors with enable India to address not only the growing domestic market with a very resilient model but also support global requirements competing with the traditional supply sources on a level playing field. The following are some major growth drivers for the ESDM industry in India

Exhibit 10: Major Growth Drivers for the ESDM Industry in India

Exhibit 11: Advantages in India

1. Robust Demand

- Second-largest manufacturer of mobile phones in the world
- Will be the 5th largest consumer of electronic products
- India has strong design and R&D capabilitiesin electronics

2. Attractive Opportunities

- India is committed to reach US$ 300 billion worth of electronics manufacturing and exports of US$ 120 billion by 2025-26.
- Addressable market for domestic OEMs is projected to be more than US$ 131.99 billion by 2025.
- The government intends to incentivise and attract investments to set up semiconductor FABs in India.

3. Policy Support

- The production-linked incentive (PLI) schemes will provide companies opportunities to establish manufacturing plants in India.
- In case of electronics items for defence, FDI up to 49% is allowed under automatic route and beyond 49%, government approval is required.
- The Indian government's National Policy on Electronics (NPE 2019) aims to facilitate a turnover of US$ 400 billion in domestic manufacturing by 2025

4. Investments

- Major Government initiatives such as ‘Digital India’, ‘Make in India’ and supportive policies including a favourable FDI Policy for electronics manufacturing have simplified the process of setting up manufacturing units in India.
- India now has semiconductor projects totalling INR 1.5 trillion in the pipeline as of Februsry 2024.

5. 3rd Largest Start-up Ecosystem

- Electropreneur Park (EP) was set up by MEITY and IESA in 2016 and created 51 hardware products, 51 patents, and 23 startups were funded.
- The EP will grow to be a hub with 20 spoke centres aimed to promote innovation and create unicorns in ESDM by offering access to a holistic ecosystem to Strengthen Tech Startup Ecosystem

6. Large Consumer Base

- India's exports is set to increase rapidly from US$ 10 billion in FY21 to US$ 120 billion in FY26
- Factors such as high internet penetration rate (over 718 million users) and second-largest global smartphone manufacturer boosted penetration of electronic products to the large potential consumer base, which in turn is driving ESDM market.

7. Increasing FDI Inflows

- The government allows 100% FDI in the ESDM sector through an automatic route to attract investments from OEMs and IDMs.
- The cumulative FDI equity inflow in the Electronics industry is US$ 4.42 billion during the period April 2000-September 2023.

The Challenges

Talent Shortage

- The scarcity of skilled chip design engineers is a major challenge hindering the industry's growth
- Bridging this gap requires targeted efforts in training and upskilling to meet the demands of a rapidly evolving sector.

Infrastructure Development

- Establishing world-class semiconductor fabrication facilities and research centers necessitates substantial investment in infrastructure and technology
- Enabling environment for semiconductor manufacturing and research, attracting foreign investment and fostering indigenous innovation.

Intellectual Property (IP) Protection

- Ensuring robust IP protection and adhering to global standards are crucial for building trust and attracting more investments from international semiconductor companies

Rapid Technological Advancements

- The semiconductor industry is characterized by swift technological advancements.
- Staying at the forefront of innovation demands continuous learning and adaptability

Semiconductors manufacturing is a very complex and technology-intensive sector with huge capital investments, high risk, long gestation and payback periods, and rapid changes in technology. These require significant and sustained investments. Also, chip manufacturers require a huge scale to be cost effective. This means large investments, often in the $20 billion range.

Additionally, developing an ecosystem for chip manufacturing in a greenfield location is a major challenge. It requires suitable infrastructure like availability of uninterrupted power, huge quantities of clean water and requires setting up expensive water purification facilities. Hundreds of chemicals and gases are also required for chip fabrication.

Semiconductors have a small freight-to-price ratio and a zero-custom duty regime under the Information Technology Agreement, 1996. Therefore, the location of raw material or sales market is meaningless due to low transportation cost. This facilitates concentration of production in a few countries where ecosystem for semiconductor manufacturing is already well established.

High-end chip manufacturing requires sophisticated technology, which very few corporations possess. Moreover, since such chips are considered dual-use technology (can be used for civilian and military purposes), countries can place curbs on their export as the US and the Netherlands have done. Recently, the Netherlands restricted export of advanced semiconductor equipment.

Conclusion

Amidst this rapid reordering of the global economy, India's value proposition as an investment and production destination for high-tech industries—from clean energy and medical devices to electronics and ICT hardware—is particularly strong. The country has already recorded notable early successes, particularly attracting Apple's eye to the extent it may produce up to one-quarter of its phones in India by 2025.

Moreover, for several decades, India has been the home of significant semiconductor design activity, accounting for 20% of the world's chip design talent. More recently, India has turned its attention to semiconductor manufacturing, notably semiconductor fabrication ("fabs") and post-production assembly, test, and packaging (ATP), where semiconductors are tested and assembled into sophisticated packages. Here too India has notched a considerable success, with the announcement from semiconductor memory chip manufacturer Micron in June 2023 that it will launch a major ATP facility for dynamic random access memory (DRAM) and NAND products in Sanand, Gujarat.

Chapter: 5 Government Initiatives, Major Developments and Way Forward

Semiconductor and Electronics Manufacturing Policy Environment

- For its dream to make India a semiconductor nation, the government of India is taking small yet important steps towards turning this dream into reality. After announcing Rs 76,000 crore incentive for semiconductor and display fabs back in December 2021, allocating Rs 3,000 crore in Budget 2023-24, and now once again allocating Rs 6,903 crores in the interim budget 2024-25, 2024 will be a break-out year for this sector in India.
- The government has allocated Rs 15,500 crore for various electronics manufacturing programs, including semiconductor mission. This amount is designated for semiconductor fab or electronic chip plants that will spur the compound semiconductors and sensors manufacturing, Rs 900 crore support for the Mohali-based semiconductor laboratory, and Rs 200 crore for the design-linked incentive scheme to add to design and Intellectual Property Right (IPR) development in India.
- GoI also proposed Rs 4,203 crore incentives for assembly, test, and packaging plants that can benefit projects like the ones set up by Micron in Gujarat, the proposed plant by Foxconn and HCL joint venture, Tata Group etc.
- The proposed outlay covers projects for setting up compound semiconductor and sensor plants.
- The government has received four proposals for setting up semiconductor manufacturing plants and 13 for setting up compound semiconductor fabs and ATMP (Assembly, Testing, Marking and Packaging) facilities. The proposals are in addition to a Rs 22,516 crore chip assembly plant being set up by US based memory chip maker Micron.

The New Establishments for Manufacturing Semiconductors

The Indian government approved the establishment of three new semiconductor manufacturing facilities on February 29, 2024 under the country's flagship incentive program. Stakeholders have announced that construction work on these facilities will commence within the next 100 days.

The three new semiconductor manufacturing units are as follows:

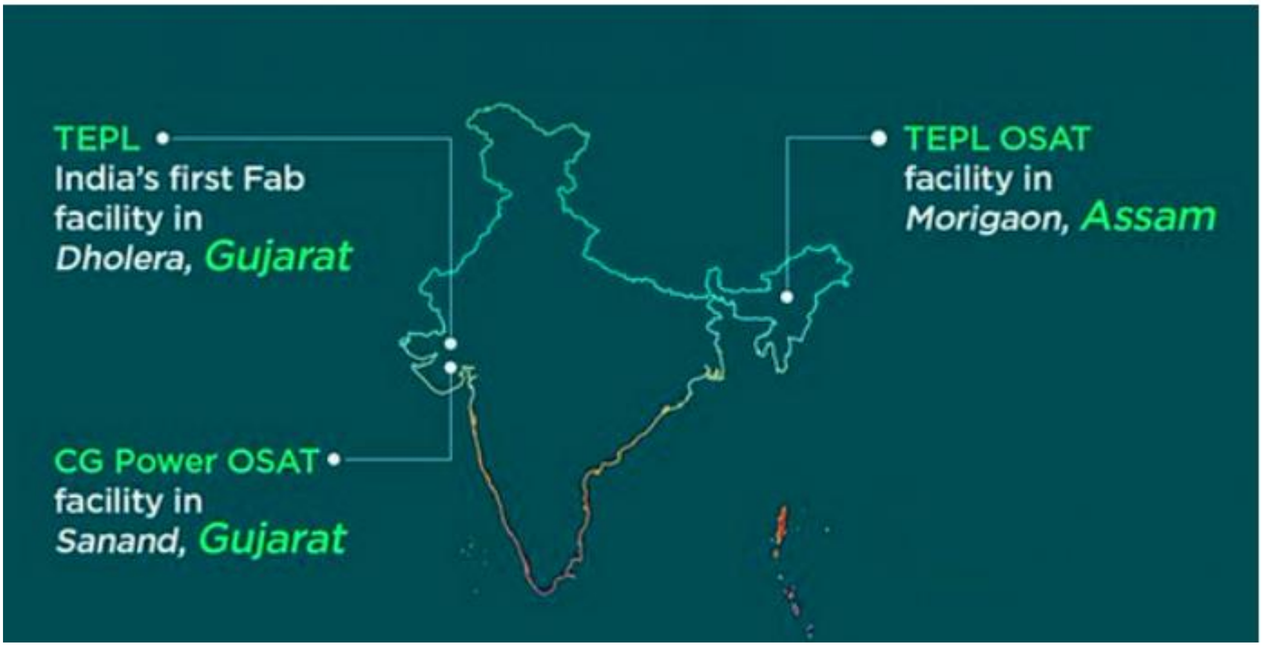
Dholera, Gujarat

This will be India's first commercial semiconductor fabrication facility.Tata Electronics Private Limited (TEPL) will collaborate with Powerchip Semiconductor Manufacturing Corp (PSMC), Taiwan, to establish a semiconductor fab in Dholera, Gujarat, with an investment of INR 9100 billion (US$109.71 billion). PSMC has six semiconductor foundries in Taiwan. The fab's capacity will be 50,000 wafer starts per month (wfsm), covering segments such as high-performance computer chips with 28 nm technology and power management chips for electric vehicles (EV), telecom, defense, automotive, consumer electronics, display, power electronics, etc.

The chairman of PSMC, Frank Huang, said that the first semiconductor chip from this plant will be ready to roll out by the end of 2026. TEPL and PSMC are yet to finalize their joint venture terms but are prioritizing technology transfer currently.

Morigaon, Assam

Tata Semiconductor Assembly and Test Pvt Ltd (TSAT) will set up a semiconductor unit in Morigaon, Assam, with an investment of INR 2700 million (US$ 325.99 million). TSAT is developing indigenous advanced semiconductor packaging technologies, including flip chip and ISIP (integrated system in package) technologies. The unit's capacity will be 48 million per day, catering to segments such as automotive, electric vehicles, consumer electronics, telecom, mobile phones, etc.



Sanand, Gujarat

CG Power, in partnership with Renesas Electronics Corporation, Japan, and Stars Microelectronics, Thailand, will establish a semiconductor unit in Sanand, Gujarat, with an investment of INR 760 million (US$91.63 million). Renesas, a semiconductor company specializing in chips, operates 12 semiconductor facilities and is a key player in microcontrollers, analog, power, and System on Chip (SoC) products. The CG power semiconductor unit will manufacture chips for consumer, industrial, automotive, and power applications, with a capacity of 15 million per day.

India's Semiconductor Program: Progress report

With the launch of these three units, India can position itself as a global hub for chip manufacturing.

Given India's strengths in chip design, the newly approved units will promote the development of chip fabrication capabilities, supporting homegrown packaging technology advancements. The change is expected to create new employment opportunities in addition to expanding semiconductor production capacity. As per the central government's estimate, the three new units will directly affect 20,000 high-tech positions and indirectly create an additional 60,000 jobs.

India now has four semiconductor manufacturing facilities after the inclusion of the three new units. Prominent American chip company Micron has committed to invest up to US$ 825 million to build a facility in India for the assembly and testing of semiconductor chips. It plans to open a production facility at the Sanand plant in Gujarat in early 2025 for assembling and testing cutting-edge D-RAM and Nand products.

With Micron's investment spread over two years, the project is estimated to generate 15,000 community employment and 5,000 direct jobs in coming years. Making use of the government's "Modified Assembly, Testing, Marking, and Packaging (ATMP) scheme," Micron will get fiscal help from the central government for 50 percent of the project cost, with an additional 20 percent coming from the Gujarat state government. Up to US$ 2.75 billion is anticipated to be invested jointly by Micron and the two governments for the two project phases.

India anticipates a "ripple effect" that will speed up job prospects in downstream industries such as automotive, electronics, telecom, industrial, and other businesses that use semiconductors. By 2026, the semiconductor industry in India is anticipated to generate over 300,000 jobs, encompassing diverse roles such as testing, engineering, software development, system circuits, validation, and operations.

The country strategically aims to enhance its manufacturing capacity for export-oriented component production, resulting in a surge in research and development (R&D), testing activities, and technological capabilities. Given India's expansive consumer and business marketplace, its proficiency in electronics production, and geopolitics affecting the nature of supply chains, the nation should capitalize on the opportunity to strengthen its position in global semiconductor value chains.

Over the next five years, India has the potential to establish additional facilities in the semiconductor assembly, testing, and packaging (ATP) segment, attracting fabs producing legacy semiconductors at 28 nm or above. This expansion aligns with India's extensive experience in semiconductor design, boasting 20 percent of the world's integrated circuit (IC) design workforce, comprising over 125,000 workers.

To attract multinational investors seeking stability and predictability, India must continue strengthening recent improvements in its business and policy environments, avoiding measures that could create uncertainty in the business landscape.

Why should India prioritize semiconductor investment?

India's government is prepared to offer some of the world's most generous investment incentives to attract greater levels of semiconductor investment. However, given the myriad challenges India faces and limited budget it possesses, the question is, why should India prioritize semiconductor investment—especially capital-intensive manufacturing facilities—over many other competing priorities? Following are the five key justification to the above question:

First, there is certainly a prestige factor at play. India is to be celebrated and commended for its recent lunar vehicle landing, making it one of only four nations to achieve that incredibly impressive feat. That India should now wish to join a select group of nations—less than two dozen—that manufacture semiconductors at commercial scale is certainly understandable. Moreover, Indian government has made attracting semiconductor manufacturing activity a key commitment and objective of its "Make In India" (part of the "Atmanirbhar Bharat" or "self-reliant India") program, which seeks "to promote India as the most preferred global manufacturing destination."

Second, India runs a large trade deficit in semiconductor products, which it seeks to balance through greater levels of domestic production. India's imports of electrical and electronics equipment reached $67.6 billion in 2022. This included an estimated $15.6 billion in semiconductors, a near doubling from India's $8.1 billion in semiconductor imports the prior year. Over the past three years, India's chip imports have increased by 92 %. An estimated 70% of India's electronics imports come from China and Hong Kong, with an additional 13% coming from Singapore.

Third, bolstering manufacturing activity in high-tech sectors such as semiconductors not only provides a significant source of high-value-added, high-paying employment opportunities, but can produce significant employment, and economic, multiplier effects. This is certainly true in the United States, where the semiconductor industry's jobs multiplier is 6.7, meaning that for each U.S. worker directly employed by the semiconductor industry, an additional 5.7 jobs are supported across the wider U.S. economy. Those jobs are highly productive, and thus remunerative, with the average U.S. semiconductor job paying $177,000, compared with the average U.S. wage of $61,900. Semiconductors also produce significant economic multipliers. As one report finds, “Every dollar added to U.S. GDP by the electronics manufacturing sector creates $1.32 elsewhere in the economy. Additionally, every dollar in electronics manufacturing output generates $1.05 of output elsewhere in the economy. Just as U.S. semiconductor jobs produce and pay more, and deliver significant economic and employment multipliers, so too would and do Indian semiconductor-sector jobs. Indeed, one study finds that the employment multiplier for jobs in India’s computer, electronic, and optical equipment industry is 16.1.

Fourth, semiconductor manufacturing can produce tremendous spillover and “learning by doing” effects across the rest of India’s high-tech economy. A robust manufacturing base ensures that the knowledge gained from ‘learning by doing’ is transferred to domestic firms as well. Economic growth is influenced by levels of ‘sophistication’ in a country’s production. The nature of production matters for economic growth. Countries that specialize in the production of goods with higher productivity are better placed to achieve higher growth.

Also, a country’s initial pattern of specialization impacts their ability to expand competitiveness in adjacent industries. The location in the product space is a crucial determinant of a country’s potential to develop comparative advantage in certain products. Countries progress by exploiting the relatedness of products requiring similar inputs including skills and technology. Thus, countries’ economic development, is not merely advancement in general attributes such as education, health, rule of law and infrastructure but also the development of ancillary support systems and activities that are specific to an industry. For India, its extant capabilities in semiconductor design and electronics manufacturing can serve as a platform to enter the manufacturing-oriented elements of semiconductor production. If India can enter the semiconductor manufacturing “product space,” this in turn could power its future ability to compete in other high-tech manufacturing sectors, such as robotics.

Finally, there are significant “learning by doing” effects in the policymaking strategies needed to attract investment in high-tech industries such as semiconductors. Indeed, the knowledge spillovers for Indian policymakers of what it takes to attract semiconductor manufacturing—to the extent it informs how India competes for other high-tech sectors such as biopharmaceuticals or renewable energy and how it manages its broader policy and business environment—are likely to be far more powerful than even the technical “learning by doing” that occurs on the factory floor.

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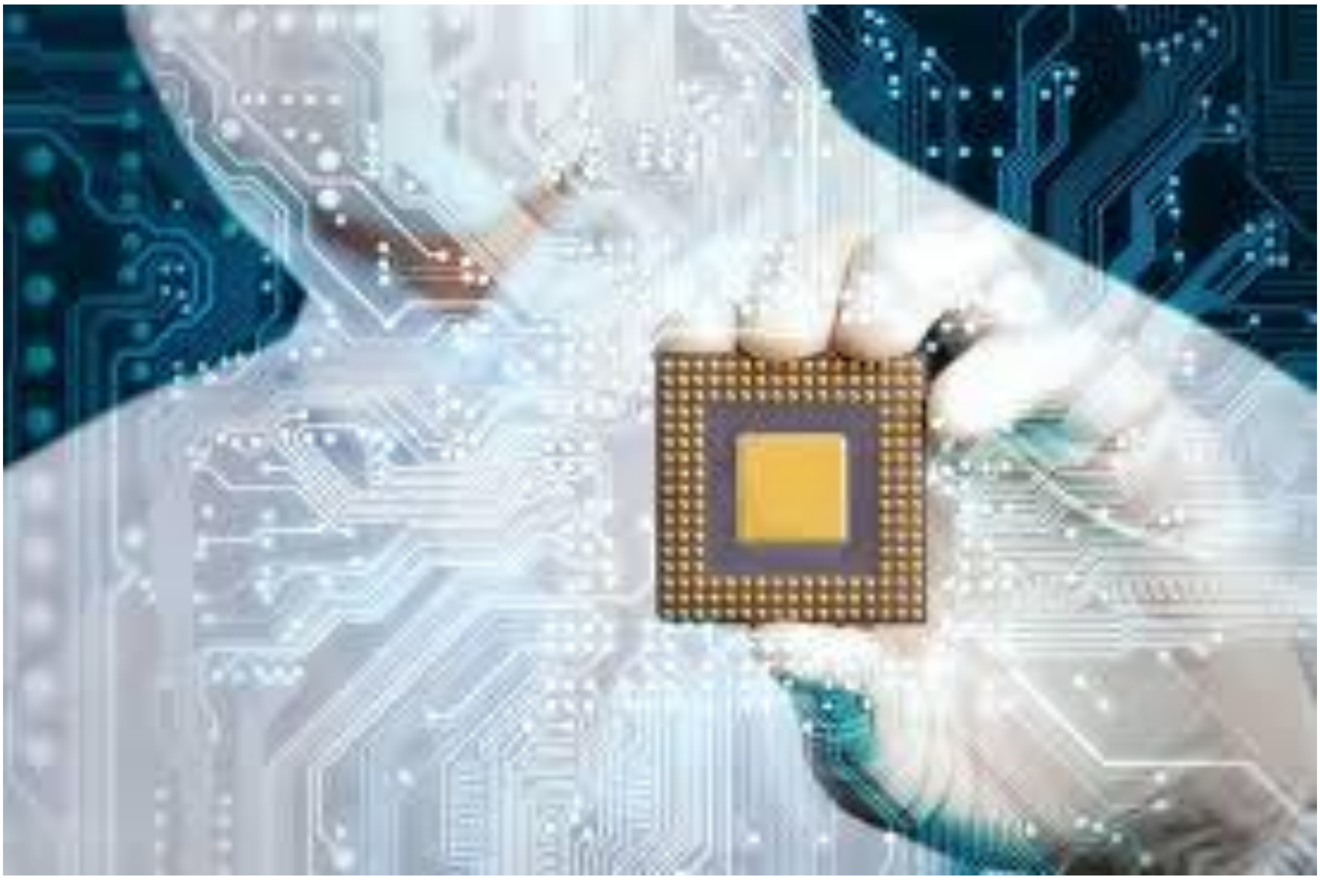

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