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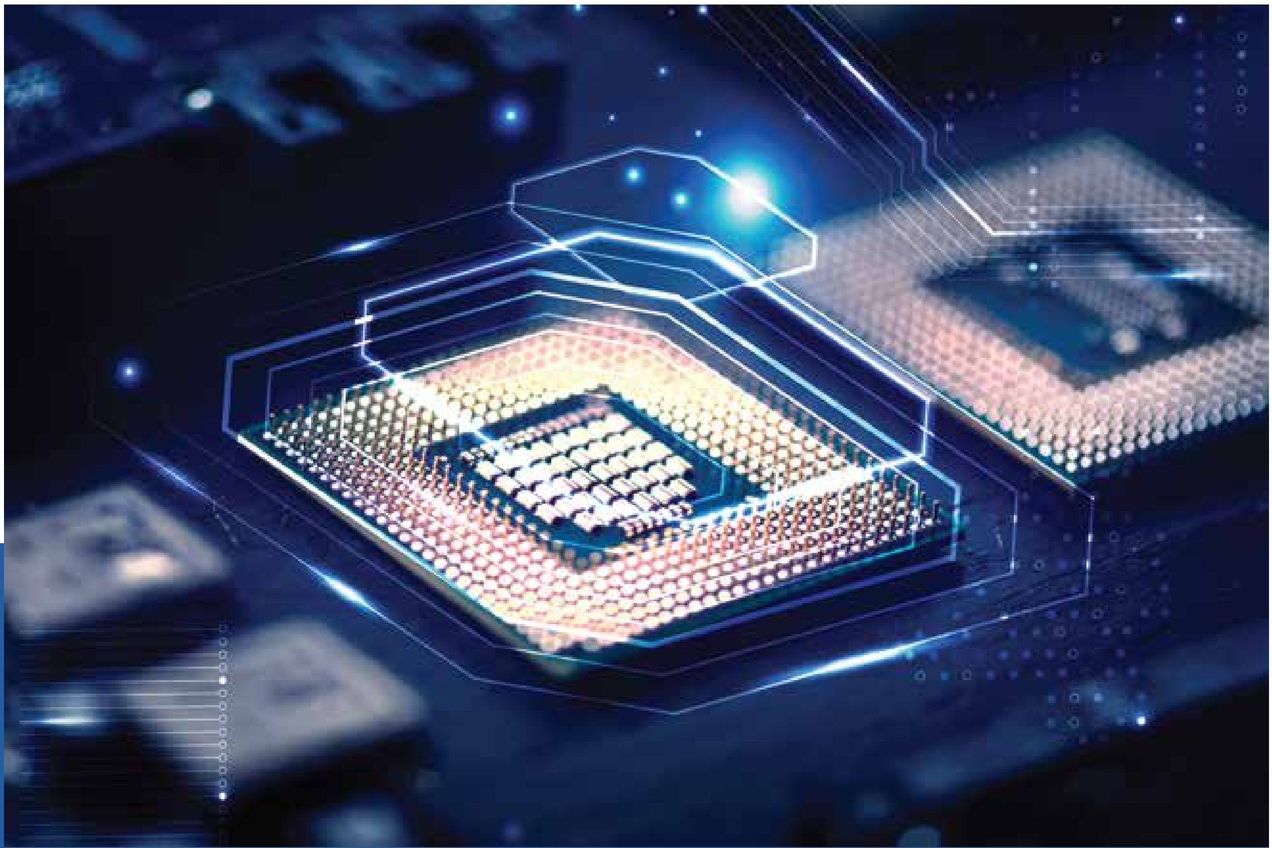

Semiconductors

Non-negotiable ecosystem for Indian dream of US$5 trillion economy

Contents

Executive Summary

What comes to mind when you think of semiconductors? In 2021, probably words like “shortage,” “supply chain,” and “Taiwan.” But if you had been thinking about semiconductors a decade ago, it might have been “smartphone.” And way back in the 1950s, it may have been “Texas Instruments,” or even “germanium” (silicon wasn’t viable for semiconductors until 1954). In the 1800s, you’d probably just say “semi-what?”

Since 1965, semiconductors have followed an exponential trend called Moore’s Law, roughly doubling the number of transistors that can fit on an integrated circuit every two years. That has enabled the creation of smaller devices, like smartphones, capable of computational power far greater than the massive, room-sized mainframe computers of yesteryear, and paved the way for machine learning, cloud computing, autonomous vehicles, and other computationally intensive technologies.

Today, the semiconductor industry contributes to nearly $2.3 trillion of the world's GDP. The past few decades have led to the success of the industry due to globalisation — countries specialised in specific parts of the supply chain, relying on trade by comparative advantage to drive cost efficiencies. Manufacturing a chip typically takes more than three months and involves giant factories, dust-free rooms, multi-million-dollar machines, molten tin and lasers. Once you spend all that money building giant facilities, they become obsolete in five years or less. To avoid losing money, chipmakers must generate $3 billion in profit from each plant. The brutal economics of the industry mean fewer companies can afford to keep up.

Just top 3 companies, Intel, Samsung and TSMC made $188 billion in revenue in 2020, as much as the next 12 largest chipmakers combined. India imports 100% of its semiconductors, spending about $24 billion annually. Ironically, India is a leading chip designer with 30000+ engineers employed in this field. Our semiconductor design market was worth more than $33 billion in 2020. India adds value by way of design but that accounts for a more modest $2 billion for which Taiwan, China and Korea manufactures worth US$20 billion from the Indian design.

Another aspect is India post becoming the second largest manufacturer for smart phones after China, the heavy import reliance for chips is worrisome. While the domestic opportunity is huge, making semiconductors is a complex process. It takes hundreds of precisely controlled steps over several months to make a chip. This report tries to highlight the

- **Evolution of semiconductors**
- **The global value chain for semiconductors**
- **Global shortage post COVID-19**
- **Trends post the shortage**
- **India's previous attempts at becoming a global manufacturing hub for semiconductors**
- **Industry landscape in the Indian scenario**
- **Government's $10billion PLI scheme for semiconductor**

The growth of entire semiconductor value chain - which includes designing, fabrication, testing and assembly, India must promise the right infrastructure apart from the financial incentives. If the right partnership for high end fab is unavailable, then the country can start creating value for domestic market through specialty, R&D and analogue fabs.

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1. Semiconductor : How Did Semiconductors Become An Essential?

Semiconductors possess specific electrical properties. A substance that conducts electricity, like silver and copper is called a conductor, and a substance that does not conduct electricity, like rubber or plastic is called an insulator. Semiconductors are substances with properties somewhere between them. A semiconductor is a physical substance designed to manage and control the flow of current in electronic devices and equipment. It either doesn't allow a freely flowing electric current or repels the current completely. Addition of small amounts of other substance can change the properties entirely. It's generally created using silicon, germanium, or other pure elements. Semiconductors are created by adding impurities to the element. The conductance or inductance of the element depends on the type and intensity of the added impurities.

Semiconductors were being studied in laboratories as early as the 1830s. In 1833 Michael Faraday was experimenting with silver sulfide. He discovered that as the material was heated it conducted electricity better. This was the opposite of how copper acted. When copper is heated it conducts less electricity. In 1947 at Bell Labs in New Jersey, the transistor was invented. This led to the development of integrated circuits, which power almost all electronic devices today. Integrated circuits that make up semiconductors are created on wafers, which are thin, circular slices of silicon. Over the past three decades, the semiconductor industry has experienced rapid growth and delivered enormous economic impact. Chip performance and cost improvements made possible the evolution from mainframes to PCs in the 1990s, the web and online services in the 2000s, and the smartphone revolution in the 2010s. Indeed, these chip-enabled innovations have created incredible economic benefits.

Innovations in semiconductors make electronic devices smaller, faster, more reliable and more efficient, so manufacturers compete to make chips as small as possible. Today's advanced chips are as small as 5 nanometers; it takes 10 million nanometers to equal one centimeter. The standard semiconductor size has steadily shrunk about 18% per year, from 22 nm in 2012 to 5 nm in 2020. Experts expect the standard semiconductor size to be about 3 nm in 2022 and 2 nm after 2023— roughly in line with the 18% rate of annual progress observed since 2012.

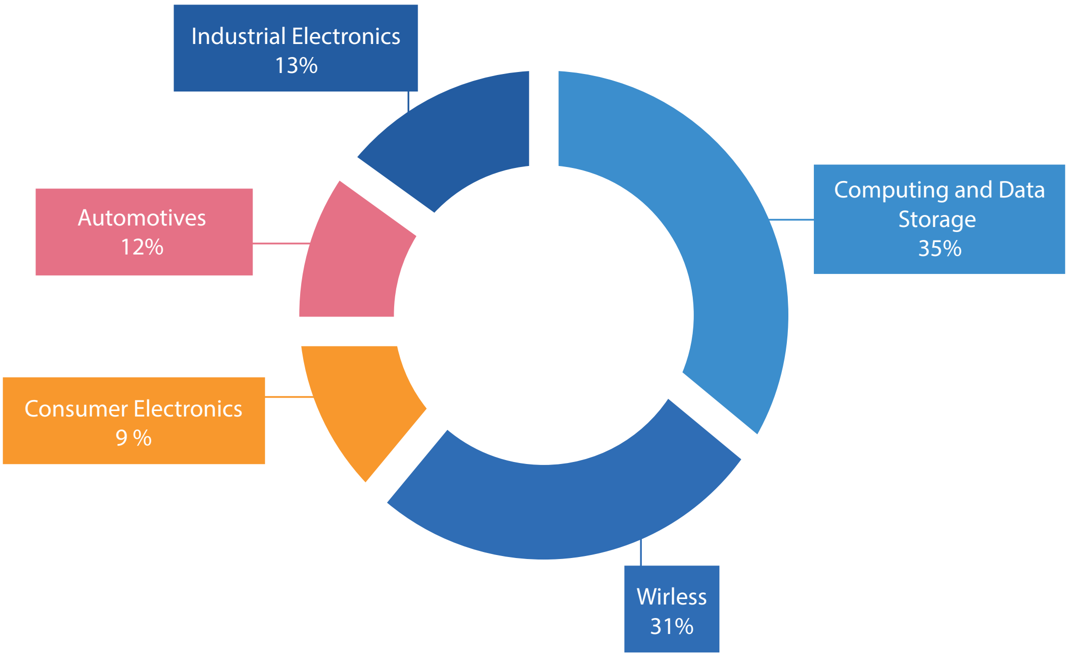
It's widely accepted that chip progress follows Moore's Law, a theory from engineer and Intel co-founder Gordon Moore in 1965 that the number of transistors on a silicon microchip is expected to double every 18 to 24 months, even as computer costs fall by half. But as chips get smaller and more advanced, it becomes increasingly difficult and expensive formanufacturers to progress at the historical rate indefinitely. Industry experts believe Moore's Law may no longer hold true as early as 2020 or 2022, according to Scientific American.

Semiconductor is The revolutionary technology. Reducing costs of a Rolle Royce from very expensive to affordable to ALL

In simple terms, if we assess the cost and accessibility parameters to the automotive industry it would be like cost reducing a Rolls Royce from very expensive to affordable for ALL Semiconductors is the revolutionary technology making modern day electronics items available for all.

2. Semiconductor, A Modern-Day Necessity

Semiconductors are the "brains" of modern-day electronics spanning consumer products like smartphones and smart TVs to more sophisticated equipment used in industrial applications, defense & aerospace. They also act as a foundational technology for advancements in other critical & emerging technologies .

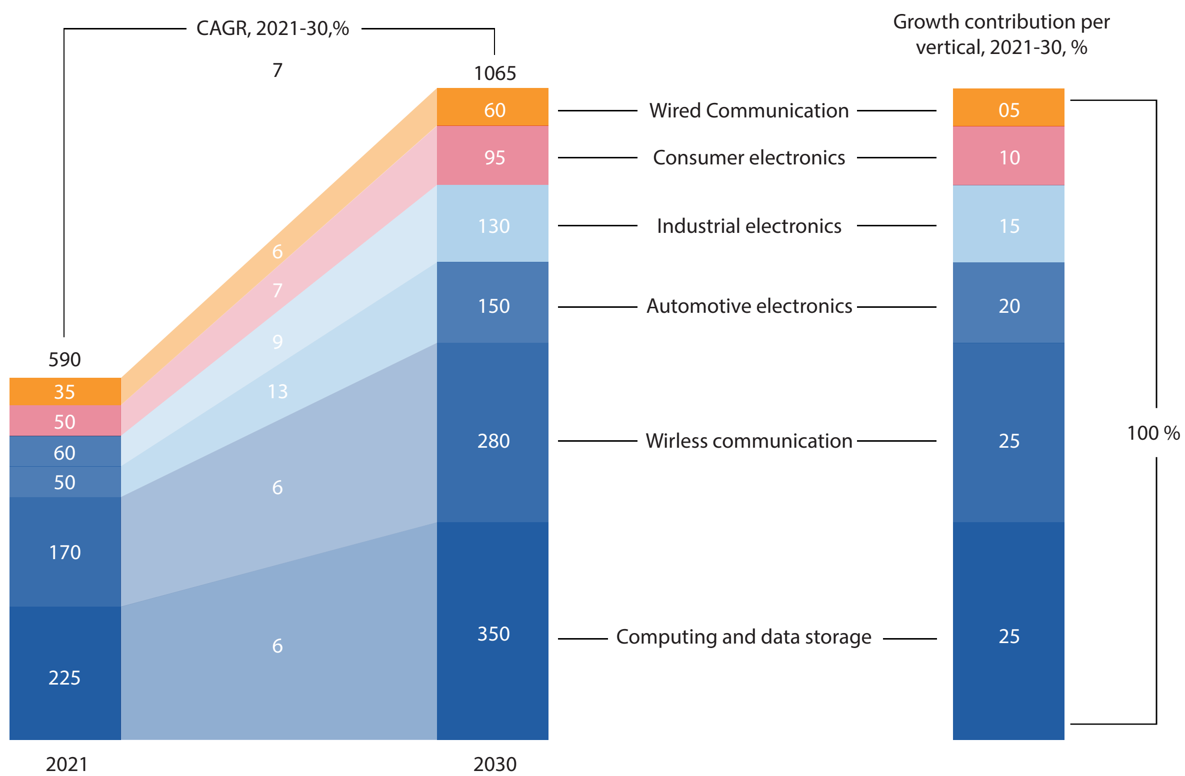


Artificial Intelligence (AI) applications require new semiconductor architectures with faster data movement between processor and memory. This architectural change demands a move away from general purpose technology to specialized processors (referred to as AI chips).

Advancements in the automotive industry covering electric vehicles, autonomous driving & stringent safety standards have led to a surge in demand for microcontrollers, sensors & memory chips. The 5G communication revolution relies on a new breed of baseband chips that can operate over a wider frequency range.

Supply shortages in the past 2 years led to bottlenecks in the production of everything from cars to computers and highlighted how tiny chips, costing less than a dollar can prevent the sale of a device worth tens of thousands have become outmost critical to the smooth functioning of the global economy. As the infusion of the chips increases in our digital lives, and businesses with revenues increasing to $600billion in 2021, the expectation by the end of 2030 has reached about a trillion dollar economy. Deep diving into individual subsegments, about 70% of growth is predicted to be driven by just three industries: automotive, computation and data storage, and wireless.

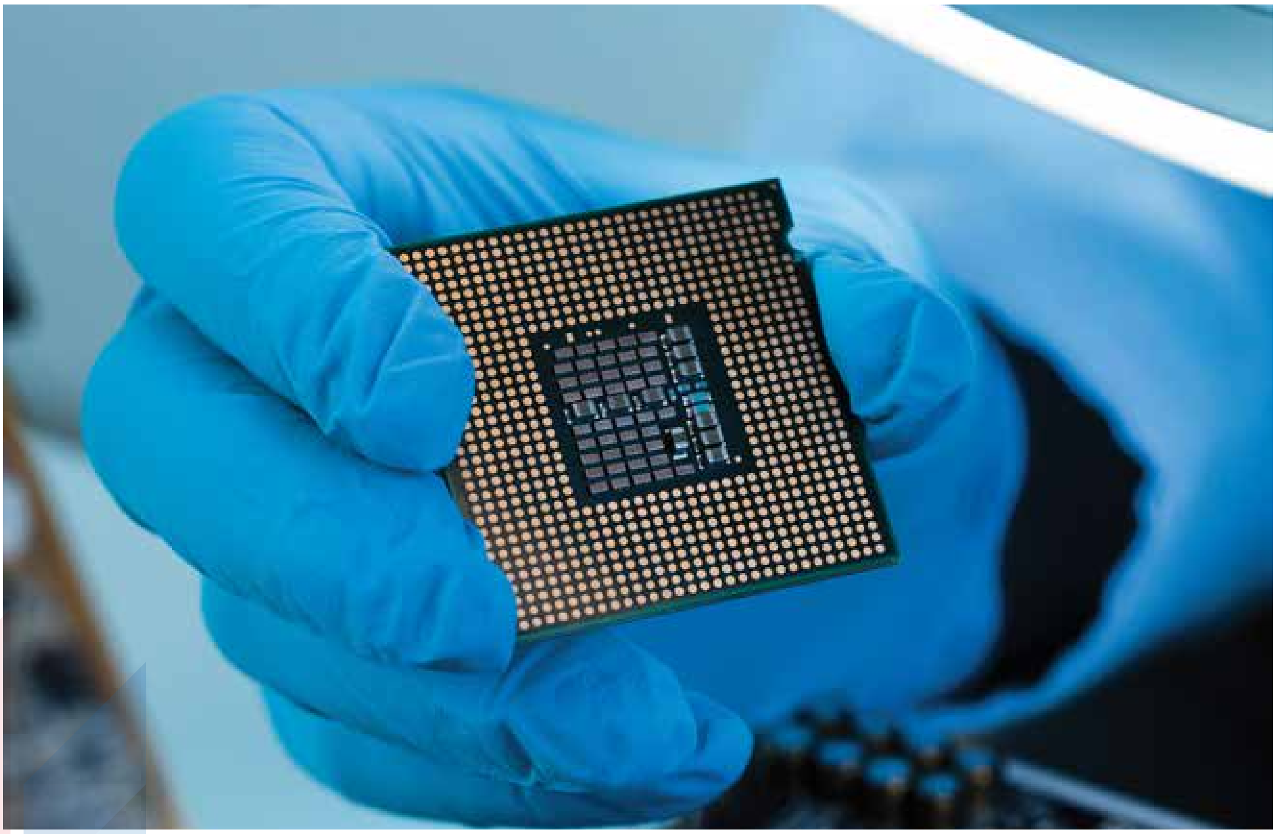
Exhibit 2: global Semiconductor market value by vertical, indicative, $billion



The importance on application of semiconductors has increased, so has the economic and geopolitical importance for the semiconductor industry. Today, the semiconductor industry contributes to nearly $2.3 trillion of the world's GDP. This includes both upstream & downstream contributions to economic value. The past few decades have lead to the success of the indstry due toglobalisation — countries specialised in specific parts of the supply chain, relying on trade by comparative advantage to drive cost efficiencies. Hypothetically, had countries relied on “self-sufficient” local supply chains, it would have resulted in at least an additional 1 trillion USD in upfront investment and adversely impacted the affordability of semiconductors. The economics of the semiconductor supply chain makes it a viable geopolitical tool.

Manufacturing facilities, equipment, and materials are concentrated in a handful of countries. Consequently, nation-states can deny their competitors access to parts of this supply chain in furtherance of their geopolitical objectives. This is why semiconductors have become a major front in the US-China trade war. Trade bans and export controls are increasingly been used bythe US to exhibit power & thwart China's attempts to achieve selfsufficiency in semiconductors. Moreover, Taiwan remains the most significant bottleneck in the global semiconductor supply chain.

Semiconductor chips are an integral part in the smooth functioning of modern-day electronic devices such as smart phones, smart TVs, laptops, washing machines, advanced vehicles, etc. They are indispensable in our daily lives, in the long term, as chips play an even bigger role in an ever-expanding array of products, global demand for chips will continue to rise. Thus, it is important to understand the value chain, leading to the global shortage.



3. Semiconductor Value Chain

Semiconductors can broadly be divided into four categories - integrated circuits (eg. a Qualcomm Snapdragon chip), Optoelectronics (eg. LED's), discrete components (eg. Single transistors), and sensors (eg. CMOS image sensors for cameras). Of the four, integrated circuits (ICs) account for 83% of the total economic value. These ICs are further divided into four categories — memory, logic, analog, and micro.

Leading companies

There are two models of manufacturing semiconductors

Integrated device model

Under this model, design and manufacturing both are carried out by the same company. Leading examples are Intel, Samsung, and Texas Instruments.

Fab foundry model

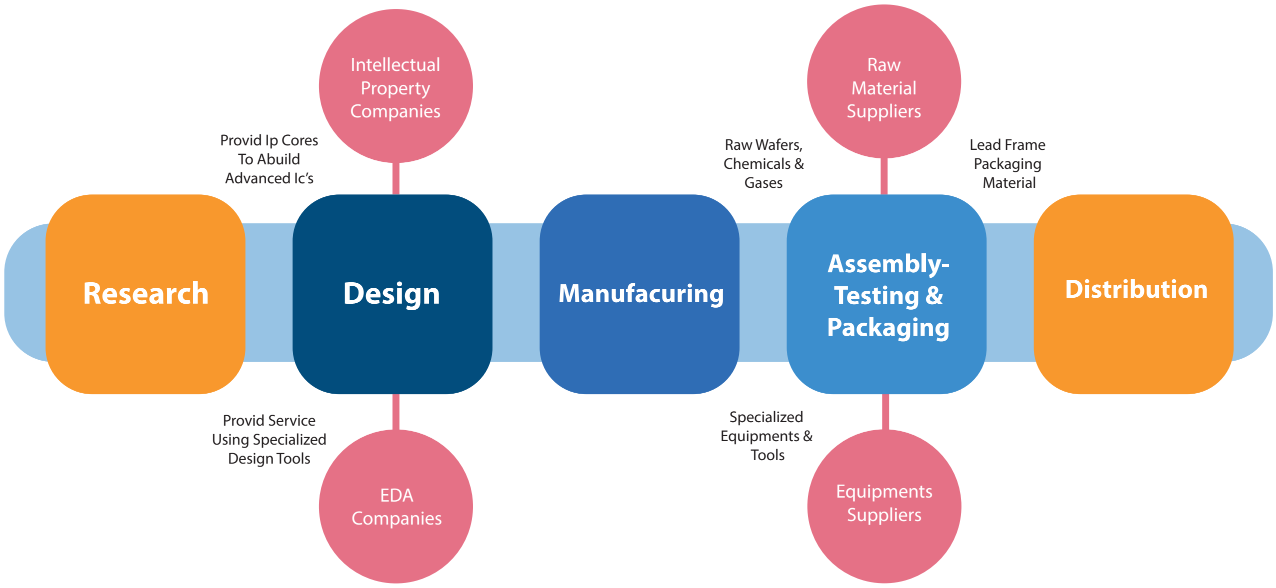
An integrated semiconductor supply chain that involves thousands of companies, millions of people, and billions of dollars. The chain can be broken up into stages which happen across the globe, better known as the foundry model.

Research

Pre-production efforts to increase processing capability & speed at a reduced cost. The focus is on surpassing the physical limits of semiconductor materials. Highly capital intensive (~25% of sales value).

Design

Semiconductor chip designs are created for specific or generaldevice usage. Highly skill intensive, access to expensive design software's and IP blocks. R&D costs are high in this stage as well.



Manufacturing (Front End)

Silicon wafers are processed through an extensive series of manufacturing steps then diced into multiple chips (also called dies or devices).

Manufacturing (Back End)

Chips are layered and assembled into packages that can be mounted onto circuit boards. Packaged chips are then tested under different electrical and temperature conditions. Highly capital intensive, access to manufacturing equipment, chemicals & wafer facilities, need to constantly upgrade facilities as per technological advancement.

Assembly and Testing

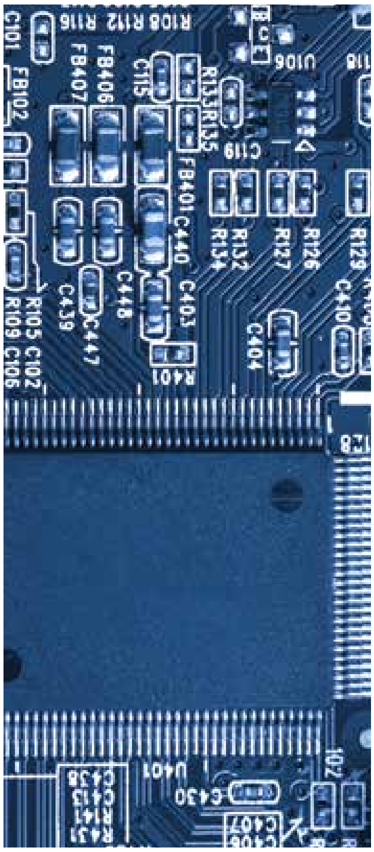
Chips are integrated by electronics and equipment manufacturers to create end products for consumers. Highly labour-intensive, less reliant on tech, high volume low margins, could be proved redundant by fabs creating wafer-level packaging. End of production.

Distribution:

End products are shipped to companies, retailer, and consumers worldwide. The entire process, from starting design and production to end product integration, takes months. Needs an efficient logistics network.

The production process for semiconductors, and in particular ICs, consists of three distinct steps: design, fabrication and assembly and test. Whether a company provides all production steps or focuses solely on a single production step for the sake of economic efficiency depends on the firm's business model.

Integrated device manufacturers (IDMs), such as Intel or Samsung, perform all three steps in-house. Historically, this has been the dominant business model of the semiconductor industry. But with the increasing complexity and costs associated with design and fabrication of leading-edge ICs, many companies now specialize in single production steps. Companies that only design chips and rely on contract chip makers for fabrication are called fabless. These companies lack a fabrication plant. Fabless companies, such as Qualcomm (US), Nvidia (US) and HiSilicon (China), therefore, closely collaborate with foundries that manufacture chips in their fabrication plants (fabs). After the IC has been fabricated by the foundry, the chip must be tested, assembled and packaged to protect it from damage. This last step is done either by the foundry itself or by outsourced semiconductor assembly and test (OSAT) companies.

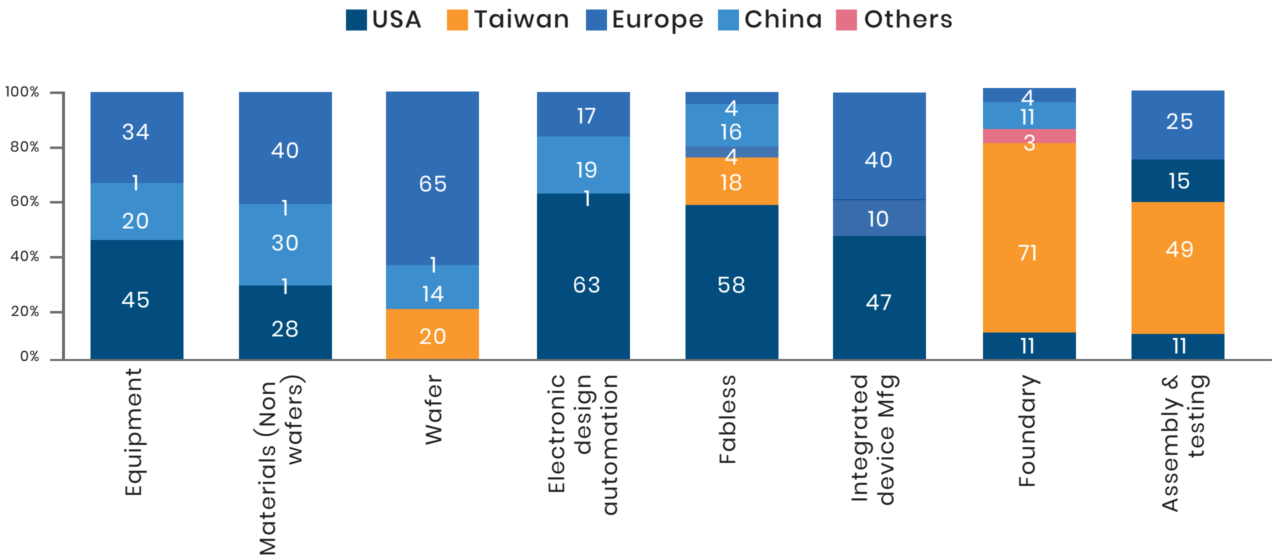


Companies that test , assemble and package chips on contract are called outsourced semiconductor assembly and test (OSAT) companies

A good example of how the different business models work together are processors from Intel and AMD. Intel is an IDM. Therefore, it designs, produces and assembles its processors (mostly) by itself. In contrast, AMD processors are designed by AMD (fabless), produced in TSMC's fabs in Taiwan (foundry) and then packaged by SPIL (OSAT). AMD and Intel produce general - purpose processors (x86), but their business models, and thus, value chains, differ.

The following chart reflects how the different countries are contributing to the global value chain: how US continues to be the leader in the equipment and electronic design automation, however, the US has lost its foundry and assembly and testing business to Taiwan and others over a period of time.

- **Fabless (chip designing) - AMD (USA), Qualcomm (USA)**
- **Foundry (contract manufacturing)- TSMC (Taiwan), SMIC (China), Samsung (S Korea)**
- **Assembly, test, packaging - Amkor (S Korea), SPIL (Taiwan)**



4. Chipmaking: It's not Rocket Science—It's much more difficult

Although the economics of the chip makers are not best favourable, but a nationwide focus in developing a self sufficient model has been taken up as a national priority across the globe. China has called chip independence a top national priority in its latest five-year plan, while U.S. President Joe Biden has vowed to build a secure American supply chain by reviving domestic manufacturing. The CHIPS Act was passed in 2021 which authorises investments in domestic chip manufacturing along with the FABs Act which would establish a semiconductor investment credit.Even the European Union is mulling measures to make its own chips. But success is anything but assured.

Manufacturing a chip typically takes more than three months and involves giant factories, dust-free rooms, multi-million-dollar machines, molten tin and lasers. The end goal is to transform wafers of silicon—an element extracted from plain sand—into a network of billions of tiny switches called transistors that form the basis of the circuitry that will eventually give a phone, computer, car, washing machine or satellite crucial capabilities.

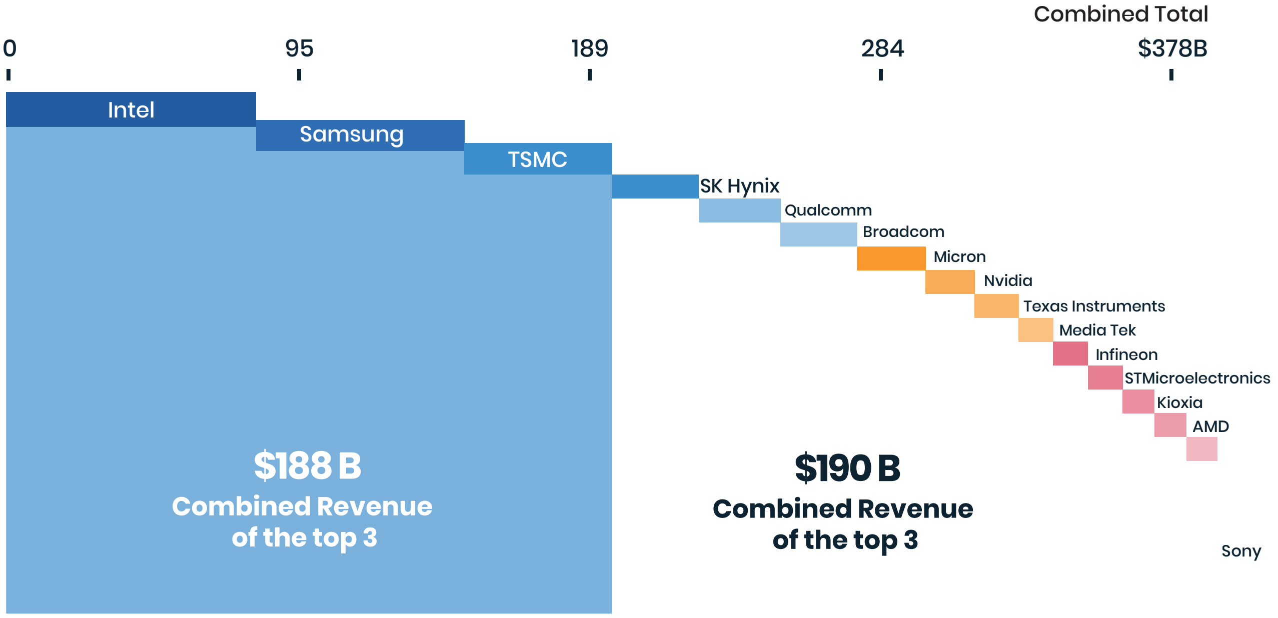
For putting silicon into chipmaking machines, a very clean room is needed. Individual transistors are many times smaller than a virus. Just one speck of dust can cause havoc and millions of dollars of wasted effort. To mitigate this risk, chipmakers house their machines in rooms that essentially have no dust. The wafers of silicon can't be touched by humans or exposed to the air. They travel between machines in cartridges carried by robots that run on tracks in the ceiling. They only emerge from the safety of those cartridges when they're inside the machines and it's time for a key step in the process.

They require continuous power supply as they run 24x7. Moreover, an entry-level factory consumes more than 20 million litres of ultra-pure water per day. Chip plants run 24 hours a day, seven days a week. They do that for one reason: cost. Building an entry-level factory that produces 50,000 wafers per month costs about $15 billion. Most of this is spent on specialized equipment—a market that exceeded $60 billion in sales for the first time in 2020.

Once you spend all that money building giant facilities, they become obsolete in five years or less. To avoid losing money, chipmakers must generate $3 billion in profit from each plant. But now only the biggest companies, in particular the top three that combined generated $188 billion in revenue last year, can afford to build multiple plants.

Big-Fish Industry

Intel, Samsung and TSMC grenrated almost as much revenue in 2020 as the next 12 largest chipmakers combined.



Note: figures for Samsung and Sony include their chipmaking businesses only.
Sources: Company data compiled by bloomberg; IDC

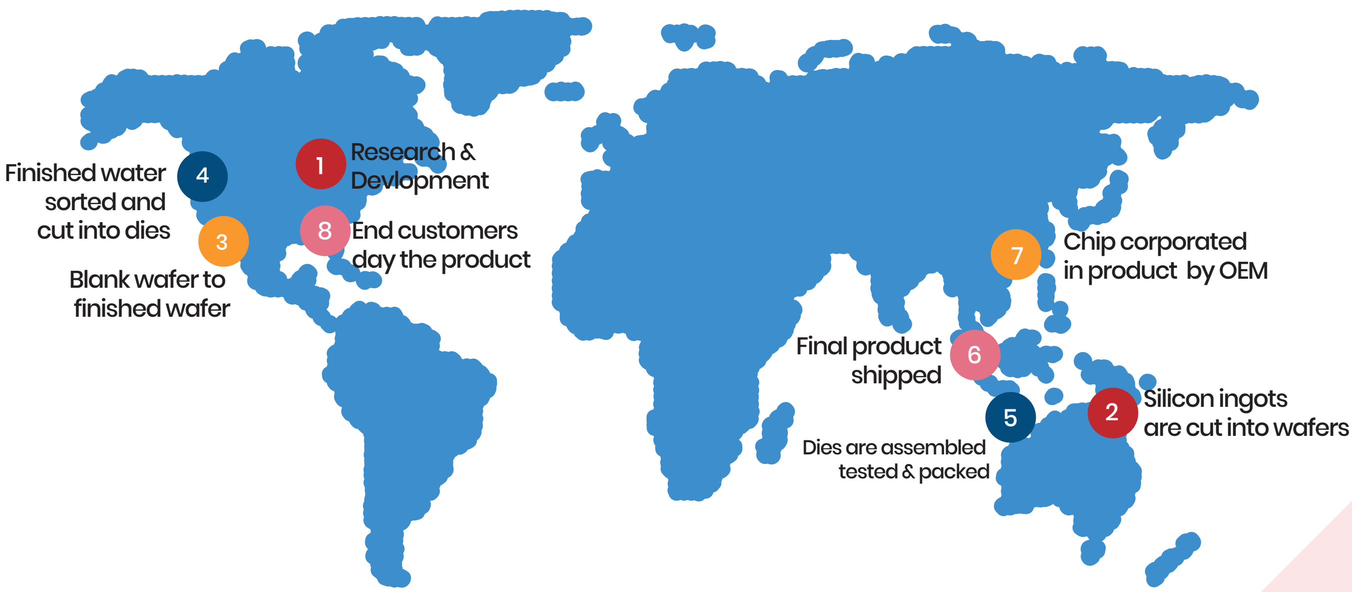
The brutal economics of the industry mean fewer companies can afford to keep up. Most of the roughly 1.4 billion smartphone processors shipped each year are made by TSMC. Intel has 80% of the market for computer processors. Samsung dominates in memory chips. For everyone else, including China, it's not easy to break in.

5. Around the world in 112 days – Semiconductor Journey

The value chain is defined by a few key countries – United States, Taiwan, South Korea, Japan, Europe and, increasingly, China. No region has the entire production stack in its own territory since companies often specialize on particular process steps (design, fabrication, assembly) or technologies (memory chips, processors, etc.) in pursuit of economic efficiency. Ultimately, no region has achieved "strategic autonomy", "technological sovereignty" or "self-sufficiency" in semiconductors.

Given the complexity and resultant costs of IC production, no country is self - sufficient in semiconductors. Instead, semiconductor powers specialise in certain parts of the value chain. A typical semiconductor production process spans 4+ countries, 3+ trips around the world, 25000 miles travelled 100 days throughput time (TPT)& 12 days intransit. Both manufacturing & assembly are highly concentrated in East Asia - vulnerable to political risks & natural disasters.

Given below is the flow of the value chain to better understanding of the value chain.



The interdependence can be explained with the example of Apple's iPhone – the largest consumer of semis globally – to illustrate why both east and west are critical and irreplaceable parts of the value chain.

The iPhone supply chain includes:

- Main processors and complementary analog, RF, memory designe in US/ Europe/Korea/Japan;

THE APPLE WAY

UNDERSTANDING THE SEMICONDUCTOR JOURNEY, THE APPLE I-PHONE WAY

- Using design tools from US based EDA vendors;
- Manufactured in part by TSMC in Taiwan and GFS in US/Europe/Singapore using many raw materials/wafers from Japan/Russia and equipment designed in US/Europe/Japan;
- Assembled and tested in Malaysia/Philippines;
- Assembled into finished electronics in China/other parts of Asia.

Separately, Asia is a larger customer for iPhones than the US, with many customers of iPhones part of the emerging middle class that is engaged in the above value chain. Similar value chain examples in other electronics products - PCs, servers, auto/industrial and consumer electronics make the same point – one cannot easily decouple designers, producers and buyers of semis in a practical timeframe.

6. Global Chip Shortage

The shortage took hold in 2020, largely due to significant swings in demand caused by the COVID-19 pandemic. Customers had reduced production and chip purchases as the virus spread across the globe. The lockdown across different countries and regions early 2020, significantly interrupted semiconductor supply. Chipmakers, meanwhile, saw surging demand for semiconductors in other sectors used to enable remote healthcare, work-at-home, and virtual learning, which were needed during the pandemic. The shortage continues to affect a range of downstream sectors, including cars, consumer electronics, home appliances, industrial robotics, and many other key goods.

The semiconductor industry has worked diligently to ramp up production to meet renewed demand during the shortage. Semiconductor industry worked to classify its operations as "essential" so they could continue operations. For all quarters during the shortage, the industry has run fab utilization well above the normal utilization level of 80%. In a cyclical market turn, demand runs higher, front-end semiconductor fabrication facilities, or fabs, have functioned above 80% capacity, with few individual fabs running as high as between 90-100%. Higher fab utilization will increase chip output and help the industry to meet the increased demand in the market. In short, the semiconductor industry has done precisely what is in its power to do in the short-term to meet the increase in demand, which is to expand fab utilization and run fabs at their highest capacity possible.

However, supply would continue to be a top issue of 2022. Next year will not be an identical repeat of 2021. In contrast, the expectation is that the severity and duration of the chip shortage, and its economic ramifications, would be less pronounced because of increased capacity, and supply chain improvements by the chipmakers, distributors. Adding new capacity began in 2021 but it won't be operational until 2023 at the earliest, some new capacity additions were already in the pipeline before the shortage.

The shortage is a reminder of the essential role semiconductors play in so many critical areas of society, including transportation. This trend will only continue as demand for electronics and connectivity grows. In the auto space, new vehicles increasingly rely on chips for fuel efficiency, safety, and other features. The expected growth in electric cars will only further this reliance.

7. Trends Post the Shortage

Financial Outcome	Capex	US Position	Niche Focused approach	Talent Crunch

Financial Outcome

2021 was banner year for global semiconductor industry, with global sales of $556billion a 26% increase over 2020. World semiconductor Trade Statistics projects global semiconductor sales to grow at 8.8% surpassing $600 billion. The industry has a consensus opinion that 95% of the businesses would grow in the next few years and one third of these opinions mention revenue growth would be beyond 20%. Another cause of concern has been the rising inflation due to the geopolitical pressures across the world due to the Russia Ukraine war, liquidity tightening measures taken by central banks across. On the profitability side, chipmakers were absorbing, much of the incremental costs due to record long material lead time, rising commodity prices, logistics costs and ongoing impact costs. However, post the demand level out, chips makers would start transferring the costs. In August 2021, TSMC was planning to hike its production cost by 20%.

Capex

On the capex side, TSMC, Samsung, and Intel have announced plan to increases capital expenditure in 2022 with TSMC planning to spend $40 billion to $44 billion. This spending would include both equipment and software and research and development spending.

U.S. CHIPS ACT – $52 billion investment in the future

US has been at the forefront in developing technology and manufacturing chips, over a period due to globalization, the industry has spread across borders for cost advantage. Semiconductor companies are trying to build foundries in the US in an effort to reverse the U.S. based chip manufacturing.

U.S. federal government is working to pass the CHIPS Act, a $52 billion investment in the future of chip research, design and manufacturing. This legislation is intended to maintain U.S leadership in an industry that is arguably the most critical component of our rapidly digitizing economy.

Niche Focused approach

Chips makers are focusing on unique application requirements, a sopposed to products that can be sold to multiple applications and users. Organisations have become more focused towards end markets such as automotive, communications or consumer electronics. Applications for automotive sector surpassed Internet of Things (IoT) are now contributing second highest revenues after Wireless communication.

Thus, if organisations start focusing on end users, then semiconductor companies will have to realign its supply of raw materials. As automotive will utilize more chips for every new model, especially for electric vehicles. This will result in lower material disruptions due to product availability gap as companies would be able to forecast their raw material better. Automotive focus would move from Internal combustion engine (ICE) to hybrid to electric. Hybrid and fully electric vehicles will have twice the semiconductor application compared to ICE. Later, fully autonomous cars with LiDAR sensors will have 8-10 times as much semiconductor content as nonautonomous vehicles.

Talent Crunch

A widespread post-pandemic worker shortage prevails, propelled in part by the "Great Resignation," in which more than 4 million American workers quit their jobs in August 2021 alone. The semiconductor industry also felt the pinch due four mega trends;

- Global semi-industry revenues by the end of 2022 will be almost 50% higher than at the end of 2019.
- Recent growth has exhausted the talent pool in Taiwan and South Korea which was well developed post the talent shortages in 2017.
- Over time, building more local chip fabrication plants (aka fabs) in the United States, China, Singapore, Israel, and other countries will lead to chip companies exploring a broader, deeper pool oftalent.
- The mix of job skills is changing, and the industry has a strong need for software skills. Industry estimates suggests that global electronic design automation (EDA) software revenue is anticipated to double from approximately $10 billion in 2020 to $19 billion by 2027.The need for software hires is likely to follow a similar trend.

8. India on Global Semiconductor map

During 2020, showed the world the growing need and dependency on semiconductor technology. This caught attention of the countries that are behind in the semiconductor fabrication, assembly, and testing. Specifically, India, which is a 100% importer of the semiconductor products/devices, spending about $24 billion annually. Ironically, India is a leading chip designer with 30,000 engineers working in field designing 3,000 chips. Our semiconductor design market was worth more than $33 billion in 2020.

Over the years, many global semiconductor giants have established their chip development R&D centres in India. This has built a critical mass of talent in semiconductor design and a vibrant domestic design services market. However, indigenous design IP creation is muted. India has a cost advantage vis-à-vis western countries due to lower salaries of design staff; however, higher power and capital costs remain impediments to development of the ecosystem.

According to the India Electronics & Semiconductor Association, the Indian Electronic System Design and Manufacturing (ESDM) market will grow from US$ 76 billion in 2013 to US$ 400 billion by 2020. Consumption of semiconductors, in the meantime, has also steadily climbed. According to a report by NOVONOUS, the domestic semiconductor industry is estimated to grow from US$ 10.02 billion in 2013 to US$ 52.58 billion in 2020 at a Compound Annual Growth Rate (CAGR) of 26.72%.

Large Domestic Market	Indian Import Dependence	Strong IC Design Ecosystem	A Few State Led R&D IC Manufacturing
• Domestic design market at US $52.58 in 2020 billion from US $15 billion in 2015	• Electronics imports worth 49 billion USD(2019) mostly from countries such as US, Japan, China & Taiwan	• Value add worth 33.1 billion USD in 2020 by design houses based in India	• SCL, SITAR & IIT Bombay . Mature nodes, Mainly used in R&D in defense and space. Pvt sector missing

Indian R&D/ fabrication existence: It is not that India does not have any semiconductor fabrication, assembly, and testing facilities. All of the existing semiconductor fabrication facilities are owned and operated by the government of India for critical infrastructures needs like defense and space technology Semi-Conductor Laboratory (SCL) is equipped for fabrication, it also has packaging and testing capability. Bharat Electronics Limited (BEL) is a public sector company that has electronic manufacturing units but not semiconductor fabrication. Society For Integrated Circuit Technology and Applied Research (SITAR) has a 6-inch wafer processing capa city but the technology node is not advanced. IIT Bombay Nanofabrication Facility (IITBNF) is another lab that has the equipment to enable 2-inch, 4-inch, and 8-inch silicon wafers, which are primarily used for research and development activities only.

Few private companies are in semiconductor assembly and testing but not into fabrication

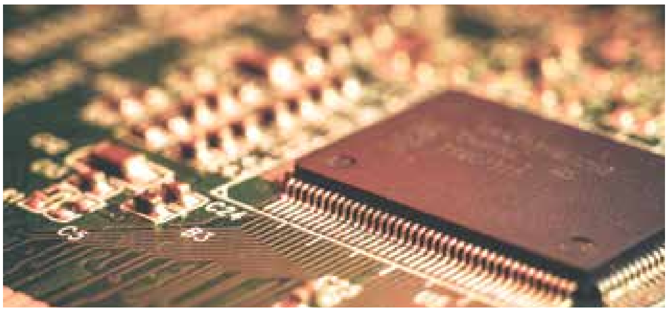
SPEL Semiconductor Limited is capable of providing turnkey post-fabrication testing and assembly solutions. ChipTest Engineering Private Limited is another (owned by SPEL's parent company) assembly and testing solution provider with an office in Asia-Pacific apart from India. Tessolve Semiconductor also provides semiconductor testing and product engineering related services.

Above data shows that the in-house semiconductor fabrication, assembly, and testing is yet to expand in India. There is a huge gap between supply and demand with respect to semiconductor manufacturing. On the other side, the semiconductor design industry in India is thriving with almost all of the top design only to ESDM design houses having R&D centers that are involved in niche semiconductor product design. Every major semiconductor company, T1, Broadcom, Intel, Qualcomm, Western Digital, Samsung & Huawei) has a presence in India.

In-house semiconductor fabrication, assembly, and testing is yet to expand in India.

IAs per Satya Gupta, Chairman of the India Electronic Semiconductor Association (IESA), Fabless chip makers design and sell their own chips, but outsource the manufacturing of chips. Qualcomm, Nvidia and AMD do that. Intel is considering doing that. More than 90% of the semiconductor companies have their research in India where cutting-edge chip development takes place. Semiconductor alone produces $US2.5 billion in revenue. Another $US 20 billion can come from electronics products and embedded systems. The total employment generated can be 6 lakhs.

Building foundries is difficult, even for superpowers, thus the viable strategy for India is to go the fabless route.



India has 1.9 million students enrolled in computer science, electronics & electrical engineering streams across India. IIT, NIT & IISc students are trained in VLSI design & related areas through the Special Man power Development Programme (SMDP) and Technical Education Quality Improvement Program (TEQIP) of the Government of India. Innovations in chip design to meet local needs (such as dealing with power fluctuations & limited signal transmission range in telecom) can create demand in India and emerging economies (such as Latin America & Africa). The large potential consumer base for white goods (domestic & industrial appliances) and automotive.

9. India's Previous Attempt at Semiconductor Manufacturing

In 1984, when Taiwan and China were yet to move in semiconductor space, the Indian company SCL, an integrated device 100% state owned manufacturer had an advantage, as rest of the world was not far too ahead of them. SCL had some financial capital, smart people, and government buy in and acquired technology from American Microsystems Inc and Hitachi. AMI was nothing like Intel or Motorola, but it was a good start. However, the dream of Indian becoming a global manufacturer was put to and end with a devastating fire outbreak in 1989. It took 7-8 years, to restart the production. By then, new entrants like TSMC (which was founded in 1987) and Samsung had entered the race. And they quickly raced ahead of the rest of the world, capturing critical global market share and scale. India lost untold amounts of progress.

Regardless, the Indian government has since attempted to revive the country's semiconductor manufacturing efforts. 2006, when the country announced a $3 billion "Fab City" project for manufacturing. AMD had been interested in putting an assembly and test facility there until bad industry conditions shut it down.

In 2014, India approved a proposal from two investor groups to build fabs in India. Both projects together would cost about $10 billion. The government would have provided ample financial support - up to 25% of the total cost in interest-free loans, tax breaks and subsidies.

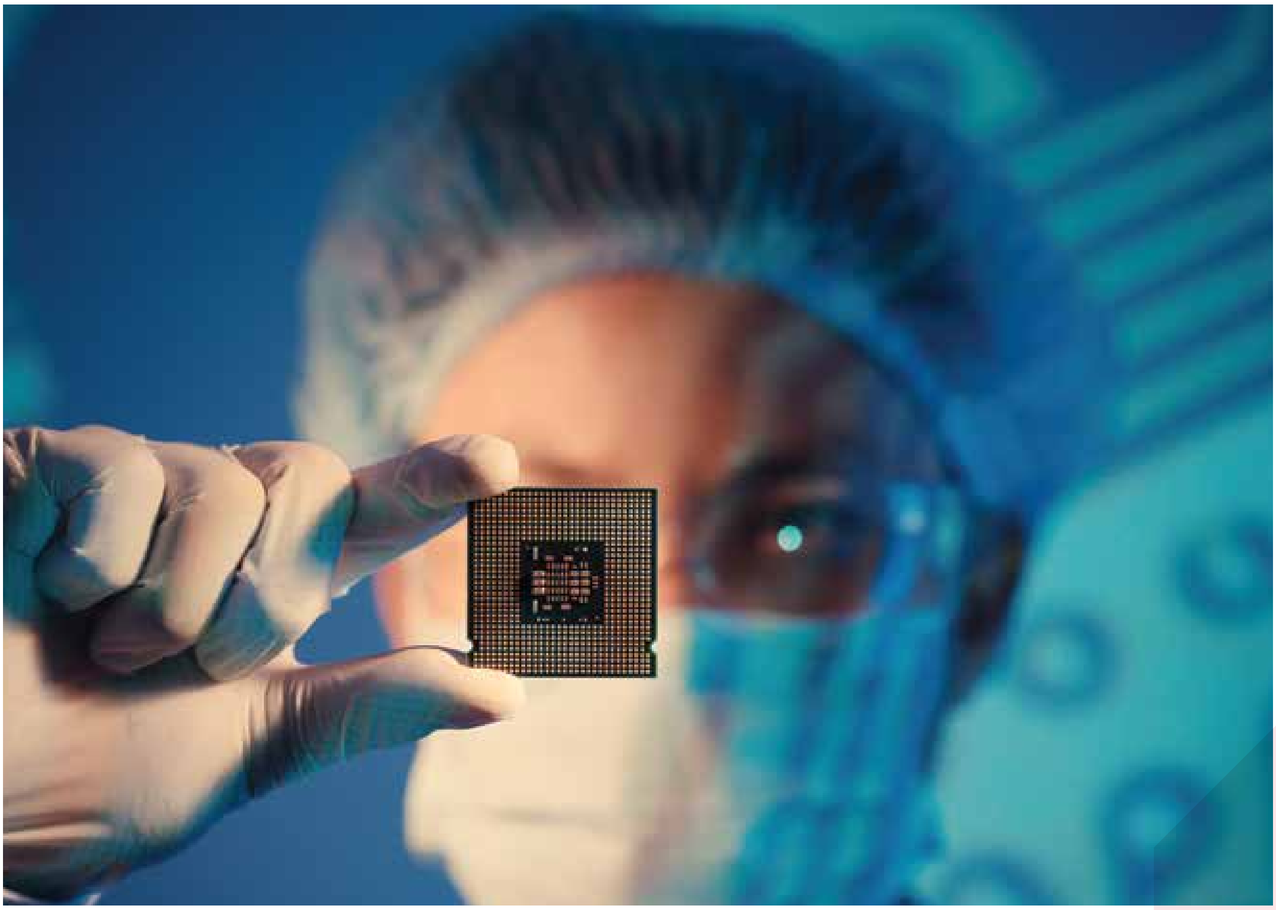
Indian government approved projects worth $10billion in 2014, including interest free loans, tax breaks and subsidies.

The first consortium had some notable names - Jaiprakash or JP Associates Ltd, Israel's TowerJazz, and IBM. But JP associates pulled out of the project as the company had a lot of debt. The second consortia were led by a company called Hindustan Semiconductor Manufacturing Corporation or HSMC. The investor consortium had tapped chipmaking expertise from European chipmaker STMicroelectronics and Malaysian state-operator Silterra. This second team also did not pan out. In 2019, the government cancelled HSMC's 2-year-old letter of intent.

“Companies in China and Taiwan have had a lot of government support over the last couple of decades to foster an ecosystem, which consists of materials, machinery, manufacturing, testing, packaging, and sales.

It is a complete ecosystem that does not exist yet in India. In fact, the Indian go vernment tried one initiative called the HSMC (Hindustan Semiconductor Manufacturing Corporation), like the TSMC (Taiwan Semiconductor Manufaturing Copany), which did not take off—based on the need for heavy initial investment and delayed return on investment,” says Ganesh Suryanarayanan; CTO Myelin Foundry Pvt. Ltd.

Thus, India had made a progressing start, till disaster struck, and hasn’t recovered since. Thus, despite of India being a semiconductor desig powerhouse, designing some of the most advanced chips in the world. But once those designs are completed, they are sent to the United States, China, South Korea or Taiwan to fabricate.



10. Indian Government's US$10 Billion Supportmap

In 2020, India's automotive component maker Bosch declared in early December, that the company was facing severe shortage of imported micro-processors (semiconductors), leading to reduced ability to deliver to the automotive market demand in India. Mahindra & Mahindra said it was bracing itself for after - effects of the disruption at Bosch. Thus, disruption in supply of even a single part in the $120 billion automotive industry can bring the entire sector to a standstill. "Operations of the company in the automotive sector will be affected by global supply shortage ofmicro-processors (semiconductors) used in electronic control units (ECUs) which are supplied by Bosch" they said. Despite strong demand, Indian carmakers are estimated to lose sales of 5 lakh units in FY22 due to chip shortage, according to ICRA India is now the world's biggest smartphone manufacturer after China. However, its heavy reliance on imported components is worrisome. The industry imported components worth $50 billion in 2019. Local electronics consumption is expected to touch $400 billion by 2020, which translates into a chip market of between $50 billion and $60 billion. "By 2020, our electronics import bill could be larger than the oil import bill," says Ajay Chowdhry, chairman, HCL Infosystems.

Aware of the dangers of such high import dependence, the government has rolled out ambitious production-linked incentive schemes to encourage production of a host of these components in the country. And in its next step to make the country a global hub for electronics production, the government has approved a $10 billion incentive package to semiconductor and display manufacturers. The Central Government has also declared that it will work closely with state governments to provide the right infrastructure for fabrication plants. Now the plan is to make India self-sufficient in production of semiconductor chips that go into phones, computers, cars and everyday electronics such as washing machines, TVs and refrigerators.

11. Semiconductors - PLI Scheme Highlights

The program aims to provide attractive incentive support to companies consortia that are engaged in Silicon Semiconductor Fabs, Display Fabs, Compound Semiconductors / Silicon Photonics / Sensors (including MEMS) Fabs, Semiconductor Packaging (ATMP / OSAT) and Semiconductor Design. Following broad incentives have been approved for the development of semiconductors and display manufacturing ecosystem in India:

Semiconductor Fabs and Display Fabs

Fiscal support of up to 50% of project cost on pari-passu basis to applicants who are found eligible and have the technology as well as capacity to execute such highly capital and resource intensive projects. Government of India will work closely with the State Governments to establish High-Tech Clusters with requisite infrastructure in terms of land, semiconductor grade water, high quality power, logistics and research ecosystem to approve applications for setting up at least two greenfield Semiconductor Fabs and two Display Fabs in the country.

Semi-conductor Laboratory (SCL)

Union Cabinet has also approved that Ministry of Electronics and Information Technology will take requisite steps for modernization and commercialization of Semi-conductor Laboratory (SCL), Mohali. Meity will explore the possibility for the Joint Venture of SCL with a commercial fab partner to modernize the brownfield fab facility.

Compound Semiconductors / Silicon Photonics / Sensors (including MEMS) Fabs and Semiconductor ATMP / OSAT Units

shall extend fiscal support of 30% of capital expenditure to approved units. At least 15 such units of Compound Semiconductors and Semiconductor Packaging are expected to be established with Government support under this scheme.

Semiconductor Design Companies

The Design Linked Incentive (DLI) Scheme shall extend product design linked incentive of up to 50% of eligible expenditure and product deployment linked incentive of 6% - 4% on net sales for five years. Support will be provided to 100 domestic companies of semiconductor design for Integrated Circuits (ICs), Chipsets, System on Chips (SoCs), Systems & IP Cores and semiconductor linked design and facilitating the growth of not less than 20 such companies which can achieve turnover of more than Rs.1500 crore in the coming five years. Vedanta Foxconn JV, IGSS Ventures, and ISMC have proposed to set up electronic chip manufacturing plants with investments totaling $13.6 billion and have sought the support of $5.6 billion from the Centre under the Rs 76,000 crore Scheme. The applications have been received for setting up 28 nm to 65nm Semiconductor Fabs with a capacity of approx. 120,000 wafers per month. ISMC is the proposal by Abu Dhabi-based Next Orbit Ventures, representing a consortium of investors, for establishing a semiconductor fab factory in India. The consortium is likely to have submitted an application for the Analog Fab in technology partnership with Israel-based Tower semiconductors (which is now in the process of being acquired by Intel Foundry Services). There are other companies who have applied for the PLI scheme under the different categories along with the ones mentioned.

12. Roadmap to $5 trillion Indian economy by 2025

It is envisaged that the scheme would bring an investment of around $22 billion leading to the employment of over 1,35,000 in the next four years. The Government is also planning to establish an "India Semiconductor Mission" to drive long-term strategies for the sustainable development of the chip and display industry.

Another positive deviation from subsidizing incubating IP creation in India through a Government sponsored agency has been to offer a large part of the incentive on successful implementation of the design by way of production linked incentive which will incentivize companies/start-ups based on success rather than intent.

The second phase of promoting India as a manufacturing destination has been set in motion through the scheme where chip manufacturers shall benefit from the overwhelming response and demand created by the first phase of PLI. Further, with substantial fiscal incentives coupled with non-fiscal benefits, it is likely that India's semiconductor dream is likely to be fulfilled and shall contribute significantly to achieving a $1 trillion digital economy and a $5 trillion GDP by 2025 and have a multiplier effect on allied sectors such as electronics, telecom, automotive, railways, electrical products etc.

13. Indian Way Forward

Global companies like Intel had all the steps of the end chip in house in the initial days, however, as Moore's law application, smaller the chips became in size, the value chain got characterized by deep interdependencies. High divisions of labour and close collaboration throughout the entire production process became the new business models for the semiconductor companies. US fabless companies rely on Taiwanese foundries to manufacture their chips. The foundries themselves rely on equipment, chemicals and silicon wafers from the US, Europe and Japan. The semiconductor value chain is thus highly innovative and efficient but not resilient against external shocks.

with substantial fiscal incentives coupled with non-fiscal benefits, it is likely that India's semiconductor dream is likely to be fulfilled and shall contribute significantly to achieving a $1 trillion digital economy and a $5 trillion GDP by 2025 and have a multiplier effect on allied sectors such as electronics, telecom, automotive, railways, electrical products etc.

During 2020, showed the world the growing need and dependency on semiconductor technology. This caught attention of the countries that are behind in the semiconductor fabrication, assembly, and testing. Specifically, India, which is a 100% importer of the semiconductor products/devices, spending about $24 billion annually. Ironically, India is a leading chip designer with 30,000 engineers working in field designing 3,000 chips. Our semiconductor design market was worth more than $33 billion in 2020. Over the years, many global semiconductor giants have established their chip development R&D centres in India. This has built a critical mass of talent in Companies are looking to diversify their centres. Factoring the quantum of IP produced for global semiconductor companies by Indians, this respect & trust commanded by Indian firms can make them attractive as partners for scalability. Also considering the China plus one model, fabless companies & integrated device manufacturers are looking to diversify their ATMP partners. Two fires at a package plant in Taiwan in 2020 & 2021 exacerbated the global capacity shortage for ATMP services. These opportunities can be capitalized for the initials.

Emerging Technologies

like cloud computing, machine learning, connected cars/automotive, IoT and AI will continue to drive the need for a new breed of chips gives an opportunity to shift focus from improving silicon performance to increasing learning ability & decreasing power usage. Government policies and market shifts from 4G to 5G can create newer opportunities. These can be used to build technology capabilities.

Focused Local Approach

nnovations in chip design to meet local needs (such as dealing with power fluctuations & limited signal transmission range in telecom) can create demand in India and emerging economies (such as Latin America & Africa). The large potential consumer base for white goods (domestic & industrial appliances) and automotive. New Government-industry initiatives such as the Semiconductor Fabless Accelerator Lab (SFAL) in Karnataka are reducing entry barriers for fabless companies Electronic manufacturing has found its roots, the backbone to its growth would be the development of the semiconductor value chain. If high end digital fab cannot be initiated at forefront, specialty, R&D and analogue fabs can be the focus. SMIC in China is one such example. They started with the world's crappiest chips, but getting somewhere now. As semiconductor innovation and global chip demand continue their inextricable rise, government and industry needs to work together to establish India on the global map.

14. Semiconductors: Automobile Industry

As sated earlier in this report, wireless communication, data storage and Automobile, would be the top three industries driving the demand for semiconductors. India Will Be the World's Third-Largest Automobile Manufacturer with a market Size of $US300 Billion By 2026. A very crucial and vital role will be played by the Original Equipment Manufacturers (OEMs) as India is already home to all of the top automobile manufacturers that are evenly spread across different clusters and states.

India has set an ambitious goal to move to alternate-fuels for automotive. First step is 100% electric cars only by 2030. This also means increased demand for semiconductor products that make up the smart Electronic Component Units to enable efficient driving. The transition from BS4 to BS6 increased the demand for semiconductors since more electronics were involved, plus the boom in features in cars (safety and convenience) added to that demand. Reports suggest that the semiconductor market today stands at $25 billion in India and is expected to grow to $100 billion by 2025.

As per industry reports, the cost contribution of automotive electronics in 2007 was 20% and in 2017 it increases to 40%, and by 2030 it is expected to be 50%. Smart mobility is changing the auto industry landscape the trend is set to go only upwards for further application. Alternate fuel will demand more smart semiconductor solutions and many of these are already in use. "While the semiconductor shortage appears to be a challenge, it also brings in an opportunity. Of course, semiconductor manufacturing requires very huge investments. The Indian automobile industry alone can-not assure full viability of such an investment in semiconductor projects. Hence, there is a need for consolidation across sectors,", SIAM President Kenichi Ayukawa, the Managing Director and CEO of Maruti Suzuki India.Thus, India cannot afford to be 100% importer of these electronic semiconductor solutions if it has to be the leader in the automobile industry in the smart mobility world.

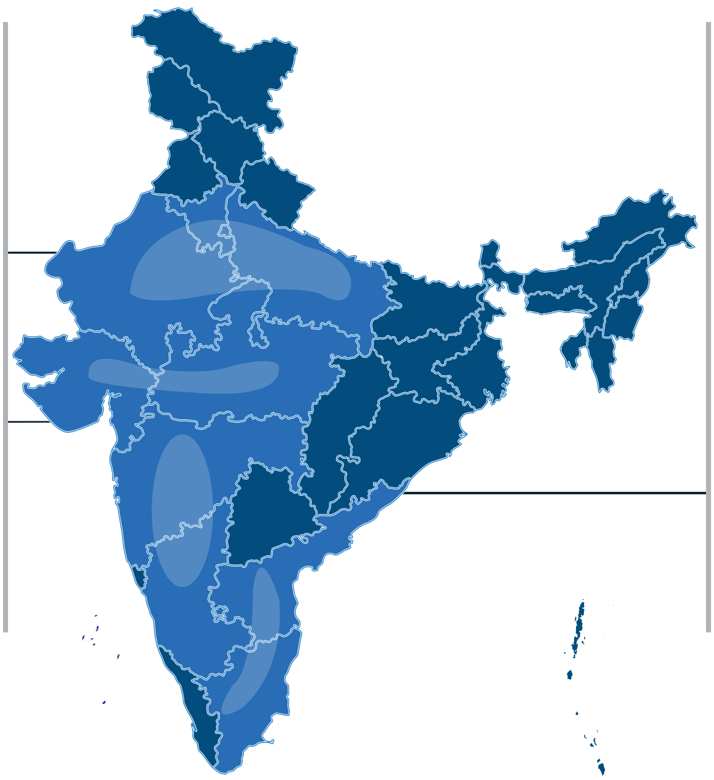
Designing of advanced automotive semiconductor chips already happens in India. The only hurdle is manufacturing and testing at large scale. The government of India is already looking to expand the local manufacturing of automobile equipment and it is about time to enable the same for semiconductor manufacturing from automobile use. The success of automobile semiconductor manufacturing in India will surely enable the growth of end-to-end semiconductor manufacturing for different domains.

From starting production to integrating in finished products, semiconductor production can take months.

Components for a chip can travel more than 25,000 miles ny the time of final product integration.

Gujrat - Madhya Pradesh
CNH Industrial
Ford
Honda Motorcycle and Scooter
Jhon Deere
SAIC Motors
TATA Motors
VECV

Maharashtra - Kranataka
Bajaj Auto
Daimler
FCA
Force Motors
General Motors
Piaggio
Scania
Toyota
Vlokswagen
Volvo



Haryana - Rajasthan - Uttar Pradesh

Eicher
Hero MotoCorp
Honda
JCB
Maruti Suzuki
New Holland Agiculture
Yamaha

Andhra Pradesh - Tamil Nadu
Ashok Leyland
BMW
Hyundai
Isuzu
Kia Motors
Peugeot
Renault
Royal Enfield
TVS Motors
Yamaha

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