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ICEA REPORT TO ADDRESS

THE CHALLENGES & OPPORTUNITIES IN INDIAN SEMICONDUCTOR INDUSTRY

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एस. कृष्णन, आई.ए.एस.
सचिव
S. Krishnan, I.A.S.
Secretary

इलेक्ट्रॉनिकी और सूचना प्रौद्योगिकी मंत्रालय
भारत सरकार
Ministry of Electronics &
Information Technology (MeitY)
Government of India

सत्यमेव जयते

Foreword

The report prepared by ICEA is a significant for realizing India's vision in the electronics and semiconductor sector. Semiconductors have evolved into the backbone of modern digital systems, finding varied applications from smart consumer devices to critical defence installations. This report comprehensively analyses existing market conditions, cutting-edge technologies, and the policy frameworks that will shape India's future in this critical sector.

While India has made appreciable strides in electronics manufacturing, the semiconductor industry demands targeted policy actions. This report provides an invaluable blueprint that incorporates diverse aspects, from design capabilities to manufacturing. Our 'Modified Semicon India Programme' aligns perfectly with the recommendations offered, emphasizing India's potential to become a global hub in electronics manufacturing.

As we strive to create an ecosystem that is both self-reliant and globally competitive, this report stands as an invaluable guide for all stakeholders. It encapsulates the government's vision and commitment towards strengthening the semiconductor sector as a crucial part of India's wider electronics industry. By offering a multi-dimensional view, it provides a strategic pathway for steering India towards greater competitiveness and innovation in the global arena.

In summary, this report provides both the direction and the detailed road map to ensure that India not only participates in the global electronics value chain but also leads in segments that are strategic and economically significant.

Best Wishes,

(S. Krishnan)

Place: New Delhi

Dated: 27th October, 2023

आज़ादी का अमृत महोत्सव

Digital India
Power To Empower

इलेक्ट्रॉनिक्स निकेतन, 6, सी.जी.ओ. कॉम्पलेक्स, नई दिल्ली–110003 / Electronics Niketan, 6, C.G.O. Complex, New Delhi-110003
Tel. : 011-24364041 • email : secretary@meity.gov.in

Shri Pankaj Mohindroo
Chairman, India Cellular and Electronics Association (ICEA)

It is with profound respect and optimism that I present the ICEA Report to Address the Challenges and Opportunities in the Indian Semiconductor Industry, a strategic document that is the culmination of the collective intellect and unwavering commitment of ICEA towards reshaping India's electronics and semiconductor industry. The significant evolution of mobile phone manufacturing, which has leapfrogged to constitute approximately 44% of our electronics manufacturing within seven years, exemplifies the transformative growth of the semiconductor demand in India, now valued at around USD 9-10 billion for FY 2023. This paper provides a thorough policy framework designed to capture and amplify this growth for our nation.

I would like to extend my heartfelt gratitude to Mr. Ajit Manocha, President and CEO of SEMI, whose global perspective, expertise and well-considered advice have been invaluable in shaping the insights of this report. Similarly, the profound contributions of Dr. Yee-Shyi Chang, Technology Ambassador (Korea, Japan, Mainland China and Taiwan), ICEA, have provided us with a pivotal understanding that are critical for India's advancement in this sector. Their expertise has been a cornerstone in the foundation of this comprehensive report.

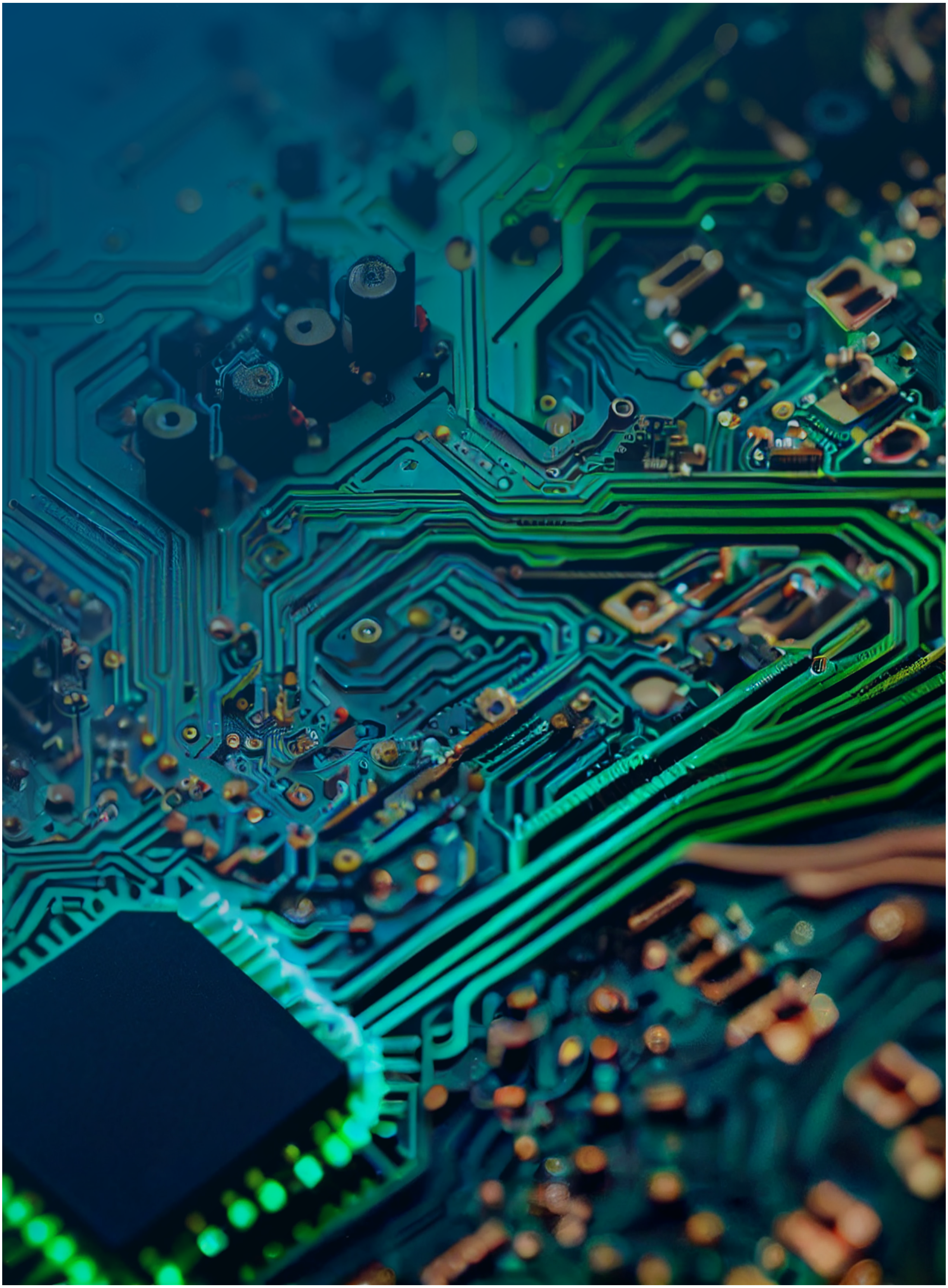
As India's electronics production scales new heights, the need for a strategic increase in domestic semiconductor production is evident. This necessitates an integrated approach that includes promoting domestic PCBA operations, circuit design, and deep value addition across electronics segments, as advocated by this report.

ICEA champions a holistic design ecosystem that considers the semiconductor industry within the larger electronics value chain. From nurturing OEMs and product manufacturers to incentivizing large corporates to delve into semiconductor design, our vision is set on fostering a robust Indian IPR framework. We urge the Government of India and State governments to consider substantial support for mask sets within the DLI scheme, thus mitigating the financial hurdles for burgeoning design firms.

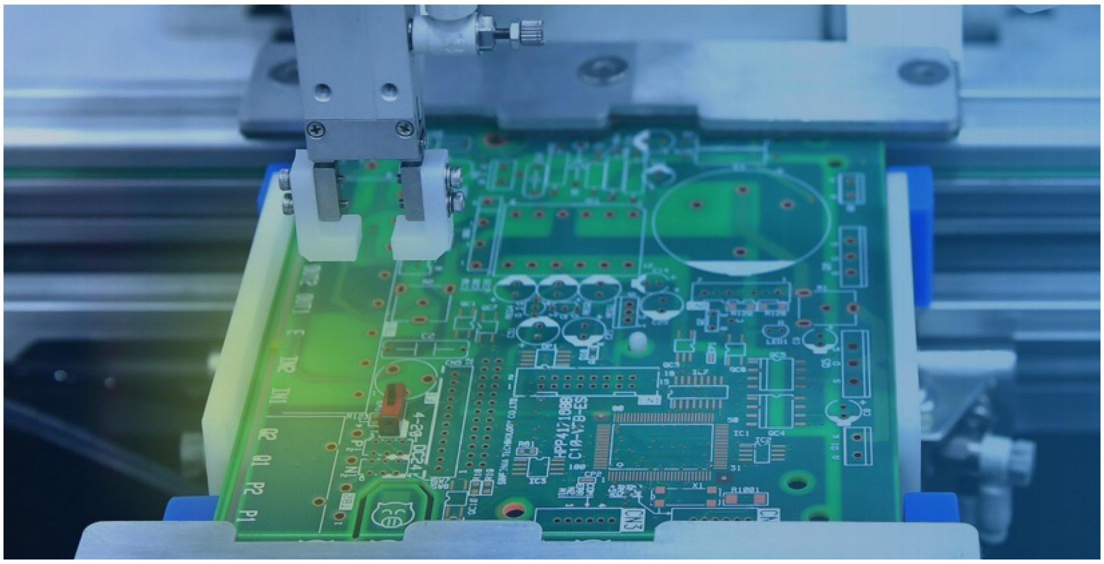
The report also underscores the pivotal role of skill development, tailored specifically to the semiconductor industry's needs. Through the creation of industry-oriented curricula and training programs, we aim to bridge the skill gap and prepare a workforce ready to lead India's semiconductor revolution.

The collective action and harmonized efforts of all stakeholders, including the government, industry leaders, and the dedicated ICEA team—comprising Mr. Rajesh Sharma, Dr. Aashish Saurikhia, Dr. Neeraj Agarwal, and Mr. Kapil Gupta —alongside our knowledge partner, Feedback Advisory led by Mr. A.M. Devendranath, will be the driving force in realizing the recommendations laid out in this paper.

Together, we stand at the threshold of an era marked by innovation, self-reliance, and global competitiveness. Let us move forward with determination and collaboration to ensure that India not only participates but excels in the global electronics and semiconductor value chain.



1. Background:



India Electronics and Cellular Association (ICEA) is the apex industry body representing the entire electronics value chain with a vision to make India a global hub for electronics manufacturing.

ICEA has undertaken a detailed assessment of India's current status and potential in Semiconductor Design and Core IP creation. This report also delves into global semiconductor markets and applies relevant learnings to the Indian context. ICEA has engaged with a wide variety of Indian and international experts in this field, resulting in a reality check and actional recommendations to stimulate Semiconductor Design and Core IP creation in India.

2. Global Semiconductors Market Overview:

Despite some headwinds in the second half of 2022, the global semiconductor industry reached record high sales in 2022, growing nominally by 3.3% to reach USD 574 billion. The year 2023 faced a degrowth of -8.2% and reached sales of USD 526.8 billion with an anticipated bounce back by 2024, as per World Semiconductor Trade Statistics (WSTS).

In regional terms, the Europe market showed the fastest growth in 2023, rising by 4% while the Asia Pacific market witnessed a huge drop of -12.2%. The global semiconductor industry is very R&D- and capital-intensive due to the necessity of developing increasingly complex chip designs at ever-smaller scales, especially if the industry is to maintain Moore's Law.

In the current geopolitical climate, India presents a robust option for most Semiconductor firms and Nations seeking to de-risk from traditional manufacturing partners, notably China, India's strengths lie in:

- *Existing semiconductor design capabilities,*
- *A large pool of engineers,*
- *A versatile and large industrial base catering to diverse industries, which can be molded to cater to Semiconductor Industry easily,*
- *Political stability and a vibrant democracy,*
- *Status as a reliable partner to developed nations,*
- *A Government with a progressive attitude towards attracting semiconductor investments,*
- *Strong EMS base which provides sufficient capacity utilization for upcoming Semiconductor units.*

3. Insights from China and other key South East Asian Countries in the Semiconductor Market

A. China – 'Over-invested' and State controlled Semiconductor industry, creating a threat for the rest of the world in Legacy Chip Production and struggling in Advanced nodes.

- China – 'Over-invested' and State controlled Semiconductor industry, creating a threat for the rest of the world in Legacy Chip Production and struggling in Advanced nodes.
  - China's Industrial Policy has focused on semiconductors since the late 60's, yielding limited success. The policy included aggressive state funding for the semiconductor industry a range of other incentives and assistance in acquiring global firms in various areas.
  - State control has, however, led to challenges such as corruption, fraud and failures.
  - The role of the private sector is diminishing as increased state funding leads to greater state control over the industry. Furthermore, companies receiving substantial funds have struggled to utilize them effectively, leading to over-leveraging and defaults among several major players.
  - At the same time, China has had success in specific areas such as Legacy Chips (>28 nm technology) and created a vast pool of Semiconductor Design firms (estimated at over 3300 firms) and a wealth of IP Creation. Semiconductor product design has of course been an outstanding success.
  - Companies based in Germany, Japan, South Korea, Taiwan, the United Kingdom, and the United States continue to be global frontrunners in semiconductor innovation. However, it's clear that Chinese policies, which unfairly seize market share from these leading global firms to support underperforming Chinese companies, will eventually erode the competitive standing of these leaders. As a result, their capacity to generate necessary capital necessary for investment in research and development (R&D) and capital expenditures, will be restricted.

  - However, due to lack of success in mature technology and overdependence on Western nations for advanced tools, equipment and materials, sanctions and the pandemic have significantly impacted the Chinese Semiconductor industry and they are now in the 'rebuilding' phase.
  - In semiconductor design, the cost of making Mask sets for testing and manufacturing the newly designed chips is a huge cost, which works as a barrier for the design ecosystem to grow. Chinese government has offered subsidies to manufacture these mask sets by providing up to 80% capex support for the design firms.
  - In China, following provinces have supported growth of semiconductor ecosystem, design, fab and OSAT:
    - The high-density cluster cities and provinces of IC design product companies are Beijing, Shanghai Zhangjiang, Hangzhou, Ningbo, Suchou, Wuxi, Nanjing, Wuhan, Shenzhen, Chengdu, Chongqing, Xi'an, Xiamen. Provinces include: Zhejiang, Jiangsu, Guangdong, Hubei, Sichuan, Beijing, Shanghai, Chongqing
- With targeted policies and strategic approach, China incentivized and motivated non-resident Chinese residing in the United States and other semiconductor leading nations, highly skilled in semiconductors, to move back to China and contribute to the growth and development of the domestic semiconductor industry.
- To ensure sufficient availability of capital/ funds, China has created an exclusive stock exchange – the "Shanghai Stock Exchange's Science and Technology Innovation Board", colloquially known as the STAR Market, in the year 2019. This acted as a platform specifically intended for science and technology companies in China, this is modelled on the lines of Nasdaq stock exchange in the U.S., serving as a platform specifically intended for science and technology.
- The STAR Market introduced unique aspects to its regulatory environment in contrast to many traditional stock markets. As of 2023, the STAR Market has a market capitalization of approximately USD 852 billion and hosts 437 listed companiesThis facilitated creation of a vibrant VC ecosystem and further supported by the respective provinces.
- **Learnings for India –** *India needs to have a policy for further aiding Domestic Semicon design firms with appropriate financial support in the beginning and then allow them to determine the market growth and development. The tremendous success of China's semiconductor product design policies is definitely worth emulating, especially by providing capex subsidies on mask sets.*
- *India needs to be vigilant and forge a coalition to prevent dumping of higher node and memory chips from China, otherwise we risk a situation similar to display wherein most global TFT-LCD companies have gone under.*
- *Furthermore, India should establish an exclusive market exchange for electronics and hi-tech industry in India. This would drive growth and innovation across the industry, while also creating capacities and outlay to becoming a global hub for electronics and semiconductor manufacturing.*

B. Singapore – A tiny nation rose up to being a regional superpower in Semiconductor Manufacturing with nearly 8-9 fabs.

- Singapore is home to over 300 Semiconductor-related firms including 8 wafer fabs, 14 silicon fabs, and around 20 ATMP units, contributing to approximately 70% of the world's semiconductor wire bonders and 20% of the global semiconductor equipment market.
- The country's success is largely attributable to various factors such as:
  - Industry-friendly **taxation rules that are among the best globally** – a network of double taxation agreements (DTAs) with over 80 countries/regions worldwide
  - **A regulatory framework** that provides a fair and competitive environment for foreign investors, devoid of foreign ownership restrictions or foreign exchange controls.
  - **Government encouragement** for innovation and development by Singaporean enterprises with a reliable legal system and **robust IP infrastructure** for protection.
  - Singapore's **efficient logistics system,** which ensures the smooth global circulation of chips. It is one of the world's logistics centers, with 24 of the world's largest logistics companies established there
  - The presence of **state-owned Financial Arm, Temasek,** which actively brings in equity investment for prospective semiconductor firms and encourages them to invest in Singapore
- *Learnings for India – "India should look to emulate and adapt relevant aspects of Singapore's government policies to encourage Semiconductor firms to invest in India. For example, its financial strength through Temasek provides meaningful lessons for India."*

C. Malaysia – A strong ASEAN OSAT nation with over 50 Semiconductor firms in the region.

- The Malaysian semiconductor industry is primarily characterized by traditional, labor intensive OSAT business. These mainly provide outsourced services such as assembly, packaging and testing, primarily to multinational companies.
- The country boasts a competitive advantage in packaging and testing, particularly following the merger of AMD with the Chinese firm, Nanjong Fujitsu Microelectronics.
- Malaysia allows liberal policy framework pertaining to finance, tax, and other free trade agreements crucial for research and development.
- Penang, often referred to as the Silicon Valley of the East, possesses a robust E&E ecosystem. Having established a long-standing presence in the industry over the past 51 years, Penang has attracted a diverse range of local suppliers and nurtured a comprehensive value chain. This includes automation, electronics, packaging, plastics, precision engineering and metal work, software development and more, all of which support the semiconductor manufacturing value chain.
- *Learnings for India – "Malaysia's approach to creating a global ecosystem in concentrated areas by following the cluster-based approach in areas such as Penang, offers lessons for India's development of an overall Semiconductor ecosystem."*

D. Vietnam – An aspiring nation in Semiconductors with a strong EMS industry creating a demand pull.

- Fueled by the large presence of Electronic Manufacturing Services and Electronic Exports (Mobile), Vietnam has been successful in attracting several Semiconductor ATMP / OSAT units over the past two decades.
- The semiconductor OSAT business in Vietnam was developed by key players such as Intel, and Samsung.
- A multitude of other firms are considering investments in the country in areas such as the OSAT business, semiconductor equipment firms and chip design.
- Packaging and testing, the sector that Vietnam is most heavily involved in, is a low-margin part of the semiconductor industry compared to the design and manufacturing of semiconductor wafers. In fact, the primary challenge that might prevent Vietnam from stepping up another ladder in the value chain is the high requirement for manufacturing infrastructure as well as the highly skilled workforce.
- ***Learnings for India** – "While Vietnam share similarities with India, it has an advantage due to presence of established OSAT firms. India should maintain a keen eye across subvertical in the semiconductor domain such as semiconductor design, ATMP, Wafer manufacturing, substrate etc.*

4. Mobile Phones offer a ready market for Semiconductor firms to address in India

Over the last 5-7 years, the Indian Electronics manufacturing scenario has drastically changed, largely due to the growing mobile phone manufacturing in India. Mobile phones production contribution in the overall Indian electronics manufacturing jumped from 10% to a **whopping 44%**[1] in the span of the last 7 years.

World over, the smartphone business has been the largest consumer of the semiconductor industry. ICEA conducted a detailed study of Smartphones Bill of Materials (BoM) last year, estimating that the total Semiconductor account for around 25-30% of a typical Smartphone's BoM. This equates to approximately USD 9-10 billion in semiconductor demand just for the smartphone segment in India in FY 2022-23.

Based on industry discussions, technology roadmaps and India's strengths, ICEA has developed a priority roadmap for semiconductors in mobile phones. This includes Memory ICs, given the proposed new investment in ATMP of memory products in India. This is outlined below:

[1]MEITY Annual reports; ** ICEA estimates

Semiconductor Products In Materials BOM	% contribution In Components	Priority for India to focus
Diodes	0.9%	Priority 1
FET	0.9%	
Power ICs	3.6%	
MOSFET	0.1%	
Sensors	0.3%	
Transistors	2.8%	
LEDs	0.5%	
Memory Chip	5.9%	
LCD Driver IC	0.5%	Priority 2
Blue Tooth IC	1.1%	
FM & Digital Radio IC	1.1%	
Graphic Controler IC	1.1%	
RF IC	2.2%	
DSP Chlp	0.4%	Priority 3
Processor IC	7.8%	
Total Semiconductor Products	**29.1%**	

ICEA Recommendation:

Not all of the above-mentioned Semiconductors represent immediate opportunities for India. For e.g., Processor Chips, which are Advanced Chips specifically for High end phones, may require some time before India can produce them at a competitive level. However, there is a commercial viability in fabricating Processor Chips for entry-level smartphones in India. This could be a consideration for the New Semiconductor Fabs.

India's smartphone consumption stood at approximately 150 million units in 2023. Industry estimates suggest that indigenizing chips for just 10% of this market i.e., 15-18 million for entry-level smartphones, makes strong commercial sense in supporting the Indian domestic fab unit. With a monthly output of around 1.5 million unit (10-14 nm) of chipsets – assuming 15,000 wafers of 300mm at 70% yield from a fab, and considering the number of die per wafer to be 148 - the annual output could be approximately 18 million chipsets. ICEA will be submitting a detailed policy recommendation on this matter.

This will make a wafer fabrication unit in India, in Processors, specifically for Mobile Phones a self-sustaining business proposition.

5. Evaluation of India's current status and potential in Semiconductor Design Development

The growing Electronics manufacturing is driving the demand for Semiconductors in India. In FY23, the total import of Integrated Circuits (ICs) reached USD 16.14 billion (out of which USD 12 billion was only for mobile phones, clearly indicating the shallow value addition in verticals other than mobile phones). This suggests that for other verticals PCBA is getting imported and only final assembly is happening in India. The current manufacturing of USD 103 billion should translate to a Semiconductor requirement of USD 26 to USD 31 billion, considering the industry average of 25% to 30% of Semiconductor components in any Electronics Product BOM. With the expected rise in electronics production (USD 300 by 2026), this number is set to rise substantially to ~USD 90-100 billion.

Therefore, the critical task before all the stakeholders is to translate the burgeoning **Semiconductors requirement into domestic production and reduce dependency on Imports.** This transition would boost domestic **procurement and increase the viability of the Semiconductor fabs in India.** This following key steps need to be addressed on priority:

A. Ensuring PCBA operations happen in India across Electronic Products and PCBA imports should be discouraged.

B. India should focus on circuit design thereby allowing the domestic decision regarding procuring components.

C. A strategy for a segment level approach to deepen PCBA localization across all verticals Electronics Manufacturing is necessary.

D. Increased focus on deep domestic value addition across Electronic Products manufacturing in India.

E. Investment in R&D (more details in next section) is required to create more New Electronics products in India.

F. The highly successful Digital India program needs to be backed by locally developed and Made in India Electronic Hardware (ICT Products) to further deepen domestic requirements of Semiconductors in India.

Semiconductor Design is one of India's key strengths, with nearly 20% of the world's Semiconductor Design Engineers based in India. Almost 3000[2] chips are designed every year in India by these engineers, making the country an attractive destination for global semiconductor design companies. However, **most of these engineers and startups primarily service MNCs,** resulting in very limited domestic IP creation. There are several challenges for creating Core IP Design in Semiconductors in India:

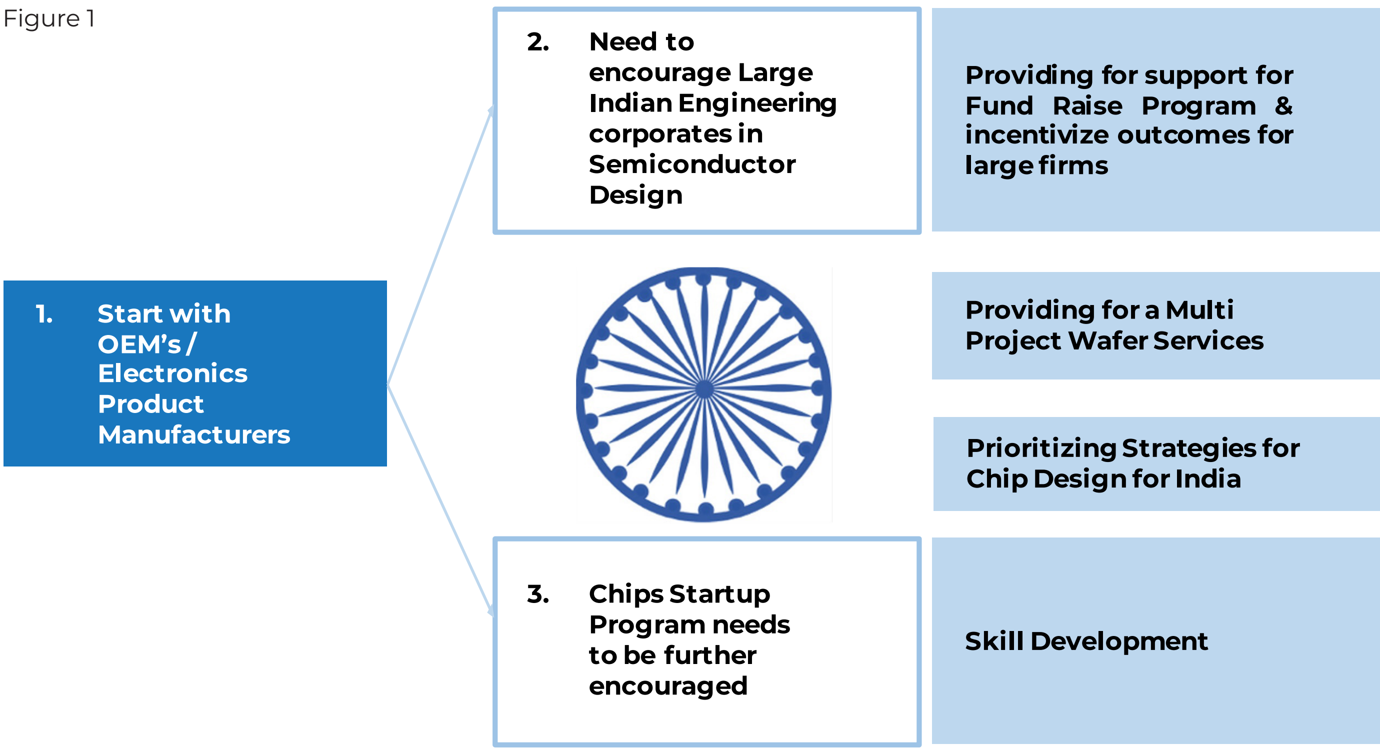
[2] https://www.dqindia.com/semiconductor-chip-designing-strategic-necessity-india/

- Very high costs are involved in Semiconductor Design and Core IP creation.
- Lack of funding.
- Low access to semiconductor fabs for domestic design firms.

6. ICEA's recommendations for India in stimulating Semiconductor Design and Core IP creation

The idea behind ICEA's recommendations for creating a robust Semiconductor Design ecosystem in India is outlined below:

Figure 1



The idea is not to view Semiconductor design in isolation. Instead, the entire Electronics value chain should be evaluated to stimulate Semiconductor Design and Core IP creation in India as shown above.

1. Start with OEMs / Electronic Product Manufacturers:

India's has few of its own Products in Overall Electronics Products Manufacturing. Therefore, it is important to aid firms in investing in R&D to create Electronics Products for both India and the world. A pull approach needs to be used, where, Semiconductor Chips created using local IP are given preferential access. Tax incentives should be given to finished products using local IP, which is more beneficial than incentivizing the IP itself. The approach can create a market pull for local IP and prevent the creation of paper IP with little commercial value.

2. **Encourage Large Indian corporates in Semiconductor Design:**

India has strong Companies / Corporates that have undertaken tasks of national importance in many sectors. It's crucial to invite companies from non-Electronics/Semiconductor backgrounds and encourage them to invest in Semiconductor Design & Core IP creation.

3. **Funding support for the Semiconductor Design ecosystem needs to be at a different level:**

India needs to transcend the traditional funding methods and explore innovative ideas, such as:

- Treat the "Semiconductor Chip Design/ Manufacturing for India" as a **strategic sector** (which indeed it is!), so that banks provide low-cost funds.
- The government could address the hi-tech sector by creating **a separate Capital Market** system, making it easier for firms in this sector to raise money.
- **Incentivising the cost of 'Mask-set'** to reduce the cost burden of Design Houses
  - The cost of creating mask sets can be quite high, ranging from USD 1 – 20 million, depending on the complexity of the design and the specific manufacturing technology used. This cost presents a significant entry barrier for small companies or those attempting to create a new chip design. ICEA has prepared a detailed whitepaper on this aspect in the Chapter 10 of this report.

◇ Among many other policy interventions and tools, **China is hugely subsidizing the maskset efforts (to the tune of 80%) for design firms.** A complete MASK SET process comprises the manufacturing of customized masks and the first wafer production lot. MASK SETS are a substantial investment for these companies, depending on the node and complexity of design. This strategy of supporting design firms has been instrumental in their development of over 3300 semiconductor product design companies. Significantly, provinces in China have also supported the subsidizing of mask sets.

◇ ICEA recommends that the **Government of India should include MASK SETS in the DLI scheme and subsidize the cost of MASK SETS by up to 80% for Indian design companies. This would facilitate the creation of a robust Indian IPR framework.**

4. **Wafer Support for Semiconductor Design Fabless companies:**

Timely and reasonably priced access to a Fab is a crucial factor in the success of semiconductor fabless companies looking to tape out their designs. Most of the Indian design firms fails to get this support system in India. The Government of India needs to acknowledge this challenge and consider methods to overcome this huge disability for the Indian SC design firms. This may be ensured in following ways:

I. As setting up a completely new fab is a cost intensive decision, ICEA suggests that Government of India should initially invest in a Refurbished Fab to support the budding semiconductor design firms, simultaneously addressing the requirement of a skilling the local youth in semiconductor domain.

II. ICEA has prepared a detailed whitepaper on this topic in Chapter 9 of this report, which further discusses the modalities of setting up a refurbished fab and its advantages.

5. **Strong focus on Skill Development for Semiconductor Industry:**

The government's recent initiatives aiming to develop general skills need to be tailored to suit the specific needs of the IC industry. This involves creating industry-oriented course curriculum and training programs. ICEA's core team of experienced IC professionals are actively working on this task, as well as developing necessary EDA tools and standards for the industry. They are also focusing on creating specialized courses for various roles in the industry. Although an undergraduate course in the VLSI domain has been proposed by AICTE but our team realizes that there are some gaps regarding its industry worthiness. ICEA is addressing this issue by identifying the gaps and enriching the course with a tailored model curriculum. Further details on this topic can be found in Chapter 8 of this report.

Chapter 1

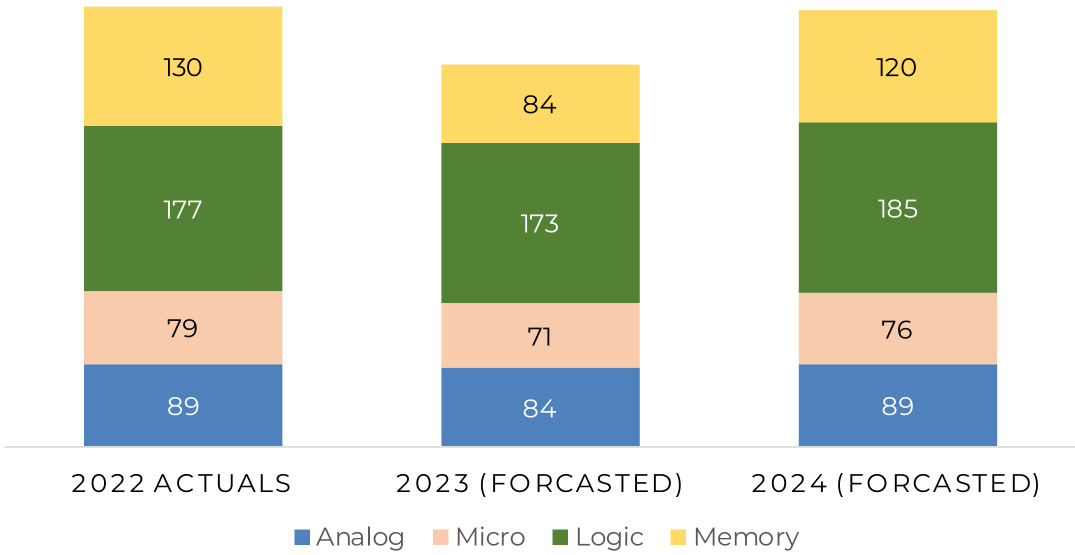
GLOBALSEMICONDUCTOR INDUSTRY AND TRENDS

A. Year 2022 review and estimates for 2023 and 2024

The global semiconductor industry reached record sales in 2022, growing nominally by 3.3% to reach USD 574 billion and degrew to USD 526.8 billion in 2023. However, factors such as inflation, geopolitical unrest, and the effects of the pandemic contributed to short-term downturns, decreased consumer spending, and fluctuating semiconductor demand.

For 2024, the semiconductor market is projected to face a decline in growth. Region wise, the Americas market is showing the fastest growth at 16.2%, while the Asia Pacific market witnessed a drop of 3.5%. The recovery is expected to be led by the Americas in 2024, with Asia Pacific projected to grow by 10.7%. Discrete Semiconductors experienced the fastest growth at 12% in 2022, while the Integrated Circuits (ICs) market experienced the slowest growth at 2.5%. The ICs market is impacted by the Memory market growth trend, which is projected to fall further in 2023 and regain robust growth in 2024.

Figure 2



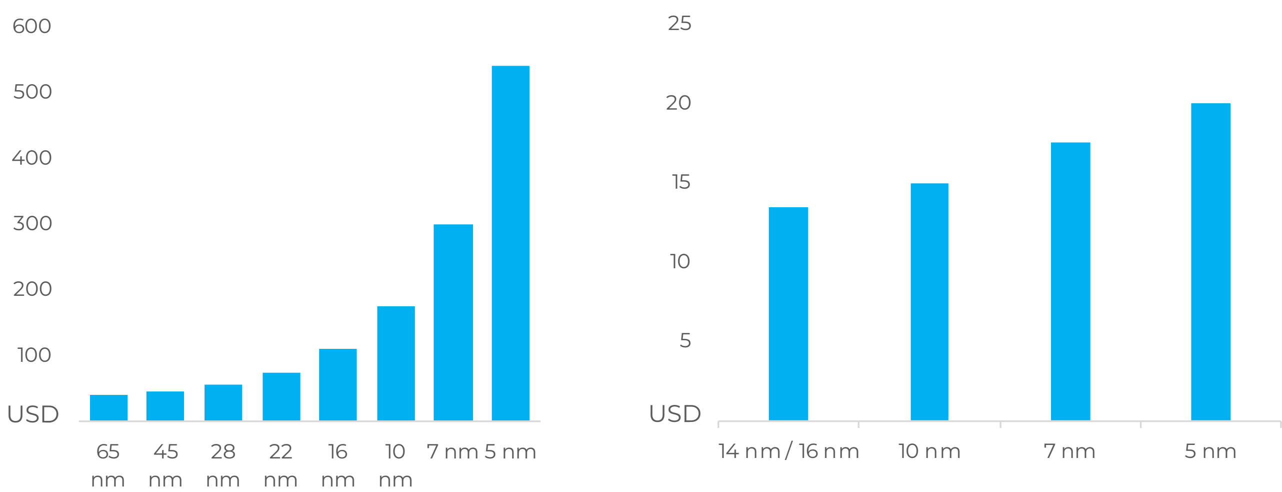
Source: World Semiconductor Trade Statistics (WSTS), Feedback Analysis

B. Global Semiconductors business costs are increasing:

The global semiconductor industry is highly R&D- and capital-intensive due to the the necessity of developing increasingly complex chip designs at ever-smaller scales. Materials-engineering breakthroughs in EUV lithography, etching, and thin-film deposition have led to a 5 nm industry frontier, with further reduction to 3 nm, 2nm, and even 1 nm integrated circuits. This requires 18 times more design engineers than were required in the 1970s to achieve Moore's Law principle. The cost of advancing chip design from 10 nm to 7nm has increased by over USD 100 million, and the cost of moving from 7 nm to 5 nm is likely to double again. These insights highlight the expertise, capital, and scale required to develop new semiconductor designs and build new fabs, which are extremely high and ever-increasing.

Cost to advance to next level of chip development (USD, millions)[3]

Figure 3



[3]Alex Capri, "Semiconductors at the Heart of the US-China Tech War" (The Hinrich Foundation, January 2020), 17 https://www.hinrichfoundation.com/research/white-paper/trade-and-technology/semiconductors-at-the-heart-of-the-us-china-tech-war/

Average cost to build a new foundry/logic fab (USD, billions)[4]

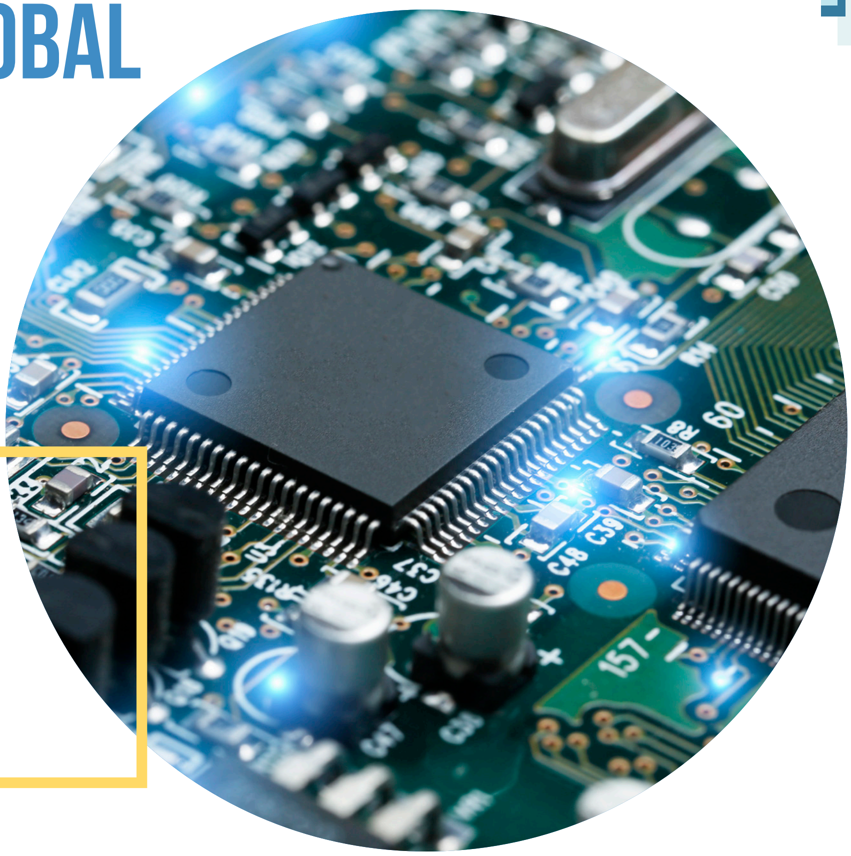
The cost of designing and building fabs for smaller chips is increasing. TSMC invested in a 5 nm fab in Arizona in 2020, and planned to build a 3 nm fab in 2022. As of 2020, building a 14-16 nm fab costs an average of USD 13 billion, while 10 nm fabs cost USD 15 billion, 7 nm fabs USD 18 billion, and 5 nm fabs USD 20 billion.

Surprisingly, the global semiconductor industry is shrinking due to the increasing cost of competing in the sector. Previously, 30 companies manufactured integrated circuits, but only 5 currently do. The 10-year cost, including setup and operating cost of a state-of-the-art fab can reach up to USD 40 billion.

[4] SIA, "2020 State of the U.S. Semiconductor Industry,"

Chapter 2

ASSESSMENT OF GEOPOLITICAL SCENARIO'S IMPACT ON THE GLOBAL SEMICONDUCTOR SUPPLY CHAIN



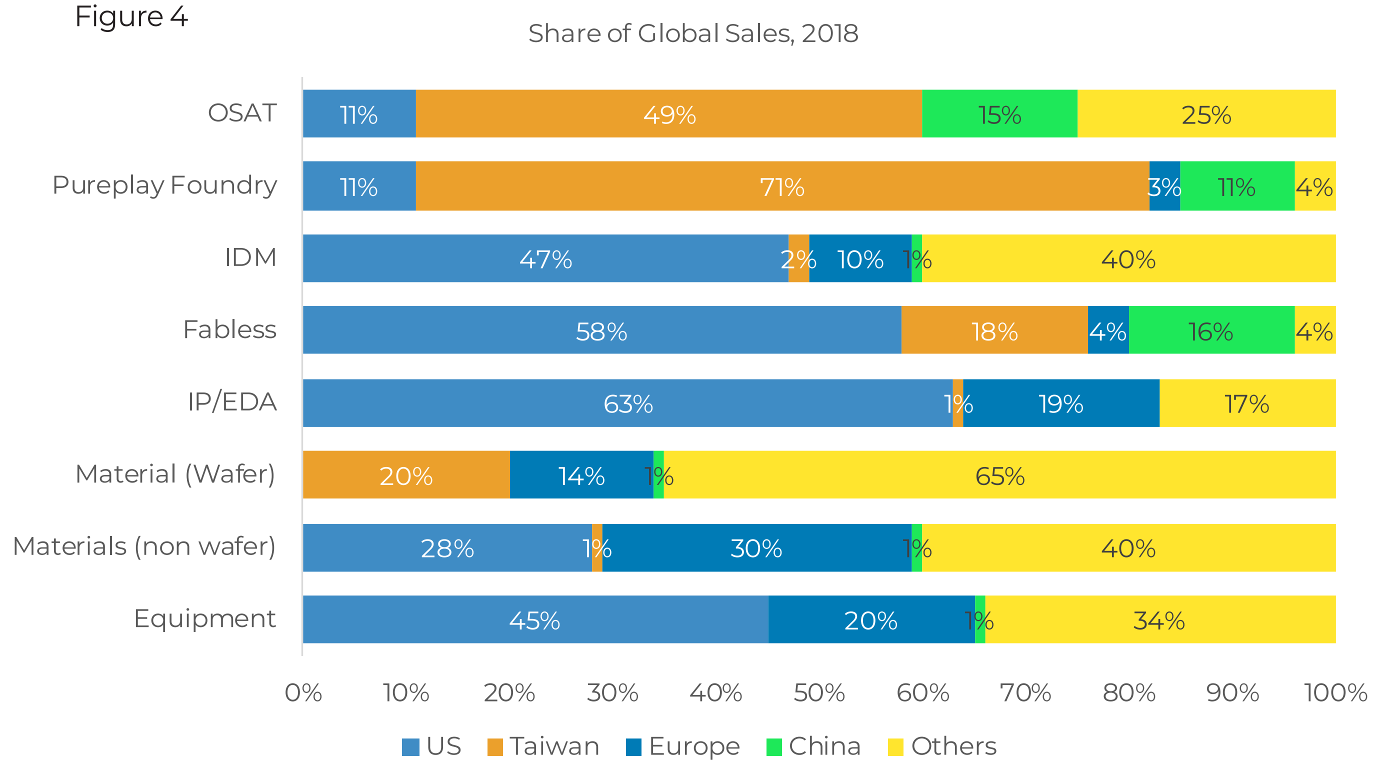
A. The Global Semiconductor Supply chain:

The semiconductor industry possesses a diversified ecosystem. No single country can claim to have all facilities such as design, silicon transfer, packaging, testing, state-of-the-art FAB tools design, and consumables production, along with significant R&D investment. In the late 1980s, integrated device manufacturers (IDMs) like Intel began facing challenges in balancing capital investments for chip manufacturing and R&D expenditures for design innovation. These circumstances led to the emergence of the foundry model, encompassing pure-play foundries like TSMC that focus exclusively on manufacturing, and fabless chip companies like Nvidia and Apple, etc. that concentrate on design only. In today's landscape, chipmakers of all types—IDMs, foundries, and fabless firms—rely heavily on a highly specialized global value chain and open trade to facilitate the movement of various chip components.

The global semiconductor supply chain, renowned for its geographic specialization, has brought tremendous value to the industry. A joint report by the Semiconductor Industry Association (SIA) and BCG estimates that achieving fully self-sufficient local supply chains would require a massive upfront investment of at least USD 1 trillion. Furthermore, this self-sufficiency would entail additional recurrent annual operational costs between USD 45 billion and USD 125 billion for the entire industry, leading to an overall spike in chip prices by 35 to 65 percent[5].

5 https://www.semiconductors.org/wp-content/uploads/2021/05/BCG-x-SIA-Strengthening-the-Global-Semiconductor-Value-Chain-April-2021_1.pdf

Figure 4



The United States is a leader in knowledge-intensive activities within the semiconductor value chain, such as chip design, electronic design automation (EDA), semiconductor manufacturing equipment (SME), and core intellectual property (IP). In 2019, half of the top 20 chip design companies and four of the top five EDA and core IP companies, based on revenue, were headquartered in the United States. Conversely, Northeast Asia houses 75 percent of the world's semiconductor manufacturing capacity. Taiwan and South Korea, bolstered by long-established industrial policies, robust infrastructure, and highly skilled workforces, specialize in advanced manufacturing. They collectively hold the entirety of global fabrication capacity in 7- and 5-nanometer processing nodes. Meanwhile, China and the United States, the two largest global chip consumer markets, rank fourth and fifth in wafer fabrication. China dominates the relatively less skill-intensive and capital-intensive back-end manufacturing activities, commanding the largest global market share in assembly, packaging, and testing, followed by Taiwan and Malaysia.

Integrated supply chains, specialization, and international collaboration have persistently driven cost efficiency and technological advancements. These elements facilitate the growth of information technology, digital services, and emerging technologies such as electric vehicles, artificial intelligence, and quantum computing. Both Washington and Beijing, key participants with complementary specializations, have benefited from the optimization of the global semiconductor value chain. However, geopolitical tensions, disruptions from the Covid-19 pandemic, and extreme weather events in Taiwan have revealed vulnerabilities in the global semiconductor value chains in recent years.

In 2021, disruptions in the supply chain led to chip shortages, profoundly affecting automotive and computer production. Coupled with rising geopolitical tensions between the United States and China, these disruptions have spurred both nations to strengthen domestic semiconductor manufacturing through initiatives like the CHIPS for America Act and the Chinese 14th Five-Year Plan. Additionally, both the Trump and Biden administrations have tightened export restrictions and blocked Chinese acquisition attempts of U.S.-listed strategic technology firms. These measures have underscored Beijing's resolve to pursue semiconductor self-sufficiency. Success in these endeavors may lead to further fragmentation in global value chains. Notably, between 2016 and 2020, technology-related foreign direct investment (FDI) between the U.S. and China plummeted by 96 percent, while domestic research and development spending on technological innovation soared.

B. The Road Ahead for the Global Semiconductor Industry

An optimal strategy for the future must address the risks associated with single-point failures, particularly evident in the concentrated semiconductor manufacturing in Asia. As the United States and Europe work to reduce dependence on Taiwan and South Korea, who collectively account for roughly half of the global semiconductor fabrication capacity, alternative approaches must be explored. Simultaneously, it is essential to reassure strategic partners in East Asia of the United States' continued commitment throughout this transition. Diplomatic, economic, and security arrangements such as the Indo-Pacific Economic Framework for Prosperity (IPEF), the Quad, and the U.S.-Taiwan Initiative on 21st Century Trade may prove instrumental in enabling this restructuring. Direct investments in countries like Vietnam, Australia, and India could further diversify the semiconductor supply chain.

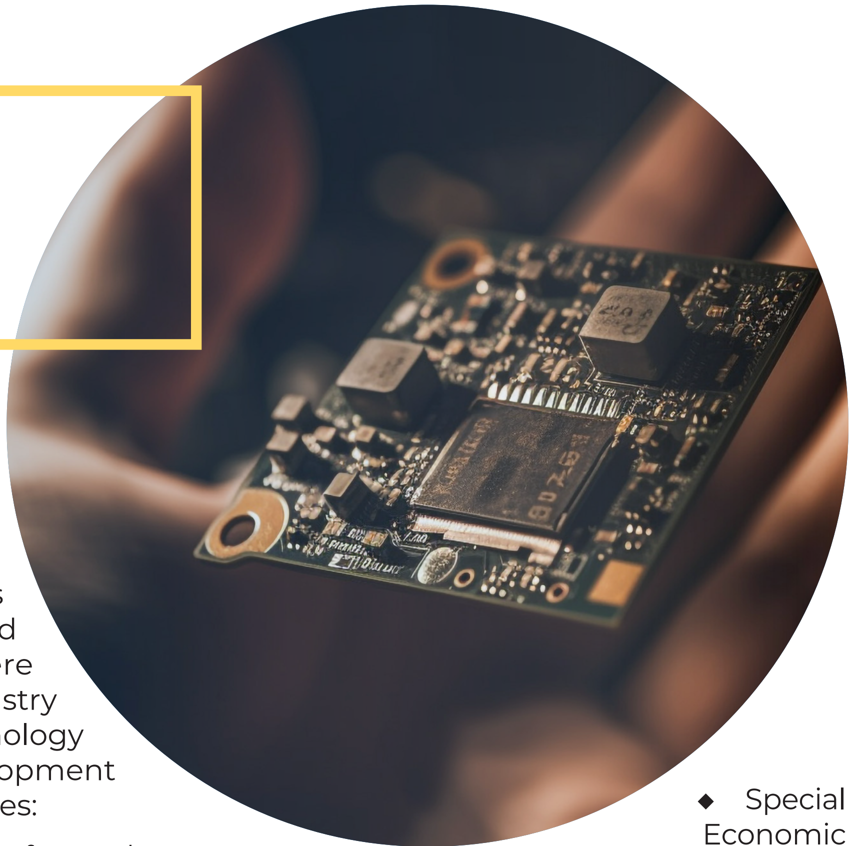
A recent report by Feedback Advisory estimated India's total potential in the three key pillars of the Semiconductor Supply Chain (Global Equipment Supply, Global SC Materials Supply, and Services) to be USD 85 – 100 billion. Intensive efforts are required to capitalize on this opportunity.

In the prevailing geopolitical climate, where most semiconductor firms and nations seek a de-risking strategy from a 'Traditional manufacturing partner'/China, India emerges as a compelling option due to its:

- **Strong existing capabilities in Semiconductor Design,**
- **Large pool of Engineers,**
- **Extensive industrial base catering to diverse industries adaptable to the Semiconductor Industry,**
- **Stable political regime and vibrant democracy,**
- **Reputation as a reliable partner to most developed nations**
- **Positive governmental stance towards attracting Semiconductor investments.**

Chapter 3

REALITY CHECK ON CHINA'S SEMICONDUCTOR DEVELOPMENT ESPECIALLY IN SEMICONDUCTOR PRODUCT DESIGN; A BRIEF LOOK AT OTHER SE ASIAN NATIONS



A. China's early industrial policy on semiconductors

China has a distinguished history of formulating strategic industrial plans for its semiconductor sector, initiated in 1956 when semiconductors were recognized as a crucial strategic industry in the "Outline for Science and Technology Development, 1956-1967". The development can be categorized into distinct phases:

- 1956 to 1967: The period was primarily focused on establishing 5-6 key semiconductor institutes and introducing semiconductors to Chinese nationals.
- 1970s to 2010: After building awareness and electronics education establishments, concerted effort were made to increase manufacturing capabilities and industrialisation across various sectors, including Electronics, Chemicals, Pharma, Metals, Plastics, and Textiles.
- Special Economic Zones (SEZ): China started setting up SEZs, capitalizing on diplomatic benefits of WTO rulings. These early initiatives transformed China into the "Factory of World", despite the absence of democratic governance.
- China intensified efforts to become the single and largest semiconductor core technology production hub but encountered mixed results characterized by failures and frauds'[6].

[6] Centre for Strategic & International Studies - Learning the Superior Techniques of the Barbarians China's Pursuit of Semiconductor Independence

- Challenges with High-tech products: Policies that worked for comparatively low-tech products did not translate to success for state-of-the-art semiconductors, despite acquiring technology transfer, production setup, and workforce training.
- China's partnership with Western companies was marked by forced technology transfer, espionage, and attempts at reverse engineering. However, China struggled to develop high-end technology independently, and the diverse development of the semiconductor ecosystem hindered easy access to desired technology know-hows[7]

China's ambitions to lead the semiconductors technology and production has been backed by continuous state backing and initiatives such as the "Guidelines to Promote National Integrated Circuit Industry" in 2014 (also known as the China "National IC Plan") and the "Made in China 2025" strategy announced in 2015. These initiatives have secured RMB150 billion (USD 22.7 billion) since their inception, contributed by administrations from provincial to county levels. All levels of state machinery and available financial systems are integral financial supporting partners in these ambitious plans.

- In the past decade alone, China has started more than 100 science, technology, and sector-specific development plans, with a particular emphasis on advancing the domestic semiconductor industry.

B. China's current status in semiconductors

China's dominant position in Electronics manufacturing also generated significant demand for Semiconductors. As China consumes an estimated 35% of semiconductors produced globally, **semiconductors have become the largest single import into China in terms of revenue.** This has resulted in a trade deficit, further emphasized by trade tensions. Meanwhile, domestic IC production has increased at a 20% CAGR between 2010 to 2020.

According to a SEMI report in 2021, all IC ecosystem sectors in China have made significant progress in 2020[8]:

- IC Design: In 2020, IC design was the largest semiconductor sector in China with over 2,200 companies. ; HiSilicon is the largest IC design company in China and ranks among the global top 10 fabless companies. However, most Chinese IC design companies have revenues below USD 1 million.
- Global Installed Fab Capacity: China currently holds a 17% share, with 31 new fab construction projects underway or planned. Logic, Memory and Discrete are core segments for fab capacity expansion, while analog and MEMS will lead the fab investment expansion.
- ATMPs: A major sector of the Chinese IC industry, leading overseas IDM and OSAT companies have facilities located there. In 2020, IC packaging & test revenue was USD 36.4 billion and emerged, as the second semiconductor industry sector in China.
- Semiconductor Materials Market: The market reached to USD 9.76 billion in 2020, with 12% year-over-year growth and 18% global share. Fab materials market may soon surpass the Packaging materials in growth.
- Semiconductor Equipment Market: In 2020, market reached USD 18.70 billion, representing 26% of the global equipment market or the largest regional market due to the large number of new and announced projects.
- Despite having large global share for China in IC equipment and qualified local suppliers for most of the wafer fabs their local supply penetration rate is limited around 8%.

[7] Ibid

[8] SEMI - China IC Ecosystem - Challenges, Opportunities and Forward Analysis

C. China's State support for developing the Local Semiconductors Industry

China's extensive state-sponsored support for domestic companies has yielded mixed results. The support mechanisms includes:

i. Huge amount of 'State-funding' to domestic Semiconductor companies:

a. At least USD 150 billion in government subsidies, sourced from central, provincial, and municipal governments, and various state-owned enterprises. To effectively allocate state funding and bolster the domestic industry, the Chinese government established the China Integrated Circuit Investment Industry Fund (CICIIF), commonly known as the "National IC Fund."

ii. In China, following provinces have supported growth of semiconductor ecosystem, design, fab and OSAT:

b. The high-density cluster cities and provinces of IC design product companies are Beijing, Shanghai Zhangjiang, Hangzhou, Ningbo, Suchou, Wuxi, Nanjing, Wuhan, Shenzhen, Chengdu, Chongqing, Xi'an, Xiamen. Provinces include: Zhejiang, Jiangsu, Guangdong, Hubei, Sichuan, Beijing, Shanghai, Chongqing.

iii. China grants, tax incentives, and low-interest loans, with an estimated value of approximately USD 50 billion (SIA, 2021).

iv. Tax breaks have been introduced to incentivize the production of advanced semiconductors. Companies operating for more than 15 years are eligible for corporate income tax exemption for up to 10 years if they successfully produce chips with a scale of 28 nanometers (nm) or below.

v. Producers of chips ranging from 65nm to 28nm receive a five-year exemption from corporate income tax and a 50 percent discount on the corporate tax rate for the subsequent five years.

vi. Additionally, financial support is offered through borrowing at below-market rates, with banks encouraged to assist the sector.

vii. R&D tax incentives are also in place, allowing companies to deduct 200 percent of their R&D costs from their taxable income.

viii. The government further assists semiconductor producers in raising equity[9] through the Shanghai Stock Exchange (SSE) Science and Technology Innovation Board, known as the STAR Market, established in 2019.

a. As of January 2021, approximately 17 percent of companies listed on the SSE STAR Market were in the semiconductor sector, with nearly half of them engaged in design activities.

b. China's regulatory environment has also played a facilitative role in mass-producing new semiconductors by implementing measures to ease consumer protection regulations.

c. Additionally, semiconductor companies involved in fabrication and assembly have been provided with land at below-market prices.

*A very detailed explanation of the Chinese support for its Semiconductor industry is tabled in **Annexure 1** in this document.*

D. General conclusions on China's industrial policy

Overall, China's industrial policy aimed at developing an advanced chip industry, supported by substantial financial support estimated at USD 150 billion, has yielded mixed results at best. These are summarized below:

- Self-sufficiency in Assembly and Packaging: Achieved in the least strategically important segment, with the lowest value-added among the three phases.
- Fabrication progress: With continued western support, China has made strides in standard

[9] García-Herrero and P. Weil (2022) 'Lessons for Europe from China's quest for semiconductor self-reliance' Policy Contribution 19/2022, Bruegel

chip production, especially for storage, although these do not represent the highest-end chips. However, a lack of new technology to increase memory density and speed may hinder progress.

- The recent export restrictions on software design and manufacturing equipment imposed by the US and other like-minded countries have further hindered China's advancement in the semiconductor industry. In addition to the US export controls, China faces talent shortages that further impede its ability to secure the production of high-end chips.
- The excessive funding for Chinese companies to assemble and produce low-end chips and memory cards has resulted in overproduction. It is declining the product price artificially and giving and edge to Chinese companies for price control. The resulted impact on the other global player is revenue loss and reduction in R&D funding, which may unstable them.
- China's reliance on global sources especially for high-end chips, will be continue despite certain acquisitions of foreign firms and the establishment of additional fabrication plants.
- **The increasing state funding has led to greater state control over the industry and reducing their autonomy and fair play.** Moreover, companies receiving huge state funds have struggled to effectively utilize them, leading to over-leveraging and defaults among several major players.
- The semiconductor industry is characterized by specialization and most of the technology concentration, with the US holding leverage over key production process bottlenecks

Thus, China has yet to achieve its own specified objectives and ambitious initiatives "National IC Plan," and the "Made in China 2025"for attaining self-reliance and overcoming technological barriers. However, a comprehensive evaluation of the outcomes of China's extensive investments in the semiconductor industry will require more time, as support for the sector began in 2014, allowing for less than a decade of preliminary assessment. Thus far, China's ambitious chip industrial policy has fostered the growth of its domestic high-tech ecosystem and achieved a certain level of market presence in the initial stages of the value chain. Nevertheless, it falls short of its grand aspirations to dominate the most advanced segments.

E. The problem for the Global Semiconductor market with China's Industrial Policy

1. Global Market distortion through State Funding of Enterprises in Semiconductors

Estimated value of total semiconductor sector funding assistance by nation/region (USD, billions) in 2019[10] explained in figure 5 below:

Figure 5

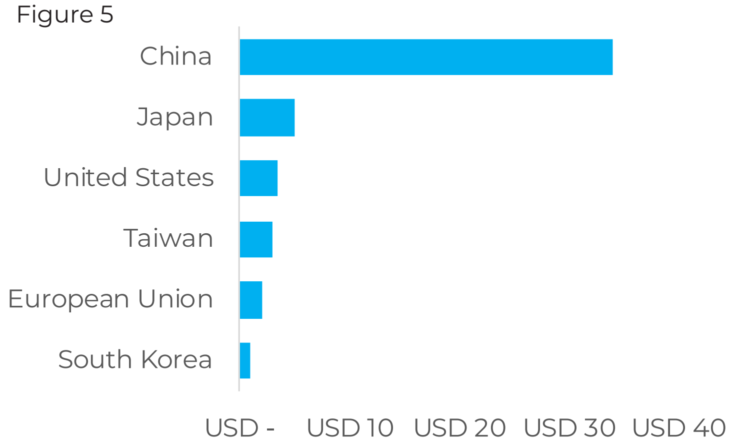
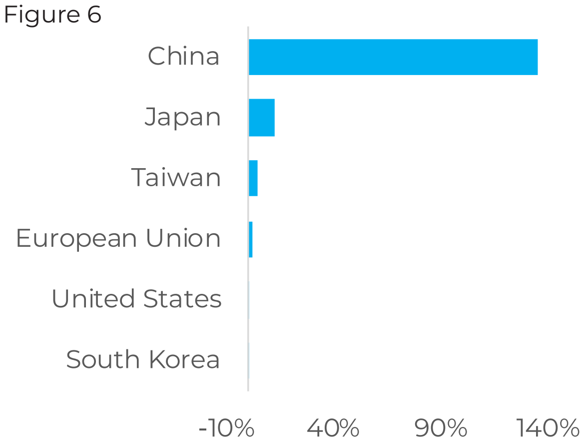


Figure 6



Estimated value of total semiconductor sector funding assistance as a percentage of global sales[11] in figure 6.

2. Global Market distortion through Below Market Financing Enterprises in Semiconductors:

Chinese companies significantly benefit from borrowing at below-market rates. As per the OECD [12], countries with a strong state presence in the economy have demonstrated a clear trend: state-owned enterprises (SOEs) receive higher proportion of subsidies and enjoy access to loans at more favorable rates compared to their private counterparts. Notably, the majority of below-market borrowing observed between 2014 and 2018 can be attributed to the Chinese financial system.

3. Government-Directed Acquisition of Foreign Firms[13]:

Chinese entities have strategically leveraged the National IC Strategy and associated funds to pursue the acquisition or attempted acquisition, of diverse foreign enterprises involved in nearly every aspect of the semiconductor process.

4. Intellectual Property Theft:

The Chinese government has been involved in sponsoring persistent state-sponsored espionage programs that specifically target Western companies and research institutions. A crucial component of China's strategy has been the acquisition of foreign semiconductor technology through the theft of intellectual

[10] Peter Cowhey, "Expanding the analysis of subsidies and semiconductors" (ITIF Report, Power Point Presentation, World Semiconductor Congress, Honolulu, Hawaii, 2019)

[11] Ibid

[12] OECD, "Measuring distortions in international markets: The semiconductor value chain,"

[13] Mercedes Ruehl, James Kygne, and Kiran Stacey, "Chinese state-backed funds invest in the U.S. despite Washington curbs," The Financial Times, December 2, 2020, https://www.ft.com/content/745abeca-561d-484d-acd9-ad1caed-f9e9e.

property (IP). As an example, in November 2018, the US Department of Justice pressed charges against China's Fujian Jinhua Integrated Circuits Co for its alleged involvement in attempting to steal trade secrets from US chipmaker Micron.

Impact summary on the Global Semiconductor market:

In conclusion, companies based in Germany, Japan, South Korea, Taiwan, the United Kingdom, and the United States maintain their position as global frontrunners in semiconductor innovation. However, it is evident that Chinese policies, which unfairly seize market share from these leading global firms to support underperforming Chinese companies, will ultimately erode the competitive standing of these leaders. Consequently, their ability to generate revenues and profits necessary for investing in research and development (R&D) and capital expenditures, vital for fostering future waves of innovation, will be constrained.

F. Assessment of China's performance in Semiconductor Chip Design

The design capabilities of China's semiconductor sector are among its key strengths. While these companies often rely on overseas foundries such as TSMC and Samsung for the fabrication of cutting-edge designs and primarily depend on US design tools, China has cultivated commendable design talent over time. Notable examples include Biren Technology and Yangtze Memory Technologies Co. (YMTC), both of which have demonstrated excellence to the extent of attracting international sanctions.

Last year saw the establishment of 433[14] new chip design companies in China, resulting in a total of 3,243 companies in the country—an increase of 15.4%. The total sales in the sector grew to approximately RMB 534.6 billion[15] (USD 79 billion). Despite the growth in companies, the average sales figure remained RMB 165 million (USD 24 million) per company, consistent with the figures from 2021. Of the total, only 566 companies generated revenues exceeding RMB 100 million[16] (USD 15 million), contributing approximately RMB 494 billion in revenue or roughly 92% of the industry's total revenue. This indicates that most semiconductor design firms in China operate with minimal revenue, employing fewer than 100 individuals and likely depedent on venture capital and government funding .

In addition to other policy interventions, **China heavily subsidizes MASK SETS facility for fledging companies, even for low-volume production.** The complete MASK SETS process includes manufacturing customized masks and the first wafer production lot. MASK SETS, ranging from USD 2 million to USD 10-20 million for a single MASK SET, depending on the node and design complexity. **China subsidizes these mask sets up to 80%, becoming** a main state support tool and helping to create more than 3300 semiconductor product design companies.

Since 2019, China's chip design sector has faced setbacks due to US sanctions. HiSilicon, for instance, saw its fabrication contract with TSMC terminated in 2020 due to US sanctions, preventing the company to produce advanced designs. In the upstream segment of the value chain, China continues to be vulnerable to US trade restrictions, and US firms also maintain their market leadership in IC design software (EDA tools), and poses further challenges for China's chip design industry.

US sanctions have impacted China's ability to develop logic chips below 16/14nm, NAND chips with 128 or more layers, and DRAM chips with a half-pitch of 18nm or less, the country's capability to design legacy chips and some advanced process nodes remains relatively unhindered, except for those targeting HPC/AI applications requiring interconnect speeds exceeding 600 GB/s or performance surpassing 4,800 TOPS+[17] .

[14] https://technode.com/2023/02/09/silicon-chinas-chip-design-industry-in-2022-the-dawn-of-living-with-us-sanctions/

[15] Ibid

[16] Ibid

[17] https://www.digitimes.com/news/a20230330VL210/china-ic-design-distribution.html

In response to constraints on domestic advanced process nodes, Chinese chip fabrication is shifting toward legacy nodes and chip design houses are exploring alternative technologies such as chiplets, GaN/SiC, and IGBT.

The pandemic and the US Sanctions have created some problems for the Chinese Semiconductor Design companies:

- Recent layoffs at Biren Tech and YMTC[18] underscore the difficulties confronted by Chinese design firms due to sanctions. The necessity of adopting local designs, whether due to imposed restrictions or voluntary decisions, can lead to suboptimal results such as compromised end products, longer time-to-market, increased defects, or reduced yields. At the same, these developments are creating opportunities for more business transparent countries with democratic governance.
- The majority of China's chip companies and their revenues primarily stem from the global demand in consumer electronics and telecommunications sectors, focusing predominantly on simpler/legacy chips designed for established process nodes. The China's chip industry wants to increase their presence in the value chain while facing challenges to navigate the landscape shaped by sanctions.
- Presently, China possesses the requisite design and production capabilities for legacy chips. However, a conundrum arises regarding Chinese companies like Biren Tech that should these companies invest considerable efforts in designing for advanced-edge technology while access to manufacturing at advanced node through TSMC or Samsung remains uncertain/restricted.
- The crux of the recent challenges confronting by Chinese design firms and the government supported system on their efforts to design powerful high-end chips while risking the loss of manufacturing capabilities after substantial investments in their development. This predicament raises questions regarding the incentive to undertake such endeavors.
- Conversely, if Chinese firms discontinue their pursuit of advanced designs, the global workforce and chip production eco system may disperse or be redirected towards projects in other countries with more promising market potential. It open ups huge opportunity to large workforce countries like India to set up chip production eco system aggressively and participate in global value chain prominently.

In conclusion, the Chinese chip design industry continues to exhibit sustainability and growth especially in legacy chips production, covering a large proportion of consumer electronics and telecommunication segments. amidst the backdrop of the COVID-19 pandemic and sanctions.

One unintended shackling consequence of U.S. export controls on advanced chip technology to China may manifest as overproduction backed by state funding, potentially leading to Chinese dominance in global legacy chip production.

Singapore Semiconductor Industry

Semiconductor Industry Landscape:

Singapore, despite its small size and limited land and resources, is a well-known business trading and manufacturing hub for high-value industries.. The country has developed high-tech manufacturing clusters in aerospace, semiconductors, chemicals, and biomedical sciences, manufacturing approximately 70% of the world's semiconductor wire bonders and accounting for 20% of the global semiconductor equipment market.

[18] https://technode.com/2023/02/09/silicon-chinas-chip-design-industry-in-2022-the-dawn-of-living-with-us-sanctions/

According to the reports by EDB, by the end of the first decade of the 21st century, Singapore is home to over 300 semiconductor companies. Renowned for its cutting-edge technology, highly transparent and stable policy environment, high-end technical education, and skilled workforce, Singapore's semiconductor ecosystem is highly mature. It includes more than 40 core IC design firms, 14 silicon wafer fabs, 8 wafer fabs for discrete components, and 20 ATMPs. Many Asia-Pacific headquarters of IC design companies such as Texas Instruments, STMicroelectronics, Infineon, and Micron are located in Singapore, along with major semiconductor equipment companies like ASM, KLA, Edwards, Teradyne, Tokyo Electron, and Lam Research.

Among the eight wafer foundries in Singapore, three are the world's largest wafer foundries:

- **Global Foundries** has five wafer foundries in Singapore, with a total production capacity accounting for about 30%.
- **United Microelectronics Corporation (UMC)** and World Advanced Packaging Electronics (APE) each have one 8-inch factory in Singapore. The factory originally belonged to Global Foundries' Fab 3E, and the production capacity accounts for around 15% of both companies.
- **Taiwan Semiconductor Manufacturing Company (TSMC)** operates the Singapore SSMC wafer foundry, which primarily focuses on 0.25-micron and 0.18-micron processes. By 2002, it had gradually introduced 0.15-micron and 0.12-micron processes and its maximum monthly production capacity can reach 30,000 8-inch wafers.

Several packaging and testing companies from neighboring countries like Taiwan and China have also opened chip testing facilities in Singapore. For example, ASE Technology's revenue from its Singapore automotive electronic-related testing plant accounts for about 20-25%. Additionally, JCET's revenue from its Singapore testing plant accounts for about 12%.

In the semiconductor distribution field, Singapore is also home to the Southeast Asian headquarters of companies such as Ampleon, Future Electronics Asia, and Arrow Electronics.

Singapore's strategic location at the southern end of the Malacca Strait, one of the world's busiest shipping lanes, makes it a key player in the semiconductor industry, **and a vital link between the East and the West.**

As the global semiconductor supply chain shifts to Southeast Asia, the region has become a new destination for the global electronics industry to outsource packaging, components, and assembly businesses.

According to IC Insights, in 2021, Singapore accounted for nearly 5% of global wafer fab capacity and held a 20% market share in the global semiconductor equipment market. Currently, nine of the top ten wafer manufacturing equipment companies purchase from Singaporean suppliers.

A large number of semiconductors are manufactured in Singapore and exported worldwide. As the fourth-largest exporter of high-tech products and an important exporter of electronic products, electronic exports account for over 30% of Singapore's total merchandise exports. In global trade, Singapore exhibits a surplus in electronic product trade and a deficit in trade with China.

Singapore also contributed to China's semiconductor growth due to cultural similarity, providing training to develop the semiconductor industry in China. Many Singapore ICs professionals were later attracted by the Chinese government and companies for higher node technology establishment.

Key success factors for Singapore Semiconductor industry:

Singapore's geographic position and favorable business environment have attracted companies from around the world. A vast ecosystem of suppliers and partners has established a presence in Singapore, covering the entire semiconductor industry chain from upstream to downstream. There is a friendly commercial environment, tax incentives, a professional regulatory framework, and a sound intellectual property (IP) system.

- Industry friendly Taxation rules:
  - In terms of taxation, Singapore is a typical "wealthy-friendly" country. It has a network of double taxation agreements (DTAs) with over 80 countries/regions worldwide, which aims to avoid double taxation, promote fair and equal tax treatment of Singaporean enterprises and their foreign partners, and reduce the cost of their overseas expansion.
  - The highest corporate tax rate for taxable income in Singapore is 17%, and there is no capital gains tax or dividend income tax.
  - Post-tax dividends paid from Singapore are not subject to withholding tax.
  - Additionally, all foreign-sourced income is exempt from tax as long as it is taxed in a country/region with a total tax rate of at least 15%.
- Singapore's regulatory framework also provides a fair and competitive environment for foreign investors, with no foreign ownership restrictions or foreign exchange controls.
- For the semiconductor industry, which is highly intensive in intellectual property, Singapore's sound IP system is also advantageous.
  - The government encourages innovation and development by Singaporean enterprises, while a reliable legal system and strong IP infrastructure protect them.
- To ensure the smooth global circulation of chips, Singapore also provides an efficient logistics system, making it one of the world's logistics centers. 24 of the world's largest logistics companies have established themselves in Singapore.
- Singapore is one of the most successful countries in the world for the development of multinational semiconductor companies.
  - It has attracted a relatively large number of well-educated workers and engineers.
  - In 2022, the number of wealthy individuals who chose to relocate to Singapore had increased to 2,800, and there were over 700 family offices in the country.
- It has had a close relationship with Temasek, a state-owned capital group, which has invested heavily in the semiconductor industry and also in many Chinese internet companies, including Alibaba, Tencent, Meituan, and Xiaomi.

Singapore has created all the required resources, such as capital, knowledge, technology, and talent, which are backbone of any semiconductor industry. In the process of attracting investment, Singapore has continuously absorbed foreign funds, technology, and experience in the semiconductor industry, continually positioning itself as an important hub for the world's semiconductor industry.

Singapore's government is reviewing the semiconductor policy to make it more industry oriented in emerging technologies. In December 2020, Singapore unveiled its National Research Foundation's "Research, Innovation, and Enterprise 2025 Plan", in which the government will maintain investment in research, innovation, and enterprise as a percentage of the country's GDP at 1% (about USD 25 billion) between 2021 and 2025 to support the electronics and semiconductor industry in seizing new growth opportunities.

Likely future investments in Singapore:

- Starting in 2020, Singapore has significantly expanded its manufacturing output, with the goal of achieving a total manufacturing output of USD 200 billion and a total manufacturing value-added of USD 50 billion.
  - This includes nearly USD 10 billion in investments from HP and Texas Instruments.
- For large chip manufacturers and supporting suppliers such as Texas Instruments and Micron, increasing production in Singapore to meet longer-term demand growth and diversify supply chain risks is a decision that is unlikely to go wrong, especially given Singapore's geographic advantage
- In terms of semiconductor materials, Soitec plans to invest €400 million (USD 430 million) in Singapore to double the production capacity of its silicon wafer plant,
- Applied Materials has started construction on a new USD 450 million plant in Singapore.
- In terms of wafer fabrication, UMC has

executed a capital budget plan and plans to invest NT USD 32.417 billion (approximately USD 1.06 billion), some of which will be used to invest in a new Singapore factory.

- GlobalFoundries is preparing to invest an additional USD 4 billion to build new plants, with production capacity expected to increase by about 30%. This project is one of the largest investment projects for semiconductor companies in Singapore in recent years.
- The Singapore government is willing to provide preferential policies such as land, water, electricity, and tax reductions, as well as sufficient human resources assistance, to encourage TSMC to reconsider building a 12-inch factory locally.
- United Microelectronics Corporation (UMC) / USD 5 billion investment - The Taiwanese chipmaker UMC is setting up a new microchip factory here, with production expected to start in 2024. It will produce 22 and 28 nm chips to support the boom in 5G and auto electronics.
- Advanced Micro Devices (AMD) - > USD 50 million investment: American semiconductor company AMD has plans to expand and upskill its Singapore workforce over the next three years. The expanded team will focus on high performance computing tasks such as developing hardware and products; analysing devices; and researching artificial intelligence.

Malaysia Semiconductor Industry

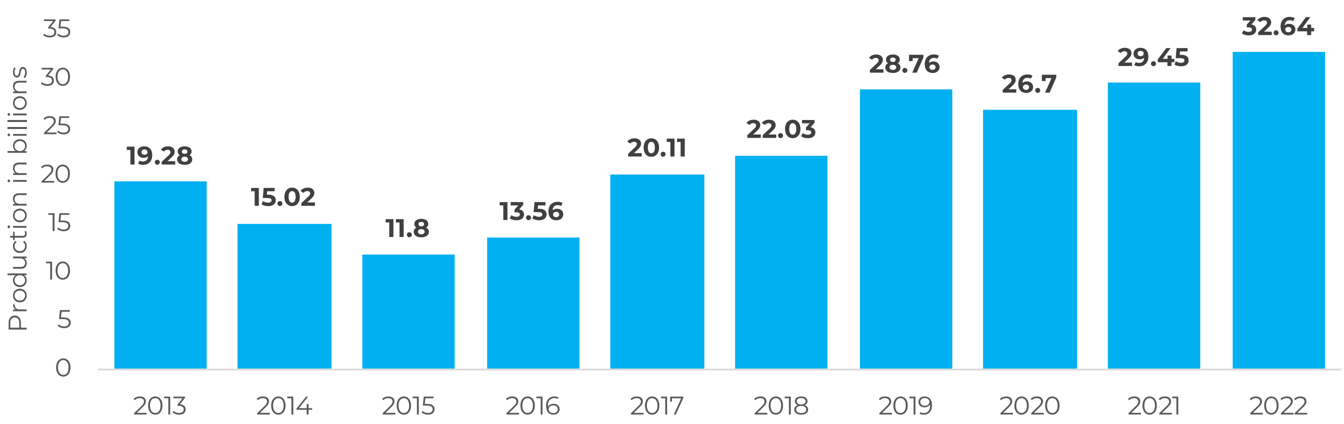
Malaysian Semiconductor Industry Landscape:

Malaysia's strategic location, low-cost opportunities, sophisticated talent pool, and favorable government and regulatory support make it an attractive hub for semiconductor players. Emerging technologies such as IoT, Big Data, connected devices and cars, 5G, and AI are driving the industry towards progress and transformation.

The Malaysian semiconductor industry is primarily dominated by the traditional labor-intensive OSAT business, providing outsourced services like assembly, packaging, and testing mainly to multinational companies. With the merger of Malaysian company AMD and Chinese company Nanjong Fujitsu Microelectronics, the country holds a competitive edge in packaging and testing.

The Production trend of Semiconductors in Malaysia, depicted in figure 7 below indicates a tripling of Production over the past seven years

Figure 7: Production Trend in Malaysia (2013 – 2022) in USD billions[19]:



Malaysia has a 13% global market share for semiconductor assembly, test and packing [20].

[19] Statista
[20] https://www.thestar.com.my/metro/metro-news/2023/02/14/chip-industry-outlook-remains-bright-says-expert

Malaysia commands a 13% global market share in semiconductor assembly, test, and packing, with 6 out of 12 key semiconductor players operating there. Some have established global hubs, excellence, fulfillment, delivery, shared centers, and control towers in Malaysia. Growth potential segments include automotive electronics, sensors, actuators, and communication chips.

Although the Malaysian semiconductor industry consists of over 50 players, a few key players dominate, competing for market share. The industry's landscape can be broadly categorized into three groups.

- **OSAT companies**
  - Dominated by OSAT business, companies like Anari Amertron, Malaysian Pacific Industries (MPI), Unisem, Globetronics Technology, and KESM Industries offer assembly, packaging, and testing to MNCs. **ATE manufacturers**
  - Providing factory automation and back-end services to MNCs and OSAT players, key participants include ViTrox Corp, Pentamaster Corp, Greatech Technology, Mi Technovation, Aemulus Holdings, Elsoft Research, MMS Ventures, and VisDynamics Holdings. **Test socket stiffeners**

Companies like JF Technology and FoundPac Group design and manufacture test sockets and stiffeners for OSAT players and semiconductor firms.

Table 1. Key Market Players in Malaysia

Company Name	Market Cap.	Description
Inari	USD 1.2 billion	OSAT for Radio frequency and optoelectronics
Vitrox	USD 850 million	Supplier of automated vision-inspection equipment
Frontken	USD 586 million	Support service, cleaning and coating of tools for fabricating wafer
MPI	USD 555 million	Automotive focused OSAT
Pentamaster	USD 491 million	Manufacturer of automated and semi-automated equipment
Unisem	USD 384 million	OSAT, owned by Tianshui Huatian Technology
Globetronics	USD 356 million	Sensor focused OSAT

Malaysia's solid back-end capabilities, particularly in IC packaging and testing, along with a sophisticated talent pool in the integrated circuits design segment, make it a noteworthy player.

The future of semiconductor industry in Malaysia anticipates a significant growth rate of 26% in wafer fabrication, packaging and testing sectors, driving industry growth by a CAGR of 5-9%[21].

Malaysian Government policies and support:

Malaysia's solid back-end capabilities, particularly in IC packaging and testing, along with a sophisticated talent pool in the integrated

[21] Ibid

circuits design segment, make it a noteworthy player.

Penang, known as the Silicon Valley of the East, has attracted diverse local suppliers and developed a comprehensive value chain over 51 years. This robust infrastructure has drawn industry giants like Intel, ASE, and AT&S to invest billions in state-of-the-art facilities.

The local government's proactive measures, including developing additional industrial land and programs like the Penang Internship Subsidy Programme, have been commendable. Collaborations with local universities ensure a pipeline of industry-ready graduates

Tax emption	Malaysia has the provision of income ax exemption between 70-100% of statutory incom for about 5-10 years
Tax allowance	Investment tax allowance between 60-100% on qualifying capital expenditure incurred within a period of 5 to 10 years
Equity Ownership	Malaysia permits foreign investors to own up on to 100% equity in any corporation established in the manufacturing sector
Repatriation of income	Malaysia has business friendly policies as if puts no restrictions on the repatriation of capital, interest, dividends, or profits
IP Protection	Malaysia is guarantees IP protection and is a signatory of the Paris Convention and Berne Convention — which govern IP rights — as well as a signatory of the Agreement on Trade. Related Aspects of IP Rights under the World Trade Organization

Table 2. Likely future investments in Malaysia [22] : (one line statement)

Company	Investment proposed in USD B	Jobs promised
Infineon Technologies	2	1,000+
Intel	7.1	4,000+
TF-AMD	0.44	
Nexperia	0.35	
Sensata	0.11	
Ferrotec	0.11	250+
Unisem	0.06	
AT&S	1.9	6,000+
TTM Technologies	0.12	
Indium Corp	0.5	
Total	12.69	~11,000+

Vietnam Semiconductor Industry

Vietnam's semiconductor industry, driven by the large presence of Electronic Manufacturing Services and Electronic Exports (Mobile), has attracted several Semiconductor ATMP/OSAT units over the past two decades. Recently Samsung and Intel also created large expansion for display panels and OSAT with dedicated technology and training support.

The Vietnamese Government prioritizes 'high-tech manufacturing,' offering incentives to attract Global Semiconductor companies for Chip Designing and Wafer fabs.

While there are evidences of OSAT firms investing in new units/expansions, no Wafer Fabs have shown interest in Vietnam. However, several Chip Design firms and Global Semiconductor companies have Research centres in Vietnam.

The semiconductor market value in Vietnam is projected to grow by USD 1.65 billion over 2020-2025, driven by the growing use of the Internet of Things and the increasing adoption of smart home technology.

Key players in Vietnam's Semiconductors market:

- Vietnam had Intel Products Vietnam (IPV), the largest assembly and testing plant in Intel's network. In 2022, Intel committed to spend USD 475 million to build a **cutting-edge microelectronics testing and assembly facility** in Vietnam. The complex, built in Vietnam, has received more than USD 1.5 billion over the past 15 years from the components industry giant, which makes the manufacturing plant one of Intel's largest factories[23].
- Samsung will begin making semiconductor parts in Vietnam in July 2023, further diversifying its manufacturing as the US, China, and others seek to diversify and hone technology supply chains. Samsung is now **testing ball grid array products and intends to mass produce them** at the Samsung Electro-Mechanics Vietnam factory in northern Thai Nguyen province with an investment of USD 920 million. Samsung, Vietnam's biggest foreign direct

[22] MSIA Presentation - Malaysia's Semiconductor & Electronics Industry
[23] https://www.vietnam-briefing.com/news/vietnams-semiconductor-industry-samsung-makes-further-inroads.html/

investor, first invested USD 1.3 billion in the electro-mechanics unit in 2013, which produces mainboards and other electronic components. Last year, the number climbed to USD 18 billion as their total investments in Vietnam. The electronics giant also has six plants in the country and is building a new research and development center in the capital Hanoi [24].

- Other chipmakers, including Qualcomm, Texas Instruments, SK Hynix, and NXP Semiconductors have also built research centers and factories in Vietnam. Those companies have laid the groundwork in terms of manufacturing and logistics infrastructure as well as research centers, which in turn has made Vietnam a more appealing destination for follow-up investment in the industry.
- Hayward Quartz Technology, a large OEM supplier, secured approval to construct a USD 110 million plant in Vietnam. Once up and running, the site will make crystal silicon blocks, plastic polymers, and other materials used in microelectronics fabrication.
- Synopsys, a reputed chip software maker based in the US, signed an MoU with Vietnam's Saigon high-tech park to provide training for Vietnamese electrical engineers while giving away 30 licenses, at USD 20 million worth, for the tech park. This move indicates both Vietnam's rising appeal in the international market and the company's caution towards the Chinese semiconductor sector amid the US-China trade war.
- Corporations like Microchip, Renesas, Applied Micro (AMCC), Marvell, Arrive Technologies, eSilicon, Sigma Designs, Uniquify... also operating in Vietnam and specializing in outsourcing and designing semiconductor and embedded software in the area. Most of the big corporations moved their production from China or Malaysia to Vietnam due to the country's low labor costs and government's support.

[23] https://www.vietnam-briefing.com/news/vietnams-semiconductor-industry-samsung-makes-further-inroads.html/

[24] Ibid

Likely future semiconductor investments in Vietnam:

- South Korean group Amkor Technology, one of the world's largest providers of outsourced semiconductor packaging and design, is eager to implement a factory at Yen Phong II-C Industrial Park in the northern province of Bac Ninh. The firm will pump USD 1.6 billion into the factory and disbursement will be completed in 2035. The first phase of the project will focus on the production, assembly, and testing of semiconductors for the world's top semiconductor and electronic manufacturers[25].
- Intel was in the process of considering a significant increase in its existing USD 1.5 billion investment in the nation as it seeks to expand its chip testing and packaging plant in Vietnam. The move could be worth an additional USD 1 billion and would signal a growing role for the country as part of the global supply chain for semiconductors, as companies push to cut reliance on China because of political risks and trade tensions[26].
- Suppliers to Dutch chip-making machines giant ASML Holding NV, a supplier to top global semiconductor manufacturers, are also considering building plants in Southeast Asia, including Vietnam, as opposed to China. The companies participating include Newways, Bestronics, HQ Group, KMWE Group, Sempro, and Sioux Technologies[27].

Vietnam Government's initiatives:

- The Vietnamese government issued many incentive and support policies to create stronger conditions for investment inflow in terms of high-tech sectors and semiconductor is a priority sector. Vietnam has also established high-tech centres in Hanoi, Ho Chi Minh City, and Danang with special incentive policies to connect research and development and invest in high-tech and innovation projects [28].
- Decision 667 lays out the strategy for foreign investment cooperation for this decade. One of the objectives is to attract foreign projects that utilise advanced and high technology of Industry 4.0, modern administration, yield high added value, and connect global production and supply/demand chains. Vietnam's unique value propositions as a stable, geopolitically neutral, low-cost supply base coupled with favourable government policies would help to attract more high-tech and semiconductor investment. The Ministry of Planning and Investment has also been tasked to draft the mechanisms and policies to attract overseas funding in chip production [29].
- To develop the semiconductor industry, the government has allocated USD 3.2 billion to set up Integrated Circuit Design Research and Education Center, Saigon High-Tech Park Labs, and two Integrated Circuits R&D centres, and launched the first Integrated Circuit Development Programme in 2009. The programmes provided training to electronic engineers to turn them into microchip designers and incubated over 30 domestic technology firms. Under the programme, in 2012-2017, some local chips have been successfully commercialised [30].

The key advantages of Vietnam as per various reports are:

- Favorable demographics with relatively low labor costs and human resources.
- Established EMS and an Electronics Manufacturing and Exports landscape provides for a local semiconductor market as well.

[25] https://vir.com.vn/scope-existing-for-semiconductor-gains-101222.html

[26] Ibid

[27] Ibid

[28] https://vir.com.vn/us-semiconductor-manufacturers-survey-vietnam-opportunities-99255.html

[29] https://vir.com.vn/capitalising-on-semiconductor-market-100079.html

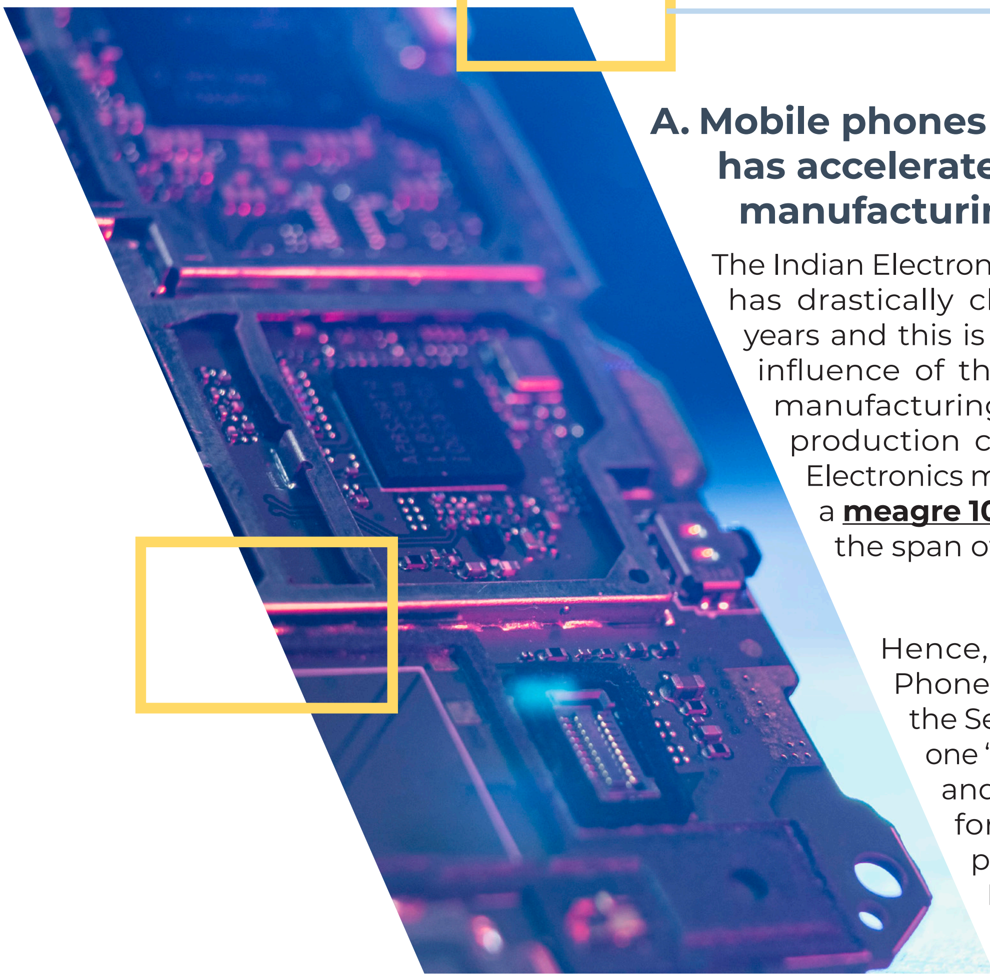
[30] https://vir.com.vn/vietnams-semiconductor-market-to-grow-by-616-billion-86316.html

- Vietnam also boasts an ambitious government that is opening the country to foreign trade and investment and adapting the local legal framework to international practices,
- A growing and willing to learn and improve – an ecosystem of local entrepreneurs, and clear plans for the future development trajectories of the country.
- In addition, the country's neutrality in the US-China trade war, as well as the Russia – Ukraine war, has also made it easier for investors to choose a place to produce and supply components for other economies.

However, Vietnam is primarily engaged in packaging and testing, sectors known for their lower margins compared to semiconductor design and manufacturing. The principal challenge hindering Vietnam's advancement in the industry likely lies in the significant demands for advanced manufacturing infrastructure and specialized labour expertise.

Chapter 4

SEMICONDUCTORS USAGE IN MOBILE PHONES & OPPORTUNITY FOR INDIA AS A CASE STUDY



A. Mobile phones manufacturing has accelerated Electronics manufacturing in India

The Indian Electronics manufacturing scenario has drastically changed over the last 5-7 years and this is largely due to a very large influence of the growing Mobile phone manufacturing in India. Mobile Phones production contribution in the Indian Electronics manufacturing jumped from a **meagre 10% to a whopping 44%**[31] in the span of the last 7 years.

Hence, ICEA has used Mobile Phones as a case study to set out the Semiconductors usage in this one "impactful" product category and to set out the opportunity for India in this important product segment for India's Electronic manufacturing business.

[31] MEITY Annual reports; ** ICEA estimates

B. Overview of Semiconductors in Mobile Phones

The Mobile Phone Semiconductor Market, valued at USD 44.9 billion in 2020 and is projected to reach USD 69.3 billion by 2026 [32], registering a CAGR of 7.49% during the forecast period 2021 – 2026 . The growth is spurred by factors such as increasing adoption of smart technologies in mobile phones and the swift emergence of next-generation mobile-communications standards, like LTE or 5G.

Though, the overall semiconductor industry witnessed modest growth, and the smartphone business was also fluctuating. However, the mobile phone semiconductor market was able to witness marginal growth, owing to the increasing adoption of RF-based applications in smartphones. **In many regions, especially Asia-Pacific, the smartphone business was the largest consumer of the semiconductor industry.**

Since the past year, the smartphone industry has been witnessing a nearing maturity state which is affecting the mobile phone semiconductor industry. However, **with the advent of 5G technology and the government's approval for the adoption of 5G technology, it is expected to enable smartphone users to shift from phones supporting 4G and LTE technology to 5G technology which would create huge opportunities for the studied market.**

The proliferation of mobile & IT Hardware devices, including Smartphones, Wearables, Tablets, and e-book readers, has been instrumental in driving the demand for various semiconductor components, including applications processors, modems, MEMS sensors, wireless connectivity ICs, and audio ICs in these devices.

The increased revenue of RF, attributed to its widespread adoption across multiple bands, a larger number of carriers aggregated, and higher-order MIMO configurations supported by an increase in smartphone ASPs. This trend was expected to continue in 2019, with the addition of the mid-band spectrum for sub-6GHz 5G and mm Wave modules in some 5G phones. Several external factors, such as changes in the semiconductor supply chain, fluctuations resulting from the US-China trade war, the Russia-Ukraine conflict, and shifting business models, have both opened opportunities and presented challenges.

Morever, the COVID-19 pandemic has wrought significant disruptions in supply chains and production, especially in the Asia-Pacific region. Major semiconductor manufacturing industries have been significantly affected as a result of Asia-Pacific being a world production center over the past two to three decades.

C. Semiconductors usage in Mobile Phones

In a modern-day smartphone, estimates suggest the inclusion of anywhere from 8 – 16 billion Transistors , compactly assembled within the device. These transistors[33] are housed within various Integrated Circuits (ICs)along with other discrete semiconductors such as Diodes, Transistors/Mosfets and LEDs used in a Mobile Phone. .

For this study, ICEA undertook a teardown of two most prominent Smartphone Models, referred to as Flagship 1 and Flagship 2. Utilizing published information from authoritative sources as iFixit and TechInsights, the total number of ICs used in these Phones has been enumerated. This is shown below in table 3 & 4 below:

[32] Mordor Intelligence; Mobile Phone Semiconductor Market - Growth, Trends, COVID-19 Impact, and Forecasts (2023-2028)
[33] https://mrfixitca.com/what-do-transistors-do-in-a-mobile-phone/

Table 3 – Flagship 1[34] ; Integrated Circuits = 49

Sl. no.	IC Name	IC Category	Popular application name
1	Bionic SoC layered	MPU	Promisor IC
2	Power management IC	Power Management	Power IC
3	Power management IC	Power Management	Power IC
4	Power management IC	Power Management	Power IC
5	Power management IC	Power Management	Power IC
6	Display power management IC	Power Management	Power IC
7	Display port multiplexer	Logic	GraphicsController IC
8	VCSEL Array driver	Opto	RF IC
9	USB 2.0 Dual Repeater	Analog	BlueTooth IC
10	DC-DCconverter	Power Management	Power IC
11	Power management IC	Power Management	Power IC
12	Load Switch	Analog	Power IC
13	Ultra-wideband chip	Sensor	RF IC
14	Front-end module	Analog	RF IC
15	Front-an module	Analog	RF IC
16	Front-aid module	Analog	RF IC
17	Power amplifier module	Analog	RF IC
18	Switch Module	Logic	RF IC
19	Filters	Discrete	RF IC
20	Electronic compass	Sensor	Sensor
21	NAND flash memory	Memory	MemoryChip
22	Secure microcontroller w/eSIM	MCU	Processor IC
23	Audio processor	DSP	DSP Chip
24	Audio codec	DSP	DSP Chip
25	Audio amplifier	DSP	DSP Chip
26	Wireless power receiver	Analog	RF IC
27	Haptic driver	Analog	Power IC
28	Power management IC	Power Management	Power IC
29	Power management IC	Power Management	Power IC
30	LED flash driver	Opto	LEN
31	DC-DCconverter	Power Management	Power IC
32	DC-DC converter	Power Management	Power IC
33	Voltage Level Translator / Transceiver	Logic	Power IC
34	Voltage Level Translator	Logic	Power IC
35	WiFi/Bluetooth module	MCU	BlueTooth IC
36	56 modem	Analog	RF IC
37	56 RF transceiver	Analog	RF IC
38	Front-end module	Analog	RF IC
39	Front-end module	Analog	RF IC
40	NFC controller with secure element	MCU	BlueTooth IC
41	Power amplifier module	Analog	RF IC
42	Envelope tracker	Analog	RF IC
43	Envelope tracker	Analog	RF IC
44	Envelope tracker	Analog	RF IC
45	RF switch module	Analog	RF IC
46	RF switch	Discrete	RF IC
47	Antenna switch module	Analog	RF IC
48	Antenna tuning switch	Analog	RF IC
49	6-Axis Accelerometer/Gyroscope	Sensor	Sensor

[34] Teardown Information from IFixit, Other assumptions / Analysis by Feedback Advisory

Please note: The categorization has been done to the best of our understanding / Literature Research (Catalogues); however there could be some errors in this understanding.

Table 4 – Flagship 2 [35] ; Integrated Circuits = 40

Sl. no.	IC Name	IC Category	Popular application name
1	Snapdragon 8 Gen 1 Octa-Core Processor	MPU	Processor IC
2	128 GB NAND Flash Memory (UFS 3.1)	Memory	Memory Chip
3	Power Management	Power Management	Power IC
4	Power Management	Power Management	Power IC
5	Power Management	Power Management	Power IC
6	MEMS Microphone	Sensor	Sensor
7	NFC Controller w/Secure Element	MCU	BlueTooth IC
8	RF Transceiver	Analog	RF IC
9	GPS /GLONASS /Galileo / BeiDou Low Noise Amplifier	Analog	RF IC
10	Front End Module	Analog	RF IC
11	Antenna Switch Module	Analog	RF IC
12	Dual SPST Antenna Aperture Shunt Switch	Analog	RF IC
13	Light/Color/Gesture/Proximity Sensor	Sensor	Sensor
14	Audio Amplifier	DSP	DSP Chip
15	Haptic Driver	Analog	Power IC
16	Wireless Power Transceiver	Analog	Power IC
17	Power Management	Power Management	Power IC
18	Power Management	Power Management	Power IC
19	2-Port DPDT Analog Switch	Analog	Power IC
20	MEMS Microphone	Sensor	Sensor
21	Power Management	Power Management	Power IC
22	Power Management	Power Management	Power IC
23	Power Management	Power Management	Power IC
24	Clock Generator	Logic	Power IC
25	SP4T Antenna Switch	Analog	RF IC
26	SP3T Antenna Switch	Analog	RF IC
27	GPS/GLONASS/Galileo/BeiDou Low Noise Amplifier	Analog	RF IC
28	RF Transceiver	Analog	RF IC
29	Front-End Module	Analog	RF IC
30	Front-End Module	Analog	RF IC
31	Antenna Switch Module	Analog	RF IC
32	WiFi 6/6E & Bluetooth 5.3	MCU	BlueTooth IC
33	Front-End Module	Analog	RF IC
34	DPDT Antenna Cross Switch	Analog	RF IC
35	6-Axis Accelerometer & Gyroscope	Sensor	Sensor
36	Pressure Sensor	Sensor	Sensor
37	3-Axis Electronic Compass	Sensor	Sensor
38	Band 71 SAW duplear	Analog	RF IC
39	Band 29 SAW filter	Analog	RF IC
40	ISM 2.46 SAW filter	Analog	RF IC

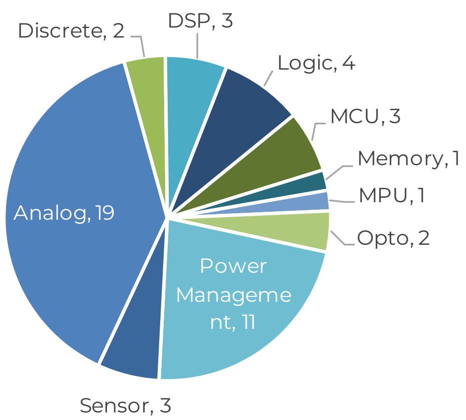
[35] Teardown Information from IFixit, Other assumptions / Analysis by Feedback Advisory

Please note: The categorization has been done to the best of our understanding / Literature Research (Catalogues); however there could be some errors in this understanding.

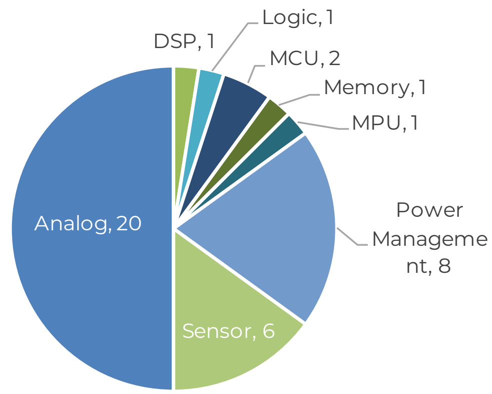
An analysis of these two Smartphone models reveals the following key insights:

1. Integrated Circuits usage in Smartphones by various categories is shown below in figure 8 & 9 Below

Flagship 1 – INTEGRATED CIRCUITS BY CATEGORY = 49

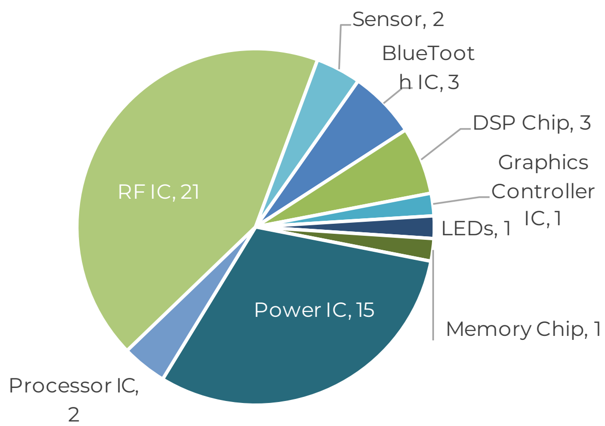


Flagship 2 – INTEGRATED CIRCUITS BY CATEGORY = 40

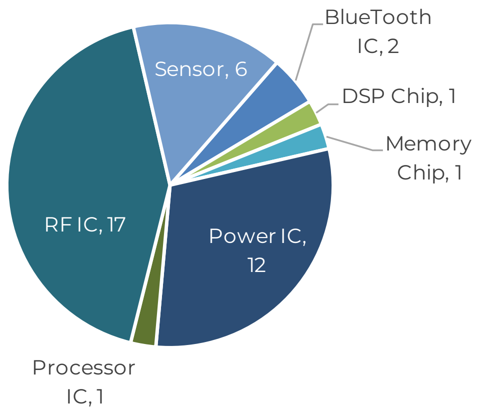


2. Integrated Circuits usage in Smartphone by popular application names is shown below in figure 10 & 11

Flagship 1 – INTEGRATED CIRCUITS BY POPULAR APPLICATION NAMES = 49



Flagship 2 – INTEGRATED CIRCUITS BY POPULAR APPLICATION NAMES = 40



Semiconductors contribution to the Bill of Materials in a Smartphone:

ICEA had carried out a detailed study of Smart Phones Bill of materials last year. The study estimated the total Semiconductor to account for around 25-30% of the Bill Of Materials of a typical Smart Phone. **This translates to approximately USD 9-10 billion in Semiconductors demand only for the Smartphone segment in India from FY 2022-23.**

The breakdown of this Semiconductors in a Smartphone Bill of Materials is shown below in table 5:

Semiconductor Products InMaterials BOM	% contribution In Materials BOM
Processor IC	7.8%
Memory Chip	5.9%
Power !Cs	3.6%
Transistors	2.8%
RFIC	2.2%
Blue Tooth IC	1.1%
FM & Digital Radio IC	1.1%
Graphic Controller IC	1.1%
Diodes	0.9%
FET	0.9%
LEDs	0.5%
LCD Driver IC	0.5%
DSP Chip	0.4%
Sensors	0.3%
MOSFET	0.1%
Total Semiconductor Products	**29.1%**

D. Opportunity for India in Semiconductors for Smart Phones:

Based on the industry discussions, technology roadmap and the strengths of India, ICEA has carved out a priority roadmap for Semiconductors in Mobile Phones. This also includes Memory ICs, given the new investment proposed by Micron in India. This is outlined below in table 6:

Semiconductor Products In Materials BOM	% contribution In Components	Priority for India to focus
Diodes	0.9%	Priority 1
FET	0.9%	
Power ICs	3.6%	
MOSFET	0.1%	
Sensors	0.3%	
Transistors	2.8%	
LEDs	0.5%	
Memory Chip	5.9%	
LCD Driver IC	0.5%	Priority 2
Blue Tooth IC	1.1%	
FM & Digital Radio IC	1.1%	
Graphic Controler IC	1.1%	
RF IC	2.2%	
DSP Chlp	0.4%	Priority 3
Processor IC	7.8%	
Total Semiconductor Products	**29.1%**	

Recommendation:

Not all of the above-mentioned Semiconductors represent immediate opportunities for India. For e.g., Processor Chips, which are Advanced Chips specifically for High end phones, may require some time before India can produce them at a competitive level. However, there is a commercial viability in fabricating Processor Chips for entry-level smartphones in India. This could be a consideration for the New Semiconductor Fabs.

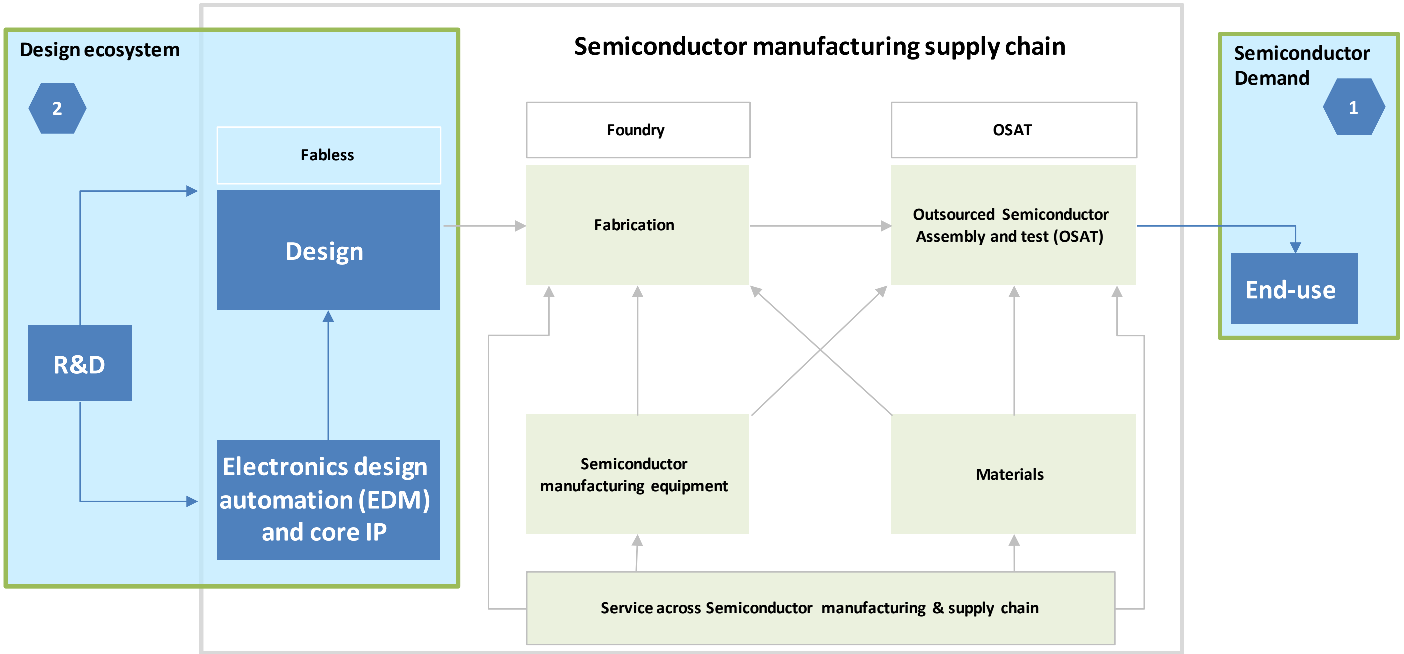
India's smartphone consumption stood at approximately 150 million units in 2023. Industry estimates suggest that indigenizing chips for just 10% of this market i.e., 15-18 million for entry-level smartphones, makes strong commercial sense in supporting the Indian domestic fab unit. With a monthly output of around 1.5 million unit (10-14 nm) of chipsets – assuming 15,000 wafers of 300mm at 70% yield from a fab, and considering the number of die per wafer to be 148 - the annual output could be approximately 18 million chipsets. ICEA will be submitting a detailed policy recommendation on this matter.

Chapter 5

EVALUATION OF INDIA'S CURRENT STATUS AND POTENTIAL IN SEMICONDUCTOR DESIGN DEVELOPMENT

A. The Semiconductor Value Chain

The Semiconductor Value Chain is made up of a wide range of activities as shown in the figure 12 below



Semiconductor Industry Value Chain

Focus for this paper

Source: Feedback Analysis

The chart highlights all three areas in figure for India to participate in the Semiconductor Industry Value Chain. In the sections below, we have explored in detail for each of these 3 areas and set out our reasoning for this current rating about India's current status and the future roadmap.

1. **End Use Market for Semiconductors in India – Large Electronics manufacturing likely to drive up demand for Semiconductors:**

Electronics manufacturing in India gaining steam:

The Indian Electronics manufacturing has reached USD 103 billions in 2022-23[36] comprises of Mobile Phones (43%), Consumer Electronics (12%), Industrial Electronics (11%), Auto Electronics (9%), Electronic components (10%), Strategic Electronics (5%), IT H/w (4%), LEDs (3%) and others (Telecom, Wearables & PCBA @ 3%) as shown in table 7 below:

[36] Source: ICEA Estimates

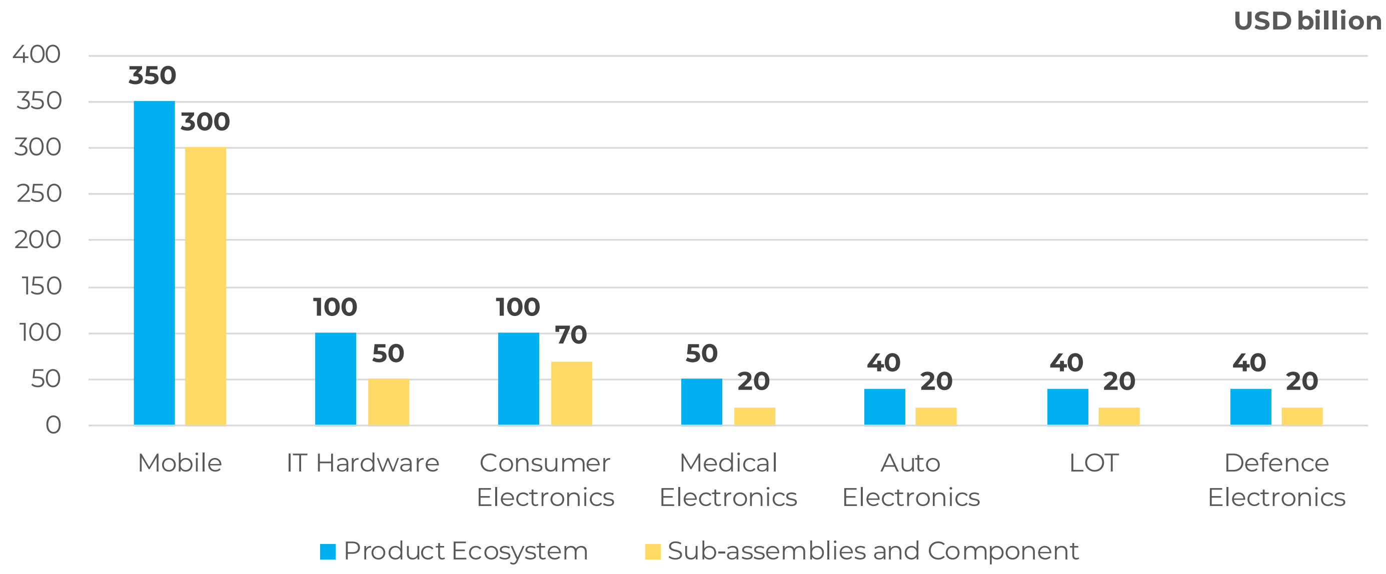
Table 7

Product Segments	2020-21	2021-22	2022-23
Mobile Phones	30	38	44
IT H/w (Laptops / Tablets)	3	4	4
Consumer Electronics (TV / Audio / Accessories)	10	10	12
Strategic Electronics	4.0	4.3	4.8
Industrial Electronics	11	11	12
Wearables & Hearables	0	0.3	1
PCBA	0.5	0.6	1
Auto Electronics	6	7	10
LED Lighting	2.2	2.5	3
Telecom Equipment	0	0.3	1
Electronic Components	9	10	11
Total Production (USD billion)	**75**	**87**	**103**

India's rise in electronics manufacturing can be seen a sharp rise in Mobile manufacturing in the last 4-5 years. India represents one of the largest- and fastest-growing electronics market in Asia, and the Indian government plans to boost this growth to take it to USD 300 billion by the year 2026[37] . The recently released Vision Document states that:

"For India to be the global electronics manufacturing hub of the future, there needs to be a clear long-term vision which must be achieved by means of the short-term goals. In order to become a USD 5 trillion economy by 2025-26, (or 2027-28 considering allowance for the two year loss on account of the pandemic), India shall strive to be a USD 1 trillion digital economy given its omnipresence across all spectrums of life. Moreover, a special emphasis shall be laid on exports to achieve this objective."

The long-term vision is to create a USD 1 trillion Electronic ecosystem in India in the next 10 years as given below in figure 13 below:



[37] ICEA Vision Document released by Minister of State, Electronics Shri Rajeev Chandrasekhar in Feb 2022

this long-term vision becomes a comfortable one after achieving a predefined USD 300 billion Electronics manufacturing target by 2026. These two, short and long term goals requires Government of India attention to:

- Build competitiveness and scale
- Shift and develop sub-assemblies and components ecosystem
- Build design ecosystem
- Nurture Indian champions
- Steadily remove disabilities in India

The growing Electronics manufacturing is driving demand for Semiconductors for India:

The growing Electronics manufacturing is driving the demand for Semiconductors in India. In FY23, the total import of Integrated Circuits (ICs) reached USD 16.14 billion (out of which USD 12 billion was only for mobile phones, clearly indicating the shallow value addition in verticals other than mobile phones). This suggests that for other verticals PCBA is getting imported and only final assembly is happening in India. The current manufacturing of USD 103 billion would translate to a Semiconductor requirement of USD 26 to USD 31 billion, going by a typical norm[38] of 25% to 30% of Semiconductor components in any Electronics Product BOM. With the rise in electronics production, this number is set to rise substantially.

Therefore, the key task before all the stakeholders is how to translate the **burgeoning Semiconductors requirement to be in India and not depend on Imports** as it is being done now. This will **then translate to Semiconductors procurement to happen in India and will also translate as a "Domestic market" for the Semiconductor fabs being setup in India, thereby increasing their viability.** This will require the following key urgent steps to be taken up:

a. Ensuring PCBA operations happen in India across Electronic Products and PCBA imports should be discouraged.

b. India should focus on circuit design thereby allowing the domestic decision regarding procuring components.

c. A strategy for a segment level approach to deepen PCBA localization across all verticals Electronics Manufacturing is necessary.

d. Increased focus on deep domestic value addition across Electronic Products manufacturing in India.

e. Investment in R&D (more details in next section) is required to create more New Electronics products in India.

f. The highly successful Digital India program needs to be backed by locally developed and Made in India Electronic Hardware (ICT Products) to further deepen domestic requirements of Semiconductors in India.

Implication for India:
India needs to work for the integration of "Design and Chip fabrication with in the country to become the global production hub. Further developments for the advance node R&D for new products in India will capture Semiconductor potential for India.

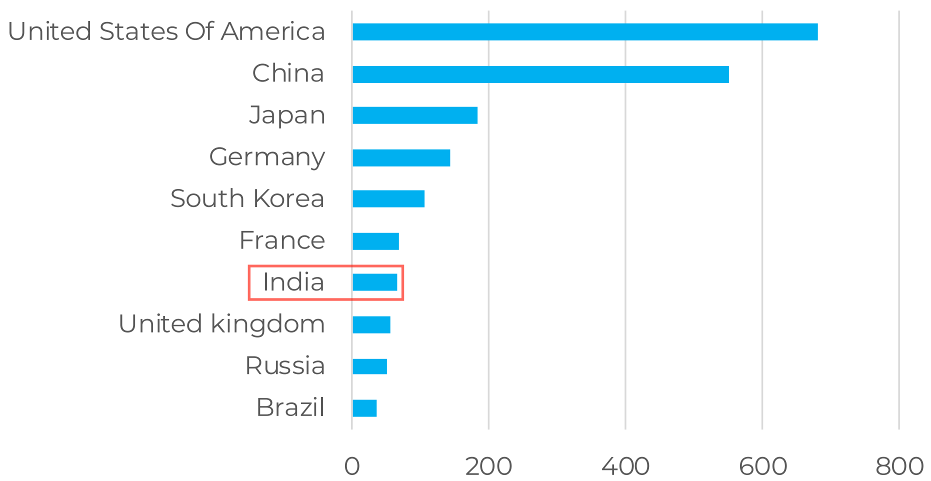
2. Design Ecosystem in India – have some positive hotspots and needs a major evaluation and concerted efforts

If we see the key actions points C/D/E above, to increase true Domestic Electronics Manufacturing in India, one of the common requirements is the need to create 'India' developed Products which requires a heavy focus on R&D in India. This is one area which India lacks, and this section outlines the key problems associated and a way forward.

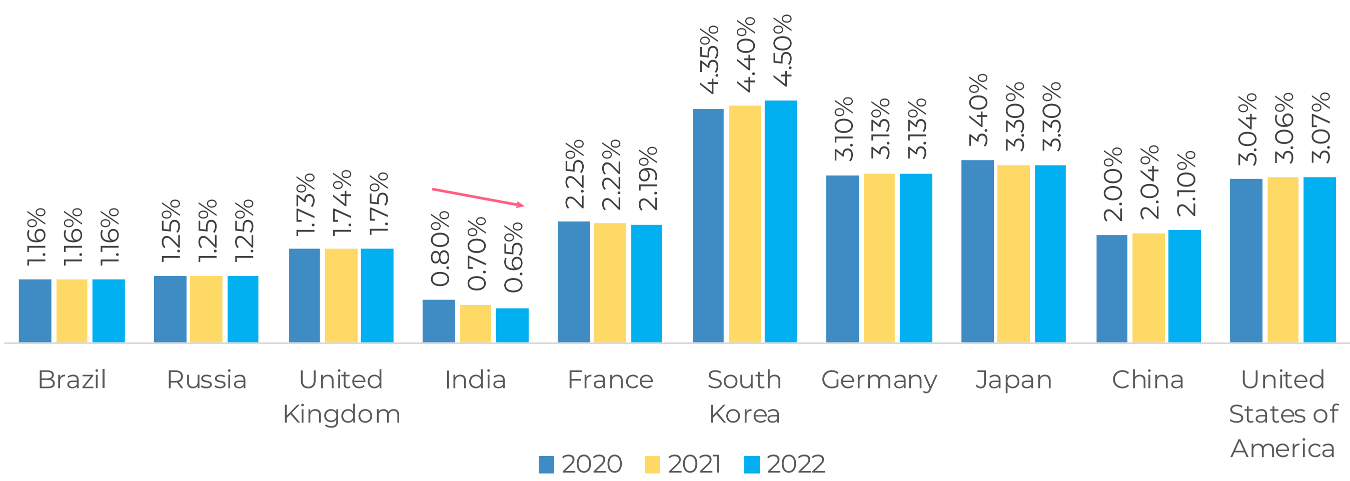
[38] ICEA estimate

a. R&D – major weakness for India

R&D spends in general and in ICT sector specifically, is a major problem area for India with very low spends compared to other nations as shown below in figure 14:



Not just low spends on R&D, the worrisome trend is the falling spends in R&D when compared to most other nations which show a rising trend, as shown below in figure 15:



Secondly, India also needs to improve the number of people participating in R&D. World Bank data, shows that in comparison of 1,597 researchers per million people worldwide, only 253 researchers per million people were available in 2018. The numbers for China, Russia, Malaysia, Iran, Thailand are close to the global average. South Korea had 8,714 researchers per million people, the highest in the world[39] . The direct impact of poor R&D capability results in to limited patents and IPR.

[39] https://www.fortuneindia.com/long-reads/how-india-can-stem-863-billion-outflow-of-foreign-ip-payouts/109633

Patents:

India has observed a steady rise in both the filing and granting of patents over recent years. The number of patents filed within the country has escalated from 39,400 in 2010-11 to 45,444 in 2016-17, and further to 66,440 in 2021-22. Similarly, the patents granted have also increased from 7,509 to 9,847 to 30,074 during these corresponding periods.

A significant shift in this trend is the growing contribution of Indian residents to patent applications, as opposed to Multinational Corporations (MNCs). The share of Indian residents in total applications has more than doubled over the past decade, rising from 20 percent in 2010-11 to around 30 percent in 2016-17, and further to 44 percent in 2021-22. In an unprecedented turn of events, domestic patent filings surpassed those filed by non-Indians at the Indian Patent Office in the last quarter (Q4) of 2021-2022.

These improvements are largely attributable to process reforms undertaken within the last five years. As a result, India's ranking in the Global Innovation Index has climbed 35 ranks, advancing from 81st in 2015-16 to 46th in 2021[40].

While this progress may appear remarkable in a historical context, India still trails far behind its global counterparts. The number of patents applied for and granted in India is merely a fraction of those in countries like China, the USA, Japan, and Korea. For instance, the number of patents filed in India accounted for only 3.8 percent of those in China and 9.5 percent of the USA in 2020, as illustrated in table 8 below [41]:

Table 8

Year	China		United States Of America		India	
	Filing	Grants	Filing	Grants	Filing	Grants
2016	1,338,503	404,208	6,05,571	3,03,049	45,444	9,847
2017	1,381,594	4,20,144	6,06,956	3,19,829	47,854	13,045
2018	15,42,002	432,147	5,91,141	3,01,759	50,659	15,283
2019	1.400,661	4,52,804	6,21,453	3,54,430	56,284	24,936
2020	1,497,159	5,30,127	5,97,172	3,51,993	56,771	26061
2021					66440	30,074

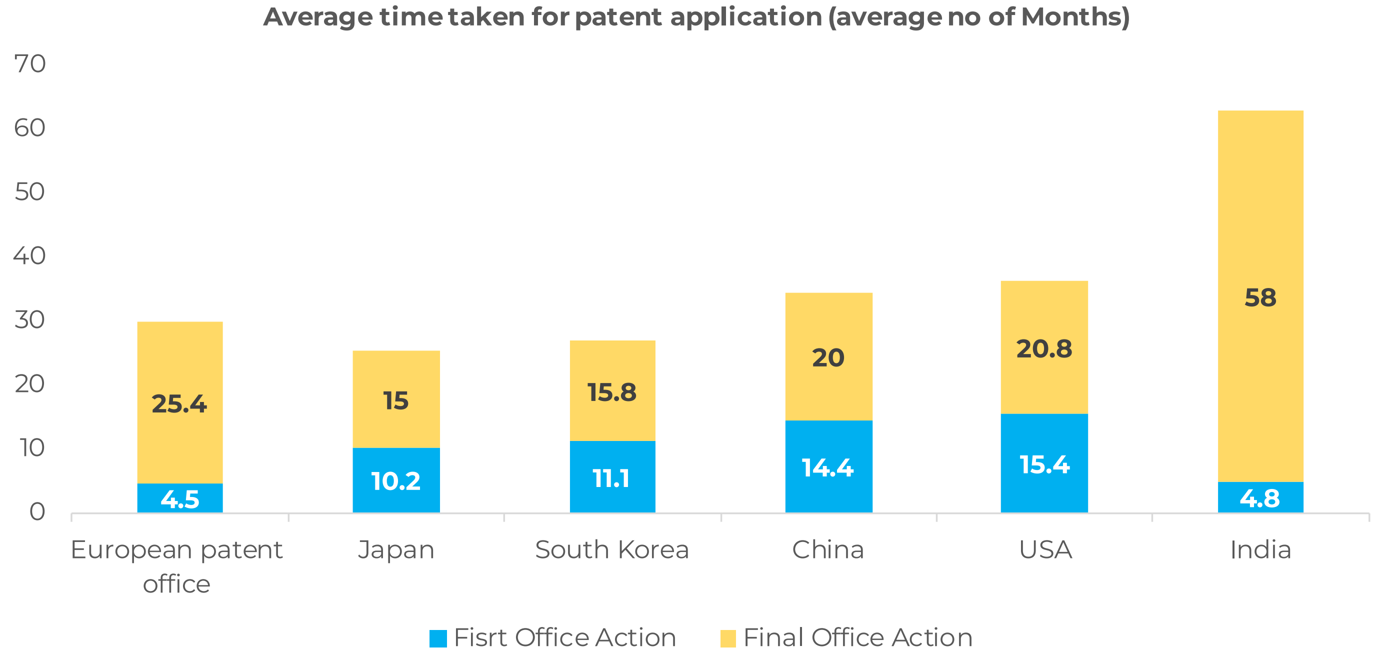
This data indicates a substantial shortfall in patents filed by the Indian Industry and R&D institutes. Another concern is the much longer time taken for patent processing by the Government of India's Office of the Controller General of Patents, Designs & Trade Marks (CGPDTM). At 62.8 months, this period is significantly longer in India compared to just 25.2 months in Japan. A comparison of the time taken by India versus other countries is depicted in figure 16 below [42]:

[40] Economic Advisory Council to the PM; EAC-PM/WP/1/2022 WHY INDIA NEEDS TO URGENTLY INVEST IN ITS PATENT ECOSYSTEM?

[41] Ibid

[42] Ibid

Figure 16



b. IP Creation:

The growth of India's semiconductor and ICT industry has been swift in recent years. Despite this, India remains significantly behind in the fields of IP creation and design capabilities when compared to countries like the United States, China, and South Korea. This section delves into the current state of IP creation in India, specifically focusing on ICT, electronics, and semiconductors. It also seeks to understand the reasons behind India's lack of core design capabilities. Moreover, it includes an analysis of Ireland, which has successfully developed its IP creation and design capabilities, to identify the contributing factors to its success.

Government Initiatives: In recent years, India has taken strides to enhance its intellectual property (IP) creation and protection framework. The Indian government has introduced several initiatives, such as:

1. **National Intellectual Property Rights (IPR) Policy:** Launched in 2016, it aims to foster a holistic environment for IP creation and protection.
2. **Startup India:** Launched in 2016 to promote entrepreneurship and innovation, with schemes like tax exemptions and fast-track patent examination.
3. **Make in India:** Launched in 2014 to stimulate manufacturing and foreign investment, including measures to protect and promote IP.
4. **Atal Innovation Mission (AIM):** Launched in 2016 to foster innovation among young students.
5. **Intellectual Property Facilitation Centres (IPFCs):** Established across the country to aid innovators in protecting their IP rights.

These efforts collectively aim to cultivate a conducive environment for IP creation and protection in India, encouraging innovation and entrepreneurship. However, challenges persist, such as a backlog of patent applications, lack of awareness about IP rights, and difficulties in enforcing IP laws [43].

[43] 2022 – International IP Index

Table 9

Field of Invention/Year	Filled/Granted	2017-18	2018-19	2019-20	2020-21	2021-22
Computer Science/Electronics	Filled	6089	5540	11126	11930	15575
	Granted	1028	1074	2141	2049	2459
Communication	Filled	5486	6308	6862	6660	7314
	Granted	1031	1414	2692	2857	3238

[44]

Table 10

Field of Invention	Computer Science/Electronics		Communication	
	Filled	Granted	Filled	Granted
2017-18	6089	1028	5486	1031
2018-19	5540	1074	6308	1414
2019-20	11126	2141	6862	2692
2020-21	11930	2049	6660	2857
2021-22	15575	2459	7314	3238

According to the 2022 Global Innovation Index (GII), India ranks 40th out of 132 countries in terms of IP protection and related indicators. In comparison, countries like the United States, Japan, and South Korea have well-established IP laws, robust patent systems, and a culture of innovation [45].

The below table presents the 2022 rankings of selected countries in various indicators of innovation, including Institutions, Human capital and research, Infrastructure, Market sophistication, Business sophistication, Knowledge and technology outputs, and Creative outputs. India's highest ranking is in Infrastructure at 78, while the lowest is in Market sophistication at 19. In terms of Institutions, India is ranked 54th, indicating room for improvement in this area. China has consistently performed better than India in most indicators, ranking 6th in Knowledge and technology outputs and 11th in Creative outputs. The USA remains a leader in Market sophistication, Business sophistication, and Knowledge and technology outputs. Germany ranks highest in Human capital and research at 2nd place. Vietnam and Ireland, though ranking lower than India, have shown improvement in several indicators. Overall, these rankings highlight the strengths and weaknesses of each country in terms of innovation and suggest areas for further development [46]. This is shown below in table 11

[44] Annual Report – Intellectual property India 2021-22

[45] Global Innovation Index 2022

[46] Global Innovation Index 2022

Table 11

Country	India	China	USA	Vietnam	Ireland
Institutions	54	42	13	51	16
Human capital and research	43	20	9	80	23
Infrastructure	78	25	19	71	15
Market sophistication	19	12	1	43	55
Business sophistication	54	12	3	50	13
Knowledge and tech nology outputs	34	6	3	52	14
Creative outputs	52	11	12	35	29

In terms of patent applications filed, India ranks 7th globally, with around 51,000 applications in 2019, as per the World Intellectual Property Organization (WIPO). However, these are mainly for utility models and not core design or technology patents.

c. State of IP creation in India in the field of ICT / Electronics / Semiconductors:

India's ICT and electronics industry has been burgeoning, with global players establishing manufacturing and R&D centers in the country. These centers predominantly focus on product customization rather than core design.

India's ranking in ICT as a sub-indicator of the GII improved from 86th in 2021 to 72nd in 2022, but it still trails countries like China and Ireland. This is shown below in table 12[47]:

Table 12

Country	China	Germany	India	Ireland	USA	Vietnam
FY22	20	48	72	41	7	70
FY21	34	32	86	28	9	79
FY20	45	15	74	23	9	76

The ICTs sub-indicator in the GII comprises various metrics, such as ICT access and use. The rankings reflect the overall performance of countries in these areas, offering insights into potential improvements.

India has around 2.2 million patent-pending applications, compared to approximately 11 million from the US & China. Additionally, India's acceptance rate of research publications in IEEE is around 4.5% (compared to approximately 36% in the US), indicating that substandard research quality may contribute to low IP creation [48].

[47] Global Innovation Index 2022, 2021, 2020

[48] Takshashila Paper on India Semiconductor Ecosystem

d. Why is core designing / IP Design not happening in India? What are the challenges that need to be addressed

Semiconductor design represents one of India's most robust sectors, housing nearly 20% of the world's semiconductor design engineers. Annually, these engineers design approximately 3,000 chips. The nation's appeal to global semiconductor companies is profound, with most major firms, such as TI, Broadcom, Intel, Qualcomm, Western Digital, Samsung, and Huawei, operating their fabless Intellectual Property (IP) & System-on-Chip (SoC) design houses within India. The design domain in India is strong, especially in areas like networking, microprocessors, analog chip design, and memory subsystems, with numerous MNCs, design centers, service houses, and local companies engaged in chip design.

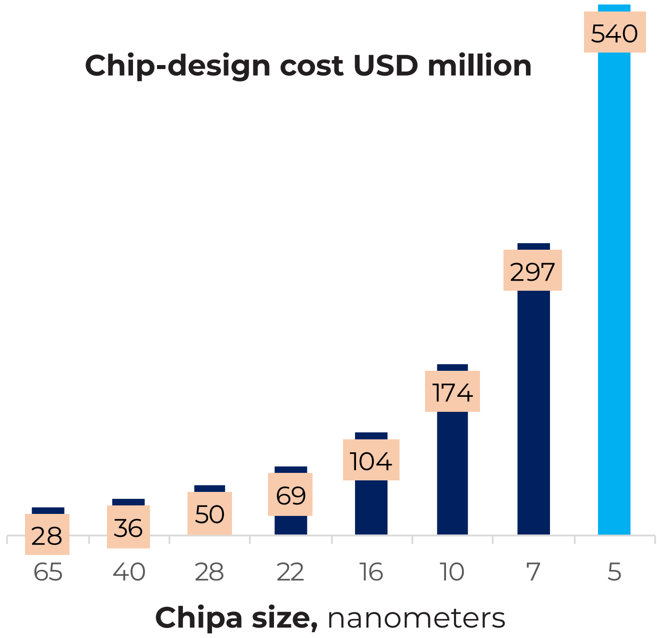
However, challenges arise due to the majority of engineers and startups servicing MNCs, leaving limited "Indian" work visible. Though there are 5-10 small domestically owned Indian fabless startups with chipsets in production and another 20-25 in the prototype/pre-proto stage, most other startups are primarily involved in design testing and verification services catering to larger MNCs. The Government of India has recognized this challenge and introduced favorable policies. .

India, while making significant strides in the field of electronics contract manufacturing, lags in core designing and IP creation.

There are several reasons for this, this is further discussed in the Section below.

i. Very high costs involved in Semiconductor Design and Core IP creation

The semiconductor chip designing process involves high-end tools, such as 'EDA Tools,' which incur very high costs. The fabs take 12-18 months to complete the tape outs and send them back, with additional high-end resources spread over an extended period. All these activities and items add up to very high costs in chip design. The key reason why this business is dominated by major MNCs in India and not Indian companies and start-ups is essentially due to the high costs in chip design and development. An example of the typical costs involved in chip design is given across different technology nodes in figure 17 below [49]:



Such high costs are a major reason why most design companies are often led to 'servicing' large MNCs with deep pockets and do jobworks for them in different areas in chip design – **while the 'brainpower' of Indians is used, it is the 'money power' of MNCs that has led to most chip designs being designed in India (to a certain extent) and its IP resting out of India.** In Semiconductors Industry, investments in R&D are very essential. In fact, the top-13 semiconductor firms in the "2019 EU Industrial R&D Investment Scoreboard" invested 18.4 percent[50] of sales in R&D, more than the bio pharma industry, as outlined in the table 13 below:

[49] https://www.mckinsey.com/industries/industrials-and-electronics/our-insights/semiconductor-design-and-manufacturing-achieving-leading-edge-capabilities

[50] ITIF Report; Moore's Law Under Attack: The Impact of China's Policies on Global Semiconductor Innovation; STEPHEN EZELL | FEBRUARY 2021; pg 7

Table 13

Company	Headquarters	R&D Investment (USD billion)	R&D Intensity (%)
Qualcomm	USA	5.2	24.9
MedlaTek	Taiwan	1.8	24.2
AMAD	LISA	1.3	22.1
NVIDIA	USA	2.2	20.3
Intel	LISA	12.6	19.1
Analog Devices	USA	1.1	18.8
Broadcom	LISA	3.5	18.1
IMP Semiconductors	The Netherlands	1.6	18.1
Renews Electronics	Japan	1.1	16.9
Samsung	South Korea	15.8	15.3
ST Microelectronics	Switzerland	1.3	14.1
Huawei	China	13.6	13.9
AWL	The Netherlands	1.6	13.4

ii. Funding is another major reason

Investor interest in the Indian Semiconductor Design Sector has been generally lacking. Globally, Semiconductor startups raised about USD 7.8 billion in 2022 [51], marking a sharp 46% drop from USD 14.5 billion in 2021. This decline is primarily attributed to the extensive timelines required for final Design completion and the need for consistent funding. Several factors contribute to this situation, including market volatilities, high sunk costs (of Electronic Design Automation tool licenses), limited demand for indigenous ICs by domestic strategic sectors, and a lack of product conceptualization knowledge. Designing and developing chips remains an expensive proposition for startups, with costs ranging from USD 2 million to USD 20 million to create the IP. Venture capital for deep tech hardware startups is scarce, leading them to rely on grants, angel investors, and a few early-stage investors willing to gamble on unproven technology [52].

However, as of late in 2023, there has been some activity in terms of funding by VCs to Chip Design firms in 2023, as depicted in table 14 [53]:

Funding date	Ciompany	Funding amount (USD)	Institutional invetsors	Angel Investors	Total funding (USD)	Overview
12-May-23	InCore	3,000,000	Sequoia Capital. Speciale invest, Whiteboard Capital		3,000,000	Provider of open-source Processor IP cores
30-Mar-23	MMRFIC	2,430,920	Sansera Engineering		2,737,904	Provider of millimeter wave la for communication applications
23-Feb-23	Mindgrove	2,350,000	Sequoia Capital. Speciale invest, . Whiteboard Venture Partners	Ashwini Asokan, Nischay Goel	2,350,000	Provider of GPR-based sensor systems for GIS data collection
19-Jan-23	XYMA Analytic	Undisclosed	Venture Catalysts, GAIL	Chirag Gupta, Vish Sahasranamam	1,111,627	Provider of process monitoring solution

51 https://www.theregister.com/2022/12/10/semiconductor_vc_funding_down_startups/

52 https://www.livemint.com/news/business-of-life/a-semiconductor-startup-ecosystem-finally-seems-to-emerge-11606671015646.html

53 https://economictimes.indiatimes.com/epaper/delhicapital/2023/jun/18/deep-dive/semi-con-ally/articleshow/101076024.cms

iii. Access to Fabs

Access to major fabs presents another significant challenge for Indian Semiconductor Design Companies. Since semiconductor technology, especially at leading-edge nodes, is rapidly evolving, strong linkages between design centers and fabs are essential to reduce the time required for testing, validation, and market entry. Fabs cannot be expected to maintain dead nodes for low volumes, and design firms must avoid situations where the production of their designs is not economical.

This issue also leads to the disheartening reality of a "Vast pool of Design Engineers ending up retiring without having seen a silicon." Aside from a few engineers at premier institutes who manage to engage with fabricated silicon through industry collaboration, Indian academia produces engineers (especially in Electronics and Communication or VLSI post-graduates) who never experience taping out a VLSI design or testing a silicon chip. Many electronics graduates become coding engineers, similar to those in other engineering disciplines. The training institutes that have sprung up in Bengaluru and Hyderabad meet the industry demand for EDA-trained engineers but offer no exposure to actual silicon.

IV. EDA and Core IP – India lacks in these capabilities:

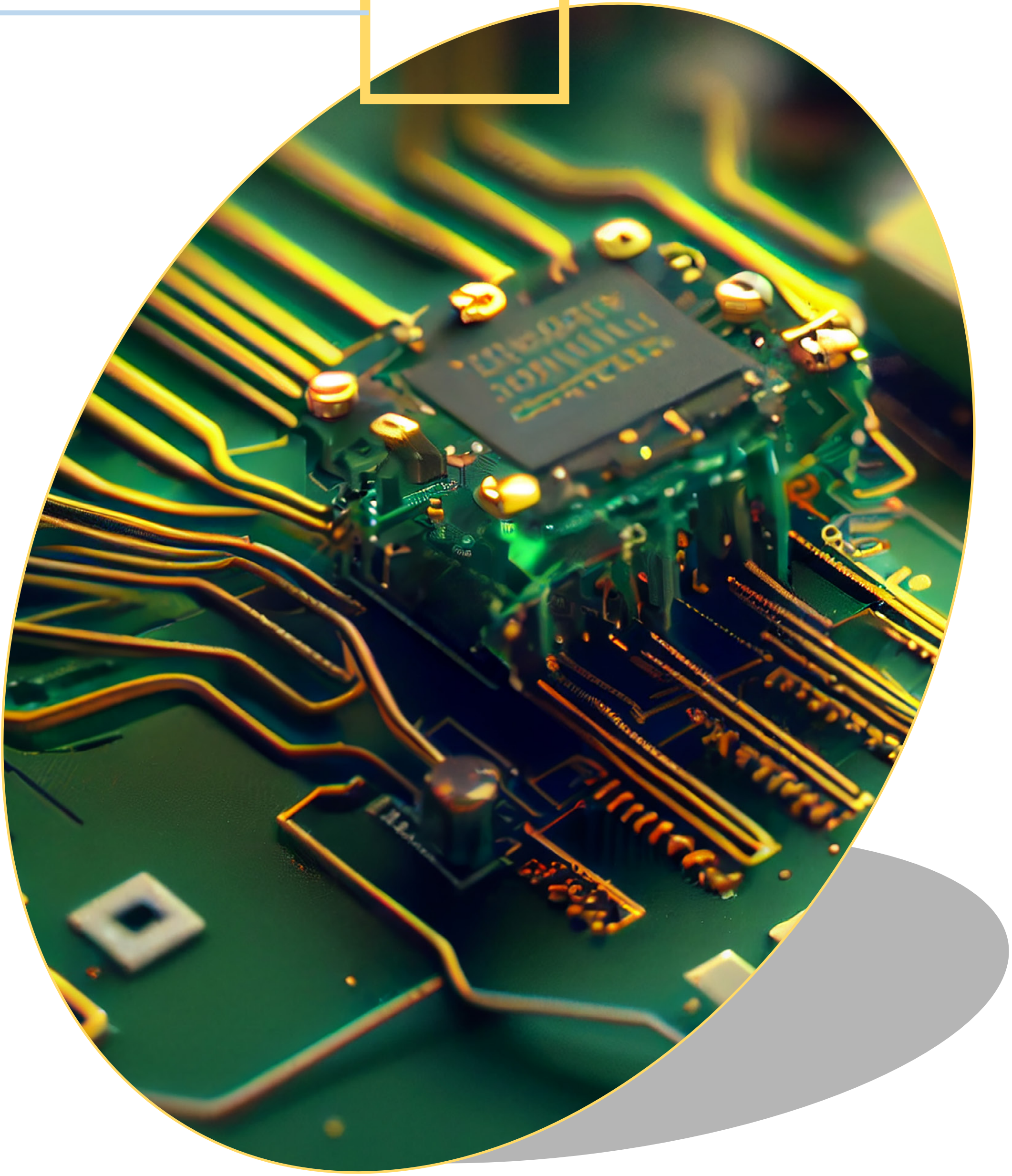
The EDA (Electronic Design Automation) is a vital component of Semiconductor Design, and it's dominated by 3-4 key global players such as Synopsys, Cadence, Siemens EDA, and Silvaco. These are well-established brands, and developing these tools from scratch would pose a tremendous challenge for Indian IT companies. Perhaps global acquisitions may be the only solution here.

On the other hand, Core IP (Intellectual Property) is a different matter. Indian startups and the government are making strides in this area, with initiatives like the Chips to Startup (C2S) Programme of MeitY. This program aims to train 85,000 engineers in the field of Very Large-Scale Integration (VLSI) and Embedded System Design. It also targets the development of 175 ASICs (Application Specific Integrated Circuits), working prototypes of 20 System on Chips (SoC), and an IP Core repository over a five-year period[54].

[54] https://www.businessworld.in/article/Design-focused-Schemes-More-Suited-For-India-s-Semiconductor-Aspirations/24-04-2023-473973

Chapter 6

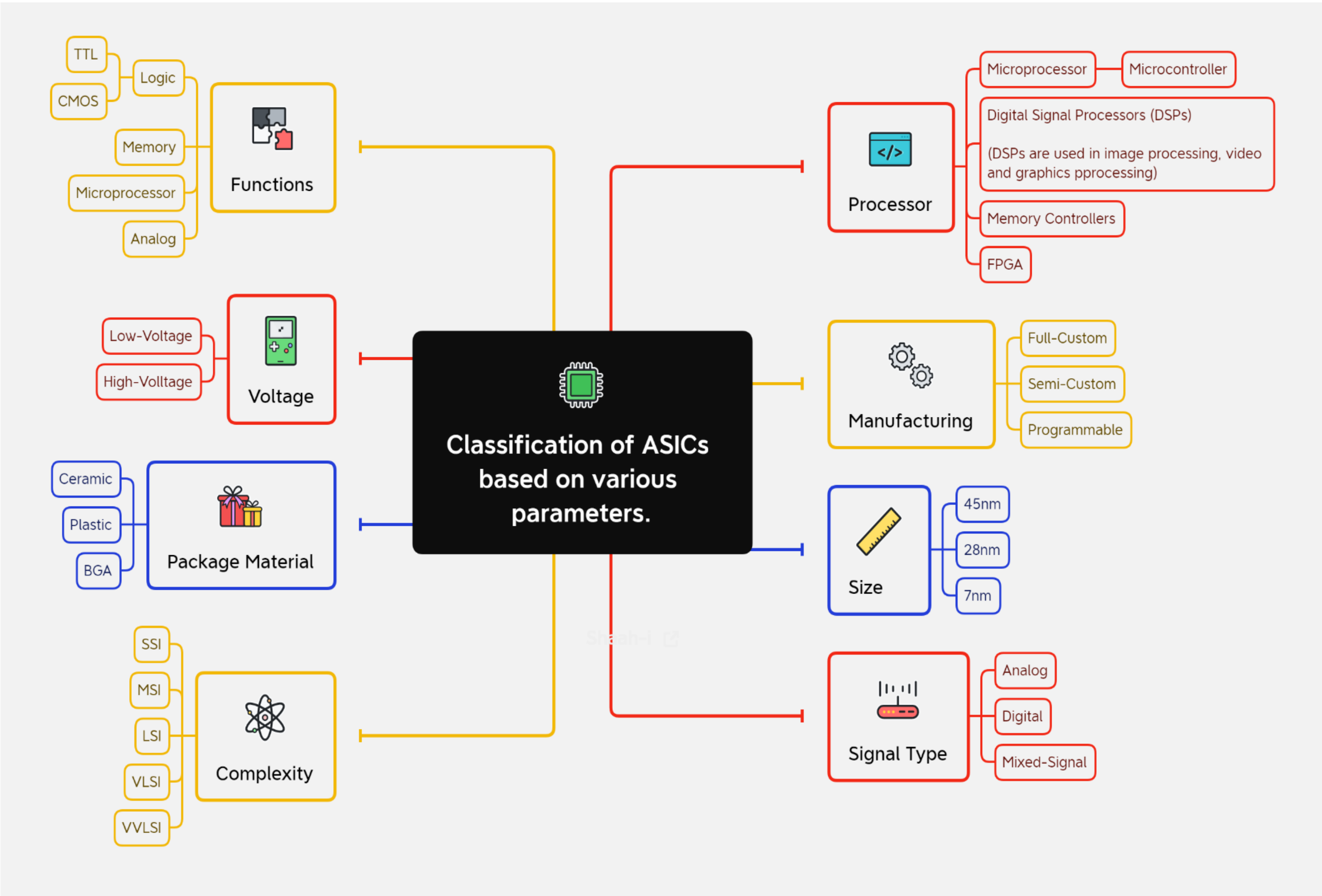
PRIORITIZING STRATEGY INDIA SHOULD ADOPT TO ACCELERATE FABLESS DESIGN IPS IN INDIA



Various global reports say, India is lagging behind major Semiconductor powers, by 20 years and some says almost by 50 years behind China. Considering these reports and the fact that we are a 140 crore population nation, with 100,000s of academic institutions and 100s Indian conglomerates, we need to aggressively attack the problem from all sides, all sectors and involve all possible stakeholders at once to address all areas of Fabless chip design and have at least few IPs in each function/area.

When it comes to prioritizing Fabless Design Ideas, there could be multiple ways and formats in which one could look at it primarily going by the way ASICs are classified in multiple parameters as defined in the figure 18 below:

Figure 18



The below section identifies various strategies that one can adopt to prioritize ASIC Design in India as an Indigenous IP

A. Prioritizing chip design based on Market/Mass Consumption/ Demand

Figure 20: Global Semiconductor Market Demand

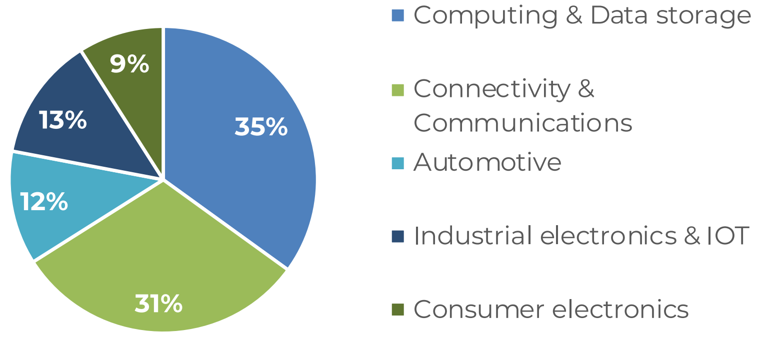
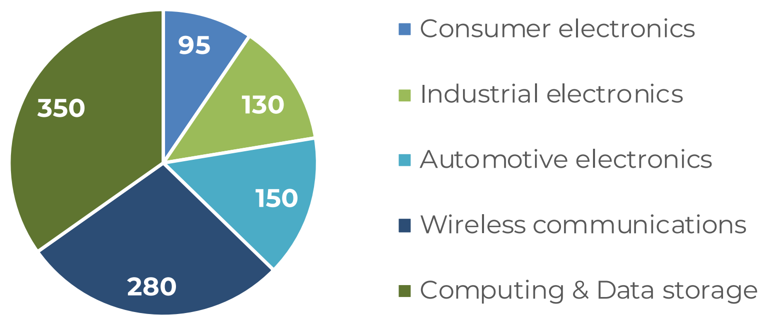


Figure 21: Market Value by Vertical in Billion USD



70% of growth is predicted to be driven by just three industries: **automotive, computation and data storage**, and **wireless** and below are some of the chips that can be targeted or prioritized for chip design based on market need and demands.

1. microcontrollers, sensors, memory

We can start with licensed manufacturing to develop the complete design to FAB eco system. Later by emulating/reverse engineering/ slight change, we can also open the window to develop indigenous processors. These ICs has omnipresence in all industries irrespective to their core applications. Further advancements in the automotive industry including electric vehicles, autonomous driving & stringent safety standards have led to a surge in demand for microcontrollers, sensors & memory chips.

2. The 5G communication revolution

This is the area where Indian companies and startup can join the main foray of latest node chip designing without any delay Our start ups are working on these design and need support of in-house and low cost fabrication. For this important aspect ICEA outlines the latest node mask set production in India as soon as possible.

3. Computing and Data Storage – GPU, TPU, CPU

Artificial Intelligence (AI) is relatively new emerging area with huge potential and opportunity to lead the world. The AI enabled applications require new kind of architectures for AI processors for faster data movement between processor and less cache memory usage. India can leverage this emerging opportunity and claim significant market by surfacing as equal level palyer in this field.

4. Connectivity chips such as wifi, bluetooth and RF

This is another area where application specific IC module can be design and fabricated independently. These segment has huge demands and supply gap to be filled by our indigenous design house and startup. Almost all verticals or any device needs connectivity today embedded inside it. WiFi and BT are the de facto connectivity chips required in most of the electronic devices today.

B. Prioritizing chip design based on Design Complexity

1. For very high complex & futuristics designs, mainly driven by HQs of MNCs currently requires silicon wafer fabrication and rigorous testing. India can establish a Centre of Excellence in national interest and invite Indian foreign nationals to work on Fabless Design and India should own the IP.
2. For Highly complex designs, MeitY/ Govt should appeal to Indian Fabless Engineers/Veterans working in MNCs to relocate themselves even for some time to contribute designs IP in national interests
3. For Medium complex designs, all IITs should be involved sincerely and 1 or 2 design functions should be assigned for each IITs.
4. For Low complex designs, Academicians & students should be invited from all Tier2/3 colleges should be invited for producing a good IC design engineer across the country the massive change in undergraduate Electronics/VLSI program and refurbished low cost FABs are required at multiple locations. ICEA is conducting a comprehensive research and immediate required change in program are discussed in Chapter 8 while a detailed white paper is presented separately. A refurbished FAB detailed structure is given below in policy note.

For the Education Industry – this will be more of experiential learning, learning by doing and more practical approach of solving real world problems than doing mere capstone projects.

This will also serve as a great collaboration and case study of efforts between government, academia and industry.

C. Prioritizing chip design based on Design Cycle Time

The first step in ASIC design flow is defining the specifications of the product before we embark on designing it. This phase typically involves market surveys with potential customers to figure out the needs and talking to the technology experts to gauge the future trends. The latter is particularly important because ASIC design cycle may be anywhere between 6 months to 2 years. It is therefore important to foresee and predict what trends would be relevant 1-2 years down the line if one needs to sell their product to a wide audience.

This marketing research translates into high-level product specifications like top level functionality of what you intend to do with your ASIC, specific computation algorithm that you want to implement, clock frequencies that would make the product appealing to the customers, package type- Ball Grid Array (BGA) or CSP (Chip Scale Package) etc., power supply, communication protocols that will help interface with the external world, temperature range that you would want your product to work in.

Developing a thorough and correct specification usually sets a solid foundation for the ASIC design. The technical specifications need refinement of the technical requirements over time, but it's important to cover the information in an unambiguous manner

**Need to initiate a survey with Experts to understand the design life cycle and hence the design cycle time required for creating the IP/Tape out which is the main output of Fabless design phase.

Further detail research is required to survey the complexities involved in some chip design such as skilled resources, tools, licenses, know-how & average design cycle time etc

ASIC Fabless Design average lifecycle time for a high design complexity is anywhere between 2 to 3 years

1. ASIC Fabless Design average lifecycle time for a medium design complexity is anywhere around years
2. ASIC Fabless Design average lifecycle time for a Low design complexity is anywhere around 5 to 6 months
3. ** Totally depends on organizational stats and baseline metrics, productivity and skills.

Design cycle time needs to co related with geo political challenges for prioritizing.

Further, if the ASIC being designed is a Derivative vs original design IPs – timelines will be different

D. Prioritizing chip design based Geo Political challenges world wide

An emphasis and collaboration with Indian industry to explore and put more efforts for specific ASICs in-house design capability and sourcing diversification is required to avoid the country specific monopoly and sudden shortage/ disruption of supply. from Trade Import – Export Analytics.

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.

Even we do not have the metrological instruments production base in the country. While these highly sophisticated tools are required in several production line and backbone of chip and innovative material industry. A promising step is academic collaboration that can be expanded to industry collaboration.

E. Prioritizing chip design based on fast replication and licensing from market leaders

1. Purchase the license and use the licensed IP for the design – This can be done for very highly complex designs for learning purpose or where India does not have much experience.
2. Reverse engineer using licensed technology to learn – This can be a good practical academic exercise which is "learning by doing" and academia aligning with National Interests and Priorities for their projects.
3. Circumvent and create own IPs – This is a faster way of learning and creating own IPs.
4. Design using expired patents which don't need license and fast replicate – same as point 2 above.
5. A patent can become free for copying, and this is when a patent has been abandoned. An abandoned patent occurs when the inventor doesn't finish the patent process or fails to pay any required fees. – same as point 2

F. Prioritizing based Patent Landscape analysis

Patent landscape reports (PLRs) provide a snapshot of the patent situation of a specific technology, either within a given country or region, or globally. They can inform policy discussions, strategic research planning or technology transfer. For e.g:

- There are some 27000 patents only in Face Recognition AI ASIC/DESIGN
- When it comes to AI ASIC DESIGN IPs – there are around 70K patents worldwide

If India has enough IPs in a particular Fabless Design, then these can be prioritized for manufacturing and generating demand from worldwide in addition to local consumption.

Patent Landscape analysis will also give us list of high end technical experts who can be approached for further collaborations.

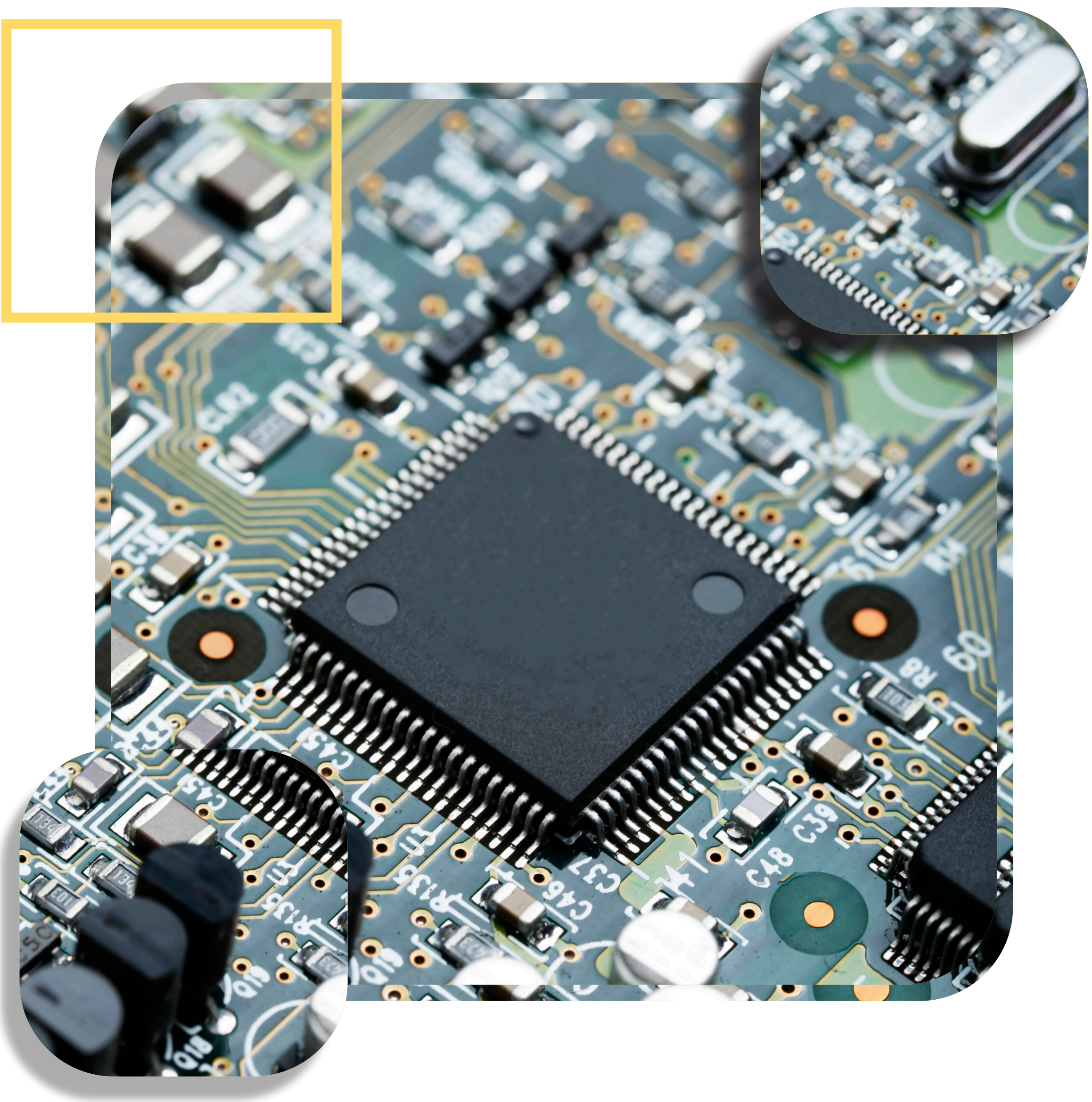
G. Prioritizing chip design based on Futuristic needs & technologies

AR & VR applications in defense are transforming traditional business ways, enabling real time simulation of complex situations & eliminating errors

Industry 4.0 led methodologies are defining the future of aerospace manufacturing causing significant disruption to existing value chain

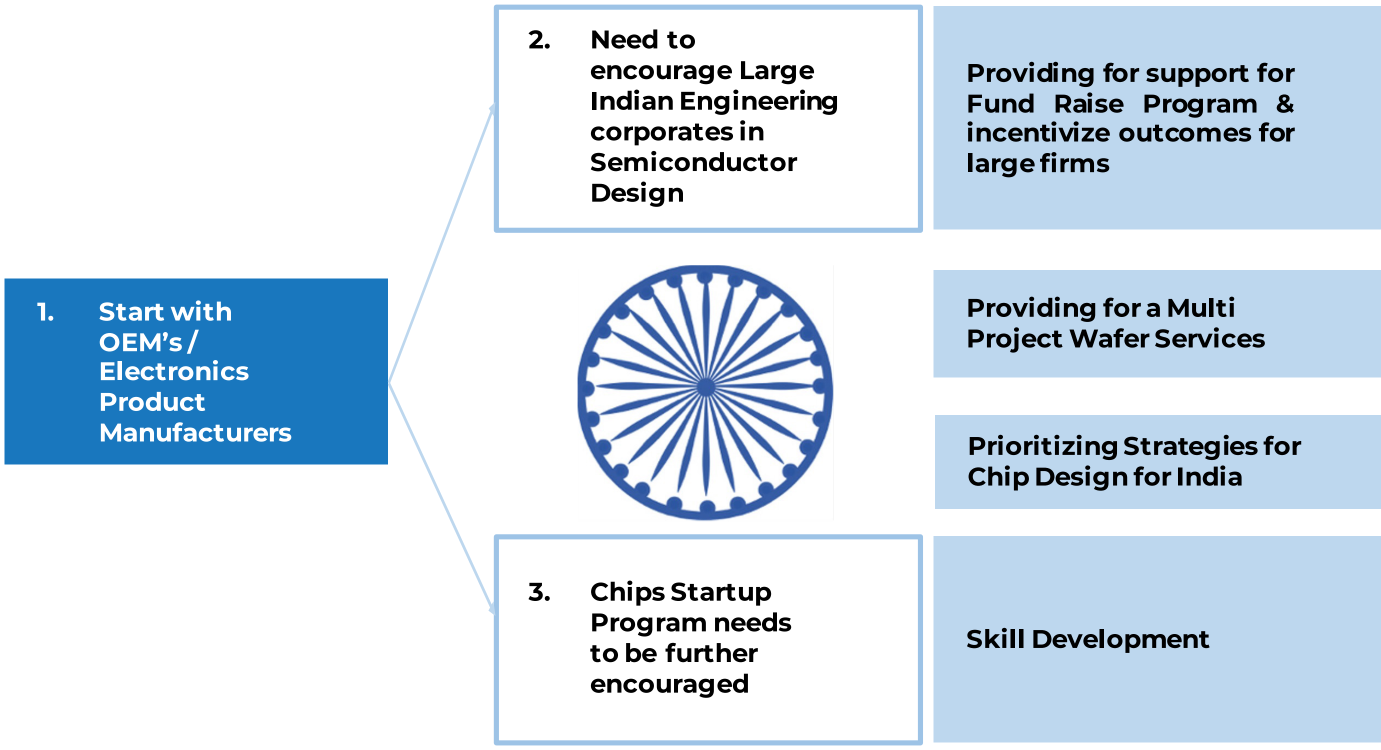
Chapter 7

ICEA'S RECOMMENDATIONS FOR THE WAY FORWARD FOR INDIA IN STIMULATING SEMICONDUCTOR DESIGN AND CORE IP CREATION



The idea behind ICEA's recommendations for creating a robust Semiconductor Design ecosystem in India is outlined in figure 21 below:

Figure 21



The idea here is ***not to look at the Semiconductor design in isolation but to look at the entire Electronics value chain and see what can be done to stimulate Semiconductor Design and Core IP creation in India*** as shown above. This is explained below:

1. Start with OEM's / Electronic Product Manufacturers

As explained in the R&D section , India's domestic products in the realm of Overall Electronics Products Manufacturing are sparse. Therefore, it becomes vital to first address this level, aiding firms to invest in R&D and innovate Electronics Products for both India and the global market.

The rationale behind this approach, and its impact on Semiconductor Design IP creation, stems from the necessity of employing a "pull" strategy as opposed to a "push". This means that Semiconductor Chips created using local IP could perhaps be granted preferential access. **Tax incentives should be provided for finished products utilizing local IP, a strategy more effective than merely incentivizing the IP itself.** Without this approach, **India's effort may result in paper IP with minimal commercial value.**

Though the Central Government has incentivized IP creation and many academic institutes and states are reimbursing IP costs, the issue persists that these IPs often remain commercially unused. The solution should pivot towards **incentivising finished products that incorporate local IP, thus** aligning with our objective of increasing value add.

Key actions required:

A. Conduct a vertical assessment of Electronics Products to identify key products for development in India, considering factors such as domestic demand, export potential, strategic needs, and import substitution.. This necessitates a detailed market assessment to pinpoint focus of Indian R&D.

B. Upon identification, encourage OEM's (whether Indian or MNC's) to undertake the requisite R&D for product development in India, offering incentives such as:

- R&D grants
- DLI support on sales of these products

C. Specifying Designed in India Semiconductor chips.

- SoC designed in India, incentive on final product (2%) – as done in IT Hardware PLI 2.0. (Assuming that cost is 10%, then the total incentive would be 20%). If the chip is fabricated in India then another 2%.

D. Encouraging Institutions for OEM/ metrological Instruments R&D withf metallurgical and mechanical professionals and academicians.

E. Creating a joint platform with existing IC professionals for specific Semiconductor chips realization.

2. Encourage Large Indian corporates in Semiconductor Design

India's Companies / Corporates have undertaken nationally significant tasks across various sectors. An urgent call to action is needed to engage companies from Non-Electronics/Semiconductor backgrounds to invest in Semiconductor Design & Core IP creation. This would require the Government of India's interventions such as:

a. Forming Tie-ups with OEM's for collaboration on specific semiconductor products

b. Collaborating educational institutions for talent acquisition.

c. Providing design infra support in terms of EDA tools and Project capex.

d. Partnering with relevant MPW Wafer Fabs

3. Elevate Funding support for the Semiconductor Design ecosystem

Understanding how nations like China have prioritized and supported this industry over decades, creating a Semiconductor and Design ecosystem, requires specific and unconventional approaches. Some considerations include:

i. Continuing standard incentives like R&D grants, DLI support on sales on these chips, Fast track approvals.

a. Pioneering new approaches such as

I. Designating the **"Semiconductor Chip Design/ Manufacturing. for India" as a Strategic Sector** for low-cost bank funding, creating a separate Capital Market system for tech investments.

II. Incentivising the cost of 'Mask-set' to reduce the cost burden of Design Houses – In chapter 10, we have elaborated more on this topic.

4. Chips Startup Program need to be further encouraged and more number of firms

The Government of India's well publicized Chips to Startup program offering a slew of incentives and is working with 100 organizations, should be be expanded to encourage more firms.

5. Shuttle Mask Based Multi Project Wafer Support for Semiconductor Design Fabless companies

Access to a Fab at reasonable prices and the earliest opportunity is vital for the the success of Semiconductor fabless companies to tape out their designs. Most firms fail in this regard.

The Government of India must acknowledge this challenge and seek methods to overcome it, learning from nations like China.

Proposed actions include investing in a **Refurbished Fab exclusively for Semiconductor Design and development of skilled workforce immediately. A refurbished fab can provide for these advantages:**

i. For Comprehensive Training on Integration of Design and fabrication process.

ii. For Skilled Semiconductor Workforce Development.

iii. Optimizing and conserving resources which are getting frittered away in sub optimum academics.

ICEA has prepared a detailed whitepaper on this aspect and is given in the next section below in Chapter 9.

b. Forming a G2G working group with select friendly countries by which their select fabs are encouraged to work with our Fabless companies, while we set up a MPW fab.

6. Have a strong focus on Skill Development for Semiconductor Industry

The government has recently launched general skill support schemes that must be synchronized with an IC industry-oriented customized course curriculum and live training programs. These initiatives aim to create a diverse and specialized skilled workforce across various verticals. There is an urgent need to develop an intensive, industry-oriented curriculum to create a specialized skilled work force from top to bottom.

ICEA has deployed a core team led by

experienced ICs professional, who have global exposure and experience. They are working on the development of model industry-oriented IC Design and Fabrication course curriculum, necessary EDA tools, and minimum standard to engage various educators and industry professionals for learning and practical exposure.

We are also in the process of developing various modular courses to create technicians, Process and Design Engineers for the ATMPS, wafer production /testing, PCB Design Engineers, and other resources.

The Country's Technical Education Body has proposed an undergraduate course in the VLSI domain, but it lacks many key learning and skill-enhancing contents. The existing undergraduate course is outmoded and falls short of industry requirements. A comprehensive **"white paper"** addressing the issues and proposing remedies will be presented separately.

This type of course may provide the degree but may not necessarily lead to job opportunities in the core field. ICEA conducted an in-depth study of this course and is working to highlight missing contents and enrich it by proposing the required model coursework.

ICEA's recommendation towards creating a strong skilled workforce development is as given below:

a. Relevant Industry oriented course module from certificate to degree program:

A brief summary of the same is given below:

- The course should encompass and emphasize core course including Semiconductor Device Physics, MOS device, CMOS analog and digital design realization, Front end and backend design techniques, Mos Device fabrication & characterization, Packaging, Testing as core course content in reference to present IC industry requirements.
- Some elective courses need to be shifted into core courses and some core courses may become elective courses.
- The order of course study order may need to be restructured.
- Fresh individual course mapping is required.
- Open elective course should be reduced to one, and program elective courses should be increased to three.
- Suggestions for individual course optimization are also mentioned.
- Core Courses should include Analog Layout Design Techniques, MOS Device Modelling/ Characterization, BGR Design, Oscillators VCO DLL PLL Design, PCB Design, Semiconductor Memories .
- A student can become a proficient VLSI design engineer after learning and practicing core subjects such as:

ii. Semiconductor Fundamental/ Semiconductor Device Physics/Integrated Circuit Device

iii. CMOS Analog Electronics 1 & CMOS Analog Electronics 2

iv. CMOS Digital Electronics

v. MOS Device Characterization/ Modelling

vi. Analog Layout Techniques

vii. VLSI Technology

viii. Packaging

ix. Testing

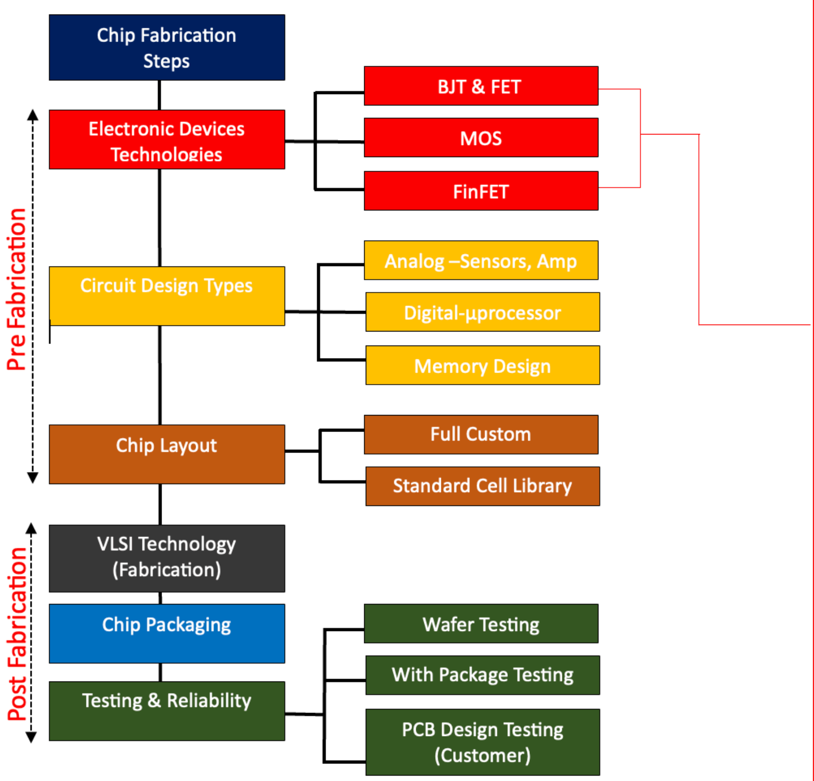
x. PCB Design

xi. Semiconductor Memories

xii. Power Management IC Design (BGR, LDO etc)

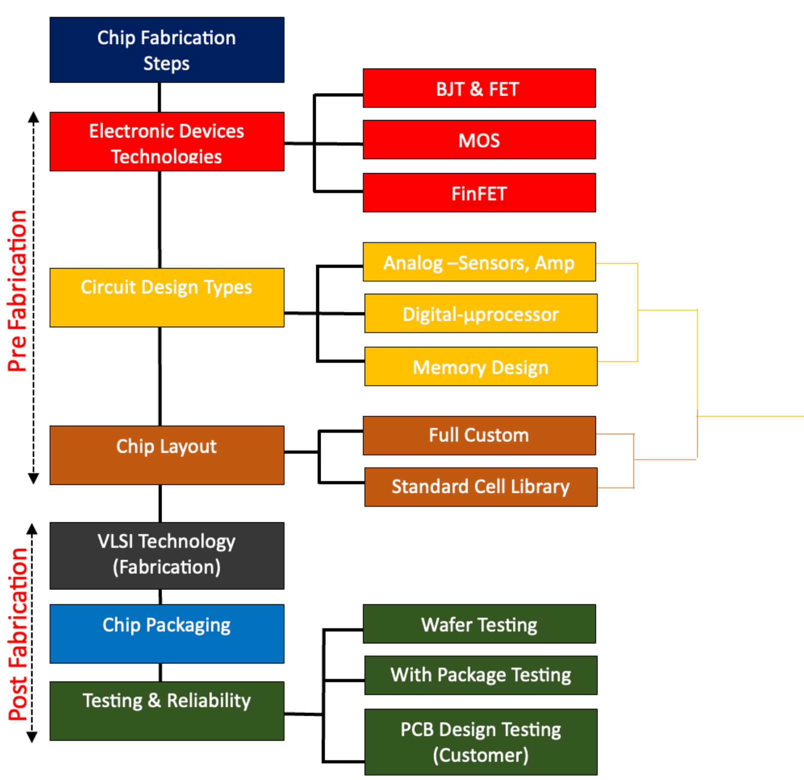
A detailed IC Design flow and required course content is present in the following flow diagram with a summary of important draw backs continuing for years in the following figure 22 & 23:

Figure 22 **Key Functional Area in the Chip Fabrications required to study for Job Profile**



1. **BJT** (Bipolar Junction Transistor) - A semiconductor device works as Amplifier. It was the main component of early stage integrated circuit fabrication (1947).
2. **FET** (Field Effect Transistor) - A semiconductor device conceptualised and invented during 1925-1960s to replace the BJT.
3. **MOSFET** (Metal Oxide Field Effect transistor)-The breakthrough for the mass fabrication and scaling.(1963)
4. **AICTE** original course content primarily includes only BJT and FET.
5. BJT is more than **80 years** old technology and not compatible with the MOS fabrication Technology.
6. FET is introductory version of MOS and around 60 year old structure. Now industry already moved up to **FINFET** even from MOSFET and AICTE program core courses focusing on BJT & FET only.
7. The INTEL co-founder and great visionary **Gordon Earle Moore** law (The number of transistor doubles in every 18 months) has already been saturated still MOS is not focused in undergraduate core courses.
8. BJT and FET configuration is old traditional technologies not compatible with present MOS technologies. Can give overview. Need to study MOSFET.
9. **Node technologies** has been scaled down more than thousand times and moving towards FinFET.

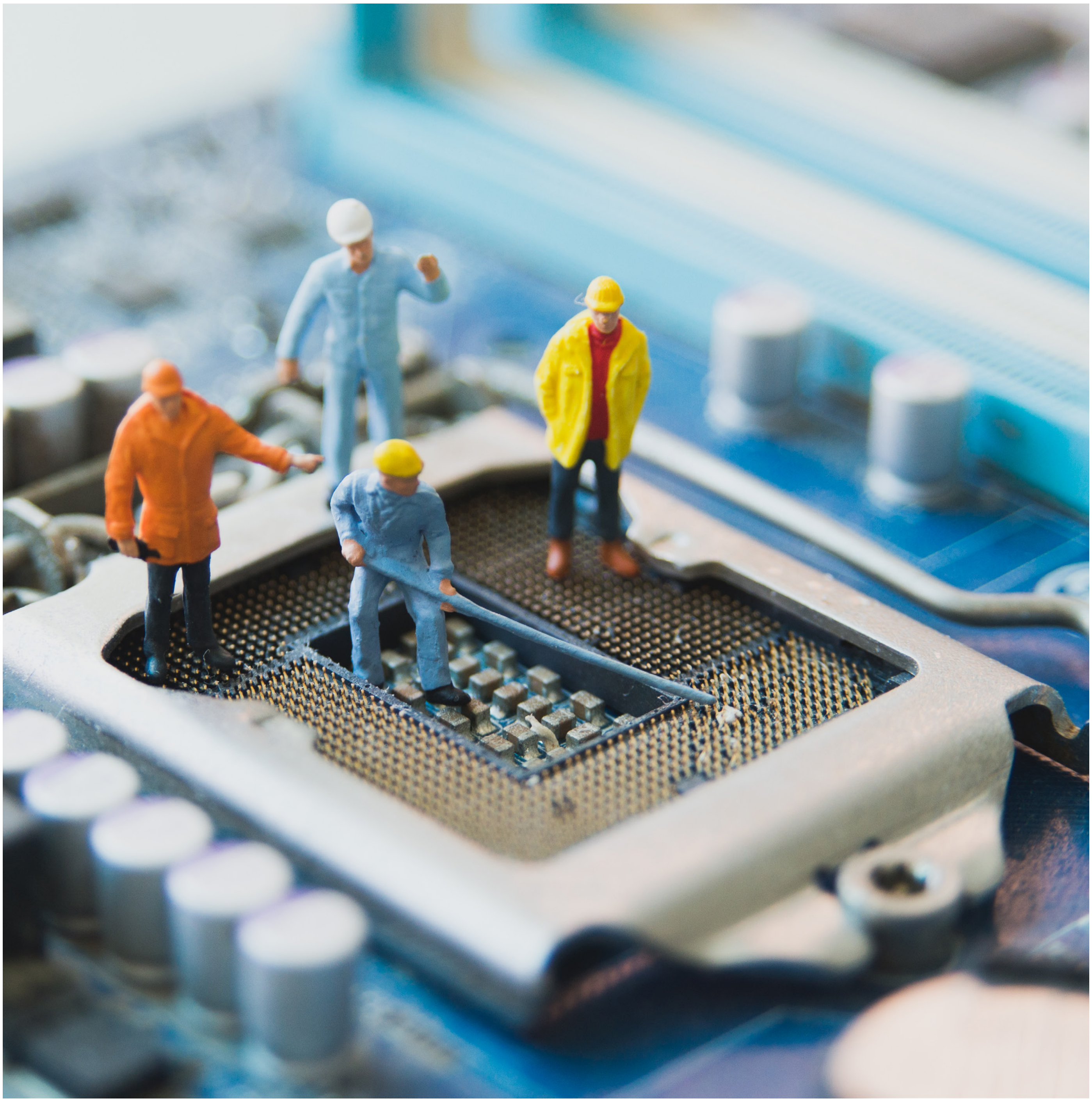
Figure 23 **Key Functional Area in the Chip Fabrications required to study for Job Profile**



1. **Analog Circuit**
   - **Need to design from scratch.** Use for sophisticated applications.
   - Full Custom Design: Complete chip architecture from scratch for high performance circuits.
   - Examples: Sensors, Satellite chips etc.
2. **Digital Circuit**
   - Considered as switches. Use 0 & 1 as off and on.
   - Use logic symbols to design and implement the circuit.
   - Standard Cell Design: Use **predesigned** existing design blocks to realize chip architecture.
   - Examples: All kind of Memories, Microprocessor, Microcontroller etc.
3. **Memory**
   - Digital memory is required every-where from Computer/Mobile Cache memory to hard disk memory.
   - It now becomes a huge independent semiconductor industry with ever increasing demand.

Chapter 8

ICEA'S POLICY NOTE ON THE STRATEGIC INITIATIVE OF REFURBISHED FAB FOR CREATING SKILLED ICS WORK FORCE



a. What is really required:

In VLSI domain, a real chip design and fabrication process flow and hands-on experience for students is highly desired to convert them into skilled IC Fab professional. A huge requirement is being observed for such experienced professionals to cater to the supply and demand gap in fab workforce across the globe. We also have to build a workforce ready for our own ecosystem.

The existing facility at SCL Mohali is tiny and does not have the organizational culture to produce hardnosed globally bench marked professionals. Therefore, **we need to have an dedicated FAB to impart the training at the earliest possible.** This will necessarily entail significant expenditure.

b. Funding and Management of the FAB:

To address this need, ICEA proposes a strategic initiative to establish a refurbished fab in higher nodes (28/40/ even higher) funded by Government of India, but not turning into a perpetual white elephant.

The objective would be to cover operational costs through nominal fee structure, soft touch royalties and sale of Wafers assuming a yield of 50%. The facility will be managed by an industry consortium with Meity/ISM participation.

c. The Training Approach and Outcomes:

The training approach focuses on practicality and immediacy. For instance, it is recommended that a 6-month intensive, live training program be launched to create skilled fab engineers. Given that India has a substantial pool of raw scientific manpower, any science or engineering graduate could join the program, thereby transforming themselves into skilled chip design support or core professionals.

The proposed fab unit, which will be a refurbished one and hence cost only a fraction of a brand-new unit, could train approximately 10,000 individuals annually, producing 5,000 wafers per month. A triple shift schedule is suggested for the program. This trained workforce could then cater to the needs of both the Indian industry and international fab markets, including the US.

To manage the running costs and initial investment return, students could be charged a nominal fee, which could be offset through higher-study bank loans or even a direct support from GOI or state governments. A separate subsidy for university students in chip fabrication may be required.

The strategy, not only meets immediate industry demands but also puts India on a path to be ambitious for the future, thus reinforcing a sense of motivation and realization for the Indian electronic industry.

d. Establishment and Operation of a Semiconductor Fab Training Facility:

The establishment and operation of a semiconductor fab training facility will involve significant initial investment and recurring operational costs. Below is an evaluation of the estimated cost factors:

1. Cleanroom Facilities: A cleanroom is crucial for semiconductor fabrication. A class 10-1000 cleanroom suitable for a monthly throughput of 5000 wafers monthly could cost approximately USD 5 million.
2. Semiconductor Manufacturing Equipment: A set of refurbished semiconductor manufacturing equipment such as deposition systems, etching systems, photolithography tools, and metrology equipment) might range from approximately USD 130 million to USD 150 million.
3. Semiconductor Design (EDA/IP) License Fee: Licensing fees for semiconductor tools depends on the technology node. The cost of these licenses can be considered USD 5 million approximately.
4. Metrology Instruments (SEM/TEM/AFM/XPS): These instruments cost could range from USD 8 million to USD 12 million.
5. Utilities and Infrastructure: The costs for utility connections (electrical power, water supply, ventilation systems, and gas supply) and infrastructure modifications can consume 8 million approximately.
6. Consumables: Consumables such as cleanroom suits, air filters, gloves, masks, wipers, and cleaning chemicals may cost between USD 2 million to USD 3 million per year.
7. Training Materials and Software: The costs for these resources can vary widely depending on the curriculum and tools chosen. This is location specific and broadly can take USD 5 million.

Table 15. Overview of the Estimated Costs:

S.No.	Items	Aooroximate Cost
1.	Cleanroom Facilities (class 10-1000)	USD 5 million
2.	Semiconductor Manufacturing Equipment	USD 150 million
3	Semiconductor Design (EDA/IP) License	USD 5 million
4.	Metrology Instruments (SEM/TEM/ AFM/XPS etc.)	USD 10 million
5.	Utilities and Infrastructure	USD 8 million
6.	Consumables	USD 3 million per year
7.	Training Materials and Software	USD 5 million

- **Total FAB Establishment Cost: USD 180 – USD 200 million**
- **On-going FAB Running Cost (Annually): USD 35-40 million**

This totals to approximately USD 200 million for the initial setup and first year operation.

e. Revenue Generation and Payback:

The initial fab is expected to have a capacity of 60,000 wafers annually. Assuming a 50% yield due to trainee operation, the facility could generate approximately USD 90 million per year (assuming a selling price of USD 3000 per commercial-grade wafer).

An intake of 10,000 students per year could be considered, each charged a fee of USD 12000 with a central/state government subsidy of USD 9000 while student will pay USD 3000. The student can also take a higher study loan for the 3000 USD portion.

The government's partial support for student fee will be USD 90 million only for initial 5 years. This can potentially transform the available raw scientific manpower in the country into a complete and well trained Design and Process Engineer in each passed Certified training practice with yield over 50% for 3 different IC products such as Microcontroller (MCU), Sensor and driver Chips.

With this targeted approach we will be conserving large resources which are getting frittered away in substantially sub optimum academic courses in Semiconductors.

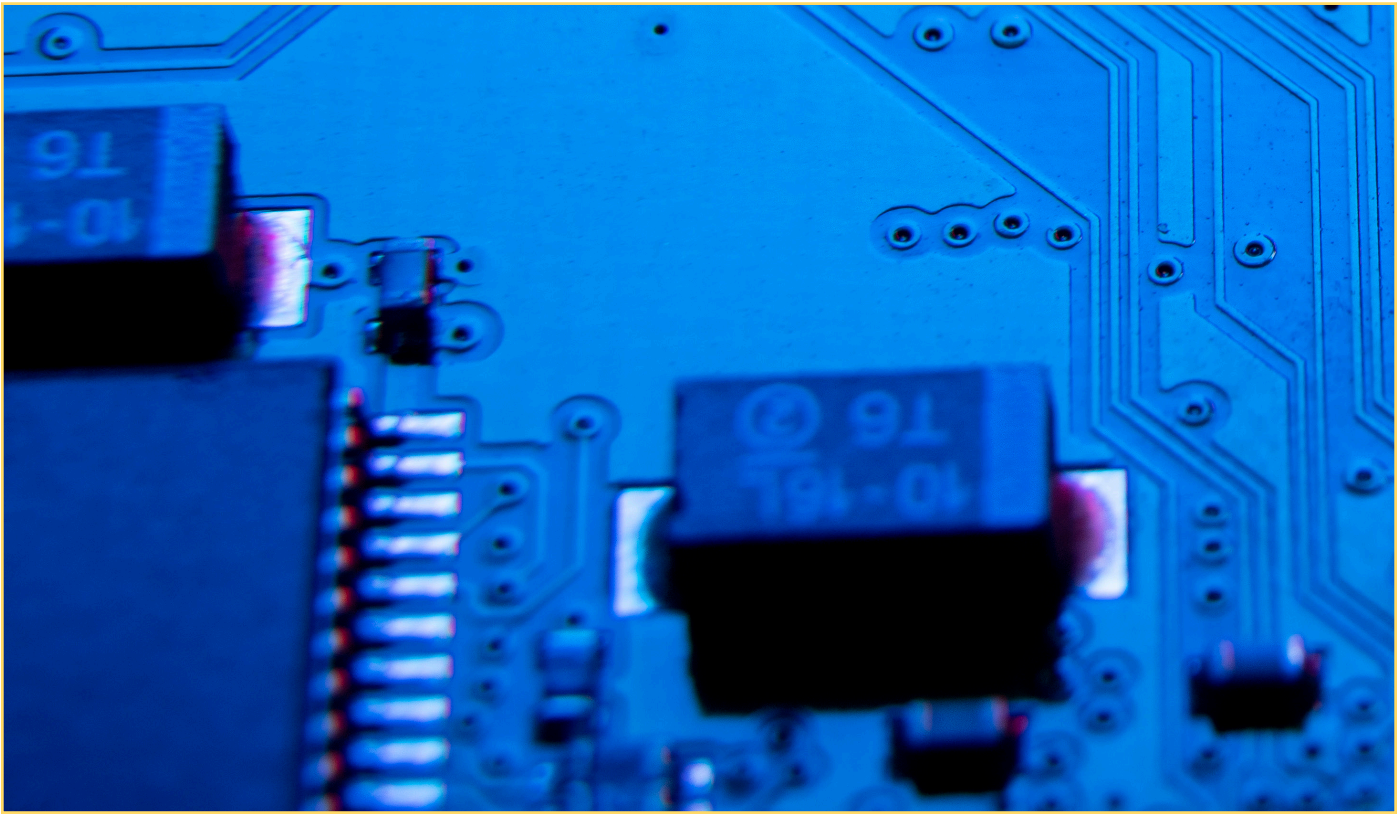
This revenue stream could contribute up to USD 120 million annually. In addition, a nominal industry royalty of 1-2% on the wafers produced could be applicable for the first 5 years.

Based on these projections, the running cost of fab unit along with technical manpower intake could be more than compensated. The Fab establishment needs to be funded by Govt. of India.

Based on these projections, the running cost of fab unit along with technical manpower intake could be more than compensated. The Fab establishment needs to be funded by Govt. of India.

Chapter 9

SUPPLEMENTING DLI TO MAKE INDIA A REAL SEMICON PRODUCT DESIGN LEADER (TECHNOLOGY SHIFT FROM 28 NM TO ≤ 7NM)



A. What are Mask Sets and their Relevance?

In semiconductor manufacturing, a mask set is a collection of photomasks, each defining the layout of a layer of the integrated circuit. These masks are used in photolithography, a key process in semiconductor manufacturing, to project the circuit design onto a silicon wafer. Each photomasks corresponds to one layer in the process of manufacturing the integrated circuit. The number of masks in the mask set corresponds to the number of layers in the chip. This is significant to mention that Masks Set is an essential and integral part of semiconductor product design.

Each mask set is specifically tailored to a certain design, so if a company wishes to manufacture a new type of chip, it will need to create a new mask set. The cost of creating these mask sets can be quite high, ranging from one million

USD to twenty million USD depending on the complexity of the design and the specific manufacturing technology used. This makes the cost of mask sets a significant entry barrier for small companies or for creating the new chip design. As the technology node shrinks, the process of creating the masks becomes more complex and expensive. Therefore, transitioning from a larger technology node (like 28 nm) to a smaller node (like 7 nm) involves significant capital investment in creating a new mask set (Master Template). This makes the cost of mask sets a significant entry barrier for small companies or for creating prototypes.

In the context of a design ecosystem, having access to mask set is crucial. Without mask sets, semiconductor companies cannot produce integrated circuits, which are the building blocks of all electronic devices. This is where our note to subsidize these costs comes into play.

B. Shuttle Masks:

To help mitigate the high costs of mask sets and wafer production, Shuttle Mask also come into play. Here multiple customers can share same mask set and silicon wafer. Each customer's design occupies a small portion, or tile, of the wafer, and all the designs are manufactured simultaneously. This mask By sharing facility provides the big opportunity the small and medium size companies to launch their innovative products and can become a competent player in the highly competitive market in presence of big and established player or those needing smaller volumes get their designs fabricated in silicon in a more cost-effective way. It also provides an opportunity for customers to design, verify, and prototype their designs before committing to the high cost of a full production mask set.

Shuttle Programs are therefore a critical mechanism for enabling innovation in the chip design industry. They lower the barrier to entry for start-ups and smaller design teams, and they accelerate the process of bringing new designs from concept to reality.

C. State of play: India and China:

India already has many leading IC companies doing and outsourcing design to India for many years. We also have some but few Semicon Product Design companies. However, we do not have Fabrication and Packaging as of now. India has already missed the first electronics revolution (BJT Transistor) era. We are also approximately loosing another electronics revolution (MOS Chip), hence now we need a giant leap step to overcome all this gapping and even one step ahead to lead the latest technology high-volume based production foray.

China on the other hand has emerged as a major destination for Semiconductor product design companies. At the last count, more than 3300 companies are doing this activity successfully. In most ASIC segments, for example, China dominates and in many is the only player! We also know how much China has progressed in Fabrication. In Semicon product design they have used a particular policy tool which has been enormously successful and we will present the same in this paper.

What is the policy tool China used, which has delivered enormous success in Semicon product design? Besides many other policy interventions and tools **China has heavily subsidized MASK SETS to the fledging companies.** A complete MASK SETS process comprises manufacturing of customised masks and first wafer production lot. MASK SETS are a major investment for these companies and can range from USD 2 million to as much as USD 10-20 million USD for a single MASK SET depending on the node and complexity of design. **China subsidized these mask sets up to 80%.** This has been the main tool which has helped them develop 3300 plus Semicon product design companies.

D. Opportunity for India:

There is an opportunity for India to build Indian capability in semiconductor design domain because of fallowing reason.

I. In the present geopolitical situation, China is facing the brunt of sanctions as a result of US actions. This has thrown up an opportunity which India can leverage. They are not able to get their Semicon Chips fabricated which are ≤14 nm fabricated at any global fabs including TSMC because of sanctions and domestically they do not have this capability as of now.

II. TSMC has spare capacity of 7 nm because many majors like QUALCOMM have leapfrogged to 5nm—3nm and now even 2nm

III. Global companies in middle and high-end technologies from US, Europe, Taiwan, Korea and even China, which were getting benefits of the Chinese policies are now looking for alternative options which can support them in their product development in ≤ 14 nm technologies.

Privileged technology IP to resolve four issues.

a. Electro migration

b. Heat dissipation

c. Cross talk

d. EMI interference

IV. A unique node (≤ 7 nm) MASK SETS technology shift can also boost the system on chip (SOC) integration. It will attract further to acquire more IPs to reduce many chip modules into a single chip module to reduce the size and increase the no of applications on the same die and yield. A major breakthrough will be reduction in the power consumption.

V. To realize "System on Chip (SOC)" in high dense mobile/consumer electronics chip production trend, the ≤ 7 nm and lower scale MASK SETS is highly beneficial.

E. ICEA Recommendations:

India has many comfortable and competitive technology edge facilities in terms of global business, language speaking friendly, large manpower availability, and customize infrastructure support that makes it a strong candidate to become a world semiconductor design hub in the present geopolitical situation. Recent trends and latest developments in international relations, faith issues, and technological restrictions can project India as neutral, transparent and business friendly player to attract the US, Europe, Taiwan, Korean companies to setup their Indian subsidiaries.

To convert this opportunity to the advantage of India, we recommend that the **Government of India should include MASK SETs in DLI scheme and should subsidise the cost of MASK SETs up to 80% to Indian companies and enable the movement of Semiconductor product design with Indian IPRs.**

Policy Support:

Inclusion of Masks Set in the existing DLI Scheme (especially for advance nodes):

The transition from the 28nm to the ≤ 7nm technology node represents a significant capital investment for companies, given the high costs of mask sets. Therefore, the government should consider the inclusion of Masks set in the existing Designed Linked Incentive (DLI) Scheme under semiconductor design providing substantial subsidies to facilitate this transition. The government should offer upto 80% of the subsidy as is offered by many nations especially China's. This could serve as a powerful incentive for companies to set up these operations in India and also domestic companies will be benefitted by the same to establish India as a leading semiconductor design nation.

Establishing a Strong Indigenous Intellectual Property Base

The inclusion of Masks set in DLI India will encourage setting up of globally competitive design ecosystem. Furthermore, it's crucial that the IPRs for technology developed in India are registered here, contributing to the growth of an indigenous intellectual property base.

Facilitating Joint Ventures

The government should facilitate joint ventures between global and domestic companies. These partnerships could provide our domestic enterprises with access to advanced technologies and global business networks, accelerating their transition to the ≤ 7nm technology node. This would facilitate domestic semiconductor product design companies to transition to the ≤ 7nm technology node, promoting domestic entrepreneurship in the semiconductor industry, and fostering a strong ecosystem for mask set production.

Annexure 1

China's State assistance to Semiconductor firm

Selected Highlights of China's Policies Promoting the Semiconductor and Software Industries (August 2020)

Measure	Selected Provisions for Enterprises and Projects Encouraged by the State
Corporate Income Tax (CIT)	**General:** ◆ Preferential treatment is provided for technology and inputs that cannot be produced in China or whose performance cannot meet demand. ◆ Losses incurred in a tax year can be carried forward to subsequent years for up to 10 years. ◆ The preferential tax policy period starts from the first year an enterprise makes a profit, or when a project receives income from production and operations. ◆ The conditions and scope of preferential tax policies shall be dynamically adjusted according to technological progress. **IC Manufacturing** ◆ IC production lines (28 nanometers (nm) and below) are exempt from CIT for 10 years. ◆ IC production lines (65 nm and below) are exempt from CIT for 5 years ◆ IC production lines (130 nm and below) are exempt from CIT for 2 years and pay half the statutory rate (12.5%) for the next 3 years **IC Design, Equipment, Software, Materials, and Packing and Testing:** ◆ Exempt from CIT for the first two years and pay a 12.5% rate for the subsequent 3 years. ◆ Key IC design and software firms are exempt from CIT for the first 5 years; and pay a 10% rate for subsequent years.
Trade and Trade-Related Taxes	**Value Added Tax (VAT)** ◆ Preferential value-added tax policies are continued **Import VAT** ◆ Imports of new equipment may pay the VAT in installments. **Import Tariffs** ◆ Producers of logic and memory chips (65 nm and below), specialty processes (0.25 microns or less) compound ICs (0.5 microns or less), and advanced packaging and testing companies may import duty free key raw materials and inputs, including: masks, 8-inch and above silicon single crystals and wafers, photoresists, packaging substrates, special building materials for clean rooms and related systems, manufacturing equipment, and related technology (e.g., software and parts).

	IC design and software companies receive preferential customs and import tariff treatment for manufacturing equipment and testing tools, related software, hardware, and components **Export Promotion** ◆ Promote the export of ICs, software and information technology services. ◆ Support companies in building global sales networks via specific Ministry of Commerce measures. ◆ Provide export financing and insurance for certain software contracts
Investment and Financing	◆ Strengthen services and guidance for the construction of major IC projects. Guide and standardize development of the IC industry (emphasis on planning and avoiding redundancies). ◆ Support IC and software companies to integrate resources. National government departments and local governments should actively support and guide corporate reorganization and mergers. ◆ Provide direct financing, equity financing, equity transfer, and other financial support. Make full use of existing national and local government investment funds to support development of the IC and software industry. Establish investment funds and increase investment in these funds. Encourage venture capital fund raising through multiple channels. ◆ Encourage local governments to establish mechanisms to provide funding—such as state financing guarantee funds—that compensate for lending risks. ◆ Offer supply chain finance and other financing that uses pledges of a company's IP, equity, and accounts receivable as collateral. Provide technology and IP insurance. ◆ Encourage financial institutions to provide medium- and long-term loans. Offer innovative credit products that specifically promote these industries. ◆ Increase financial support for major projects; guide insurance funds to invest in equities. Support bank wealth management companies, insurance, trusts, and other non-bank financial institutions to create specialized asset management products. ◆ Vigorously support companies to list and raise funds domestically and overseas. Accelerate China's domestic listing review process. Smooth exit options for original shareholders. ◆ Encourage companies to issue corporate bonds. Broaden financing channels to allow firms to issue medium- and long-term bonds as well as short- and medium-term notes.
R&D	◆ Strengthen academic programs and cultivate advanced-level talent in universities in accordance with national industrial development needs. ◆ Encourage cooperation between universities and companies to create pilot microelectronics colleges. Prioritize the creation of industry-academic integrated enterprises. Thirty percent of investment amounts in these enterprises can be deducted from education surcharge taxes. ◆ Encourage the government's-industry funds to increase investment in university programs, joint industry-corporate programs, and IC talent training. ◆ Cooperate with foreign universities and multinational companies, and introduce foreign teachers and resources to jointly develop China's talent.

Intellectual Property Rights (IPR)	◆ Encourage companies to register in China their exclusive rights for IC layout designs and software copyrights. ◆ Vigorously develop IP services that support companies' IPR protections and legal rights. ◆ Strictly enforce IPR protections and increase penalties for violations. Strengthen the protection of the exclusive rights of digital IC design and software copyrights ◆ Explore creating a mechanism for software legalization that requires all computers sold in China to have legal or legitimate software pre-installed. Implement government procurement measures and promote the standardized use of legal or legitimate software in important industries
Market Considerations	◆ Support the creation of IC clusters and build high-end software industry parks. ◆ Support backbone enterprises, scientific research institutes, and universities to create technology accelerators, business incubators, and university science parks. ◆ Develop information technology and R&D service businesses that support the government (e.g., e-government, data centers, and data processing). ◆ Improve digital privacy and trade-secret protections. ◆ Promote software products and services that meet government security requirements. ◆ Strengthen anti-monopoly enforcement, crack down on monopolistic behaviors, review operators, and maintain fair competition. ◆ Government support in the role of industry associations and standardization agencies. Accelerate the formulation of standards for ICs and software. Promote specifications to evaluate IC quality and software development costs
International Cooperation	◆ Encourage domestic universities and research institutes to strengthen cooperation with foreign counterparts. ◆ Encourage foreign companies to build R&D centers in China. ◆ Strengthen communication and exchanges between domestic and foreign industry associations ◆ Support domestic enterprises to cooperate with foreign firms in China and overseas ◆ Actively participate in setting global standards
Supplementary Provisions	◆ All qualified IC and software companies established in China, ***regardless of the nature of ownership,*** can enjoy this policy

Source: CRS with information from the Notice of Several Policies to Promote the High Quality Development of the Integrated Circuit (IC) and Software Industries in the New Era, Guofa [2020] No. 8 issued by the State Council in August 2020; Notice on the Import Tax Policies for Supporting the Development of the Integrated Circuit Industry and the Software Industry, Caishui [2021] No. 4 issued by the Ministry of Finance, the General Administration of Customs, and the State Administration of Taxation on March 16, 2021; and the Notice on the Measures for the Administration of Import Tax Policies to Support the Development of the Integrated Circuit Industry and Software Industry, Caishui [2021] No. 5, issued by the Ministry of Finance, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the General Administration of Customs, and the State Administration of Taxation on March 22, 2021. This analysis is based on an informal translation and review of these documents by the author.

ICEA
INDIA CELLULAR & ELECTRONICS ASSOCIATION
Inspire.Enable.Lead

LeMeridien Commercial Tower, 7th &
9th Floor, Raisina Road, Windsor Place,
New Delhi, 110001, Phone: 011 4934 9900

Feedback Advisory

1st Floor, Sumo Sapphire, #738, 15th Cross Rd,
JP Nagar 6th Phase, Bengaluru, Karnataka 560078
Landline Number: 080 - 40623800