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GLOBAL CHIP CRISIS AND INDIA'S PROSPECTS IN SEMICONDUCTOR TRADE.

Under the Guidance and Supervision of

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CERTIFICATE

This is to certify that Mr. VISHAKH K A (Reg. No. LM0223015) has prepared andsubmitted the dissertation titled " GLOBAL CHIP CRISIS AND INDIA'S PROSPECTS IN SEMICONDUCTOR TRADE " in partial fulfillment of the requirement for the award of the Degree of Master of Laws in International Trade Law, to the National University of Advanced Legal Studies, Kochi, under my guidance and supervision. It is also affirmed that the dissertation he submitted is original, bona fide, and genuine.

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I, Vishakh K A (Reg. No. LM0223015), pursuing Master in International Trade Law, do hereby declare that the Dissertation titled 'GLOBAL CHIP CRISIS AND INDIA'S PROSPECTS IN SEMICONDUCTOR TRADE', submitted for the award of L.L.M Degree in the National University of Advanced Legal Studies, Kochi, during the academic year 2023-2024 is my original, bona fide and legitimate research work, carried out under the guidance and supervision of Asst. Prof. HARI . S . NAYAR. This work has not formed the basis for the award of any degree, diploma, or fellowship either in this university or other similar institutions of higher learning.

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LIST OF ABBREVIATIONS

AI – Artificial Intelligence

ADAS - Advanced Driver Assistance System

AIFTA - ASEAN-India Free Trade Area

ATMP – Assembly, Testing, Marking and Packaging

BIS - Bureau of Industry and Security

C2S - Chips to Startup

CECA - Comprehensive Economic Cooperation Agreement

CEPA - Comprehensive Economic Partnership Agreement

COVID – Corona Virus Disease

DLI - Design Linked Incentive

DRAM – Dynamic Random Access Memory

EDA – Electronic Device Automation

EMC – Electronic Manufacturing Clusters

ESDM – Electronics System Design and Manufacturing

EV – Electronic vehicle

FAR- Federal Acquisition Regulatory

FDI – Foreign Direct Investment

FTA – Free Trade Agreement

GATT – General Agreement on Trade & Tariff

GDP – Gross Domestic Product

GPS - Geo positioning by satellites

GST – Goods & Services Tax

IC – Integrated Circuit

IDM – Integrated Device Manufacturer

IESA - India Electronics and Semiconductor Association

IP – Intellectual Property

ISM - India Semiconductor Mission

ITA – Information Technology Agreement

LCD – Liquid Crystal Display

LED – Light Emitting Diode

MNC – Multi-national Company

MeitY - Ministry of Electronics and Information Technology

MSIPS - Modified Special Incentive Package Scheme

NAFTA - North American Free Trade Agreement

NITI Ayog – National Institution for Transforming India

NPE 2019 - National Policy on Electronics 2019

OECD – Organisation for Economic Cooperation and Development

OEM – Original Equipment Manufacturer

OSAT – Outsourced semiconductor assembly and test

PC – Personal Computer

PLI – Production Linked Incentive

R&D – Research & Development

SAFTA - South Asian Free Trade Area

SPECS - Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors

SCM – Subsidies and Countervailing Measures

TSMC - Taiwan Semiconductor Manufacturing Company

TRIPS – Trade-Related Aspects of Intellectual Property Rights

TSMC – Taiwan Semiconductor Manufacturing Company

UNCTAD – United Nations Conference on Trade and Development

UV – Ultraviolet

WTO – World Trade Organisation

CHAPTER 1
INTRODUCTION

1.1: BACKGROUND AND INTRODUCTION

In today's world, technology is a cornerstone that has profoundly impacted our lives. Automating processes has ushered in unprecedented efficiency, reducing the time and workforce needed for repetitive tasks. Furthermore, the advent of advanced technologies like AI and machine learning has revolutionized how we handle large volumes of data. These new technologies enable faster and more informed decision-making in various fields, which is crucial in today's fast-paced world. Additionally, technology has emerged as a significant time and cost saver, taking over tasks that traditionally required substantial manual effort and attention to detail. In the fiercely competitive landscape of today's world, technology provides a company with the competitive edge it needs to outperform its rivals.

On another note, technology has also transformed the way we communicate. It has made connecting with people around the globe simpler and quicker. The internet, a significant technological advancement, has democratized information, providing easy access to a wealth of data. This global connectivity fostered by technology has bridged the gap between nations, promoting international understanding and cooperation. Furthermore, digital innovations can speed progress towards achieving the Sustainable Development Goals, fostering a more sustainable and fair global future. In conclusion, technology has permeated almost every aspect of our lives, making them more straightforward, productive, and interconnected. It continues to evolve, promising even more significant transformations in the future.

Semiconductors are at the core of contemporary technology and profoundly influence our everyday lives. They are the driving force behind computing devices, using binary code to carry out commands, from initiating a program to downloading and storing a document. A semiconductor is a tiny electronic device composed of elemental compounds with electrical properties (insulators and conductors) that store data, process the same, and perform analytical and logical operations. This is the functional

basis for information and communication Technology.[1] Semiconductors also play a pivotal role in telecommunications. For instance, the semiconductor chips in a smartphone control various functions, including its display, navigation, battery usage, and 4G reception. Moreover, semiconductors are integral to household appliances like washing machines, refrigerators, microwaves, and air conditioners.

Furthermore, semiconductors lay the groundwork for modern technology, paving the way for endless innovation and progress. They also play a crucial role in sustainability, using devices like solar panels to contribute to clean energy solutions. In essence, semiconductors are the bedrock of modern-day technology. They power various digital devices, from computers to tablets, enabling faster data processing. The recent global chip shortage underscores the importance of semiconductor chips, highlighting why restoring and increasing their production is vital to modern living.

Since semiconductors play a critical role across various industries and the global economy, they are crucial in international trade. They rank as the fourth most traded product globally, following crude oil, refined oil, and cars. The trade value of the finished product, considering the entire value chain needed to produce them, reached $1.7 trillion in 2019, four times the value of their global semiconductor sales. In this highly specialized value chain, over 60% of the world's countries are involved, either as exporters or importers.[2]

The production process for semiconductors comprises three main steps: design, fabrication, and assembly, each characterized by regional monopolies. The United States, Taiwan, South Korea, Japan, Europe, and China specialize in different process steps and rely on specific inputs from suppliers.[3] Thanks to the World Trade Organization's Information Technology Agreement, all semiconductor-related products, materials, and tools are subjected to one of the lowest tariffs in global trade.

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[1] Measuring distortions in international markets The semiconductor value chain, (2019), https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/TC(2019)9/FINAL&docLanguage=En.

[2] SEMICONDUCTORS: KEY INTERMEDIATE GOODS FOR INTERNATIONAL TRADE ISPI, https://www.ispionline.it/en/publication/semiconductors-key-intermediate-goods-international-trade-30709 (last visited January 2, 2024)

[3] *Id*

However, while creating economic benefits, this geographic specialization also brings vulnerabilities. There are over technology or process steps along the value chain wherein one region holds over 65% of the global market share. Consequently, if one of these “choke points” were affected by a natural disaster, an international conflict, or export control measures, the whole supply of chips could be fundamentally disrupted.

The global chip crisis and semiconductor shortage were significant from 2020 to 2023. This period saw a severe scarcity of semiconductors or “chips,” impacting over 169 industries worldwide. The shortage led to substantial price hikes, extended waiting periods, and reselling among consumers and manufacturers for products that require integrated circuits. These products span a wide range, including automobiles, graphics cards, video game consoles, computers, household appliances, and other consumer electronics.

The crisis was set off by a series of events, often described as a perfect storm. The primary catalyst for the escalating shortages was the ripple effect of the COVID-19 pandemic. The Global pandemic led to disruptions in supply chains and logistics, along with a 13% surge in global demand for PCs due to the shift to a stay-at-home economy in several countries. This situation affected the availability of critical chips necessary for manufacturing various electronics.

Other contributing factors included the China–United States trade war and the 2021 drought in Taiwan. The crisis was further intensified by poor planning, a surge in demand for new 5G handsets as global networks transitioned to the latest network technologies, and increased remote work and remote learning. The COVID-19 Lockdowns led to the shutdown of chip production facilities, resulting in the depletion of inventories.

The global chip crisis had a significant impact on international trade. The shortage led to substantial price increases and delays in producing and delivering products requiring integrated circuits, affecting many industries. This crisis brought car production to a standstill, delayed the launch of consumer electronics products, and impacted companies’ ability to onboard new employees. As the shortage began to ease, businesses had to gear up for production ramp-up and deal with the lasting impacts of

this economic crisis. Addressing the chip shortage and preparing for a return to "normal" meant grappling with a new shortage: labor. This crisis prompted a reevaluation of systems and production models.

Trade tensions between the US and China and geopolitical uncertainties in key chip-producing regions exacerbated the shortage. These tensions made it difficult for companies to source essential materials and invest in new chip manufacturing facilities, hindering the industry's ability to respond to the increased demand. In conclusion, the global chip crisis profoundly impacted international trade, leading to disruptions in supply chains, increased costs, and production delays. The scarcity of semiconductors highlighted the critical need for durable and flexible supply chains to satisfy the escalating demand for these chips.

The COVID-19 pandemic significantly contributed to the intensification of the global chip crisis. The COVID-19 pandemic led to disruptions in supply chains and logistics, which, combined with a 13% surge in global demand for PCs due to some countries' transition to a stay-at-home economy, affected the availability of essential chips required for manufacturing a wide array of electronics. The uncertainties brought about by the pandemic also resulted in sharp fluctuations in orders, complicating chipmakers' task of aligning capacity with demand. This situation is why car Manufacturers had to pause production in 2021 and why gaming consoles like Playstations and Xboxes became increasingly difficult to find in stores.[4] In February 2021, lead times—when a chip order is placed and When it is filled; for the first time since data collection began in 2017, the average duration has extended to 15 weeks. Lead times for Broadcom Inc., a key player in the industry due to its involvement across the supply chain, were lengthened to 22.2 weeks, up from 12.2 weeks in February 2020.[5]

India perceives the global chip crisis as an opportunity to bolster its position in the worldwide semiconductor ecosystem. The US Semiconductor Industry Association (SIA) and the India Electronics and Semiconductor Association (IESA) have jointly

[4] Ian King et al., *Microchips Needed in Your Car, PlayStation and Phone Are In Short Supply*, BLOOMBERG.COM, March 29, 2021, https://www.bloomberg.com/graphics/2021-semiconductors-chips-shortage/ (last visited January 2, 2024)
[5] *Id*

initiated plans to establish a private-sector task force to enhance collaboration between the two nations in the global semiconductor ecosystem. The task force aims to conduct a "readiness assessment" of the semiconductor ecosystem in India, bring together industry, government, and academic stakeholders to identify near-term industry opportunities and facilitate the strategic development of complementary semiconductor ecosystems over the long term.[6]

The task force will also recommend opportunities and challenges to enhance India's role within the global semiconductor value chain, including chip manufacturing. It will identify and facilitate workforce development and exchange opportunities for both countries. India is already a significant hub for semiconductor research, chip design, and equipment engineering, but its future potential is even more substantial. However, the global chip shortage has evolved throughout 2022. As demand for consumer electronics decreased, the shortage of specific advanced components rapidly diminished. The shortage is now primarily an automotive chip shortage as automakers struggle to secure steady supplies of chips. Production cuts for automakers across the globe were a hallmark of 2022.

In conclusion, India's prospects in the global chip crisis are promising, with initiatives underway to strengthen its role in the global semiconductor ecosystem.

1.2: STATEMENT OF PROBLEM

Technology is pivotal in the contemporary world, transforming our lives in numerous ways. It enhances connectivity, promotes financial inclusion, and improves access to trade and public services, acting as a great equalizer. It provides substantial advantages that influence our everyday activities and the functioning of numerous sectors, including automotive, healthcare, communication, manufacturing, business, and others. Semiconductors, or "chips," are integral to this technological advancement. They can be discovered in various items, including computers, mobile phones, vehicles, home

[6] US AND INDIA SEMICONDUCTOR GROUPS ANNOUNCE INITIATIVE TO STRENGTHEN PUBLIC-PRIVATE COLLABORATION IN CHIP ECOSYSTEM SEMICONDUCTOR INDUSTRY ASSOCIATION, https://www.semiconductors.org/u-s-and-india-semiconductor-groups-announce-initiative-to-strengthen-public-private-collaboration-in-chip-ecosystem/ (last visited January 2, 2024)

appliances, gaming consoles, and medical devices. Semiconductors drive innovation and productivity in many industries, making them incredibly important for today's economy.

However, the semiconductor industry has challenges. The COVID-19 pandemic has significantly disrupted global supply chains, leading to a scarcity of semiconductors. This shortage has spurred international changes across sectors and issues, such as delayed smartphone production and a new defensive trade policy.[7] The situation becomes more complex due to persistent global trade conflicts, which could increase the price of semiconductor materials and disrupt international cooperation in the sector. Despite these challenges, the international trade of semiconductors remains vital as it is among the most critical sectors of the global economy. Semiconductors are crucial elements in contemporary electronic devices, with their supply chain encompassing a sophisticated web of firms engaged in their conception, production, examination, packaging, and delivery. The worldwide semiconductor sector is a vast and expanding market, amassing earnings of $574.1 billion in 2022. The strategic importance of semiconductors, as shown by their wide range of industrial applications, high technology intensity, and highly concentrated market power, is likely to produce a geopolitical race for global leadership in producing such microscopic components.

The Current chip crisis highlighted India's vulnerability to global supply chain disruptions. The government of India has taken steps to address the chip crisis, such as providing incentives for semiconductor manufacturing in India. However, more must be done by the Indian Government to make India a more self-reliant player in the semiconductor industry and become a Global Semiconductor Hub.

The study aims to delve into the current global chip crisis, which has far-reaching implications across various industries. A vital aspect of this study involves scrutinizing the initiatives undertaken by the Indian government to bolster India's position in the semiconductor trade. Another area of focus is India's potential to transform into a global hub for semiconductors. However, it is equally important to understand the hurdles that

[7] A GLOBAL SEMICONDUCTOR SHORTAGE WORLD101 FROM THE COUNCIL ON FOREIGN RELATIONS, https://world101.cfr.org/global-era-issues/globalization/global-semiconductor-shortage (last visited January 2, 2024)

India might encounter in its journey to become a global semiconductor hub. Lastly, an analysis of the Impact of Indian laws and policies on India's prospects in the semiconductor trade is also part of this comprehensive study. This will provide insights into how these factors could influence India's ambition to become a global semiconductor hub.

1.3: RESEARCH OBJECTIVES

- To Study and Understand the ongoing Global Chip crisis.
- To examine the role of the Indian government in promoting India's emergence in the semiconductor trade.
- To assess India’s prospects in the semiconductor trade for becoming the global semiconductor hub.
- To study and understand India's challenges in becoming a global semiconductor hub.
- To analyze Indian legislation and policies that affect the prospects of India becoming a global semiconductor hub.

1.4: HYPOTHESIS

The Existing Legal framework and policies in India are not conducive enough to transform India into a Global Semiconductor Hub.

1.5: METHODOLOGY

- This Dissertation focuses on the Global Chip Crisis and the new policies and schemes of the Indian government to become a global semiconductor hub.
- The methodology employed in this research is purely doctrinal.
- Sources- Legislations, International Agreements, Journals, Press Releases, Government Publications, Online Articles, Newspapers, Books.

1.6: RESEARCH QUESTIONS

1. What is the History and Evolution of the Semiconductor trade, and What is the significance of semiconductors in the modern world?
2. What are India's challenges in its quest to become a global semiconductor hub, and how can India address these challenges and become a global semiconductor hub?
3. What are the opportunities for collaboration between India and other countries in the semiconductor trade?
4. Are India’s legislation and policies effective enough for India to become a Global Semiconductor Hub?
5. What is India’s role in tackling the Global Chip crisis by becoming a Global Semiconductor Hub?

1.7: OUTLINE OF CHAPTERS

I. INTRODUCTION.

This chapter briefly introduces the area of study, its relevance and significance, the research problem, the research questions, and the literature review conducted concerning this research.

II. HISTORY AND EVOLUTION OF SEMICONDUCTOR TRADE.

This chapter covers the study of the history and evolution of Semiconductors, the Semiconductor Industry, types of business models in the semiconductor supply chain, and the significance of the WTO in the semiconductor trade.

III. CURRENT GLOBAL CHIP CRISIS.

This chapter discusses the ongoing chip crisis around the world. This chapter looks deeply into the reasons behind the current chip crisis, the aftermath of the chip crisis, and various measures taken by nations to tackle the chip crisis.

IV. INDIA'S ROLE IN SEMICONDUCTOR TRADE.

This chapter discusses India's role in the semiconductor trade. It looks into how vital the role of India is in the semiconductor trade and how well the Indian nation performs in fostering the global semiconductor trade.

V. ANALYSIS OF INDIAN LEGISLATION AND POLICIES AFFECTING INDIA'S PROSPECTS OF BECOMING A GLOBAL SEMICONDUCTOR HUB.

This chapter goes through Indian legislation, policies, IP regimes, etc., and analyses how these affect India's becoming a global semiconductor hub.

VI. CHALLENGES AND OPPORTUNITIES FOR INDIA IN SEMICONDUCTOR MANUFACTURE AND TRADE.

This chapter examines the challenges the Indian nation will face in becoming a Global Semiconductor Hub. Also, it looks into India's opportunities to become a Global Semiconductor Hub.

VII. INDIA'S ROLE IN TACKLING THE GLOBAL CHIP CRISIS.

This chapter discusses various measures India took to tackle the global chip crisis and other possible suggestions for overcoming the chip crisis and becoming a global semiconductor hub.

VIII. FINDINGS, CONCLUSION AND SUGGESTIONS

This chapter contains the significant findings of the Researcher. It also provides some relevant suggestions to tackle the identified issues. It also discusses the various steps that India should adopt to boost domestic semiconductor production.

1.8: LITERATURE REVIEW

- "Chris Miller, Chip War: The Fight for the World's Most Critical Technology", October 4 2022, Simon & Schuster-UK.

In this book, the author talks about how essential semiconductors are in our daily lives, how the US became a leader in making and designing chips, and how these chips are used in military equipment. China is the main rival to the US in the chip race. In the introduction, he states, "World War II was decided by steel and aluminum and followed shortly after that by the Cold War, defined by atomic weapons. The rivalry between the United States and China may be determined by computing power." it reveals the tension between the US and China.

- Sean Ashcroft, Supply Chain Risk Management- Timeline: causes of the global semiconductor shortage, Supply Chain- January 11, 2023.

In this article, the author takes us to the timeline of the Global Chip Crisis. It also deals with a brief overview of COVID-19, the US-China Trade war, the Russia-Ukraine war, etc., which
caused the Global Chip Crisis.

- Lauren Hart, Semiconductor Manufacturing Process: How are semiconductor chips made? 2023 MRL.

This Article deals with the manufacturing of semiconductors. It gives an idea about the manufacturing process, raw materials used, chemicals involved in manufacturing, time taken for manufacturing, its life span, etc. Information regarding the raw material used is essential to understand which nations have rich deposits of these materials and also to analyze the environmental impacts that may be caused by manufacturing the semiconductors in our country.

- Press Information Bureau Government of India, SemiconIndia Conference 2022 kicks off on a high note- Ministry of Electronics & IT, PIB Delhi, 29 APR 2022.

This press release deals with SemiconIndia Conference 2022. The conference is in sync with broader national initiatives like Atmanirbhar and Bharat Make in India and is seen as the springboard for the India Semiconductor Mission (ISM).

- Press Information Bureau Government of India, Setting Up Semiconductor Industries- Ministry of Electronics & IT, PIB Delhi 27 JUL 2022.

This press release deals with schemes introduced under the Semicon India program. It discusses the setting up semiconductor fabs, Display fabs, design-linked incentives, etc.

- Objectives | India Semiconductor Mission.

The official website of India's Semiconductor missions sets objectives of India Semiconductor Mission. It outlines a long-term plan for the growth of semiconductors, ensuring supply chain security, initiating design and startup, and fostering native intellectual property and partnerships. It also facilitates collaboration and partnership schemes with domestic and global agencies, industries, etc.

- William A. Reinsch, Emily Benson, and Aidan Arasasingham, Securing Semiconductor Supply Chains An Affirmative Agenda for International Cooperation, Center for Strategic and International Studies (CSIS) (2022)

This Article discusses various nations' initiatives to secure global semiconductor supply chains. It also discusses the Quad cooperation, India's Fab, R&D capacity, Risks and benefits, etc.

CHAPTER 2

HISTORY AND EVOLUTION OF SEMICONDUCTOR TRADE

2.1 INTRODUCTION

Trade has its roots in prehistoric times when the advent of agriculture led to the first instances of commerce among sedentary societies.[8] As societies evolved, so did their trading practices. Around 3000 BC, trade began to take a more structured form in Ancient Mesopotamia and the Indus Valley, where traders exchanged goods such as spices, metals, and cloth.[9]

The Silk Road, an early and significant trade route, connected the East and West.[10] This facilitated the exchange of goods and led to the sharing of ideas. The Middle Ages saw a further expansion of trade with the rise of the modern nation-state.[11] The Industrial Revolution and the Age of Sail were followed by a period marked by significant increases in international trade, facilitated by advancements in technology and navigation. The 20th century further advanced this trend with the establishment of the General Agreement on Tariffs and Trade (GATT) in 1947, which later evolved into the World Trade Organization (WTO) in 1995.[12] These organizations were established to further facilitate international trade.

Today, trade is crucial in supporting economic development and promoting peaceful relations among nations. It is constantly evolving in response to global trends and changes in technology. Semiconductors are essential in our modern world and crucial to operating computing devices, with microchips and computers being the most common applications. Materials that are not conductors or insulators and have an

[8] WHAT IS TRADE? – CONCEPT, ORIGIN, HISTORY, AND MORE GLOBAL MARKETING GUIDE, https://www.globalmarketingguide.com/what-is-trade/ (last visited December 25, 2023).
[9] SUTORI, https://www.sutori.com/en/story/history-of-trade--V2eNSdYq2HhRCizcCDnJ8PDZ (last visited December 25, 2023)
[10] WTO | THE HISTORY OF MULTILATERAL TRADING SYSTEM, https://www.wto.org/english/thewto_e/history_e/history_e.htm (last visited December 25, 2023)
[11] INTERNATIONAL TRADE | DEFINITION, HISTORY, BENEFITS, THEORY, & TYPES | BRITANNICA MONEY, https://www.britannica.com/money/topic/international-trade (last visited Dec 25, 2023)
[12] *Supra* note 3,

energy gap of approximately 1 eV (electron volt) are classified as semiconductors.[13] Semiconductors control smartphones' computer functions, affecting display, navigation, battery use, 4G reception, and more. They are also found in many household appliances like fridges, microwaves, washing machines, and air conditioners. Essentially, semiconductors power almost everything in our daily lives, from smartphones to planes, improving technologies and providing convenience.

When it comes to sustainability, semiconductors play a vital role. They allow tech to be reliable, compact, and affordable, making them essential for creating electronics. Semiconductors are the foundation of modern computing and communication infrastructures, enabling global connectivity. They are vital to electronic devices, facilitating progress in communications, computing, healthcare, military systems, transportation, clean energy, and numerous other fields.

Semiconductors have a wide array of applications in various technological fields. One of the most common uses is in creating transistors, electronic devices that amplify or switch electronic signals and electrical power. The functionality of these devices is mainly due to the properties of the semiconductors used in their construction. Another application of semiconductors is in the creation of diodes. Diodes are electronic devices designed to permit current flow in only one direction. The properties of semiconductors make them ideal for this purpose. Semiconductors also play a crucial role in the manufacture of integrated circuits. These devices are extensively used because of their small size, dependability, energy efficiency, and affordability. The use of semiconductors in integrated circuits has revolutionized the electronics industry.

In the field of renewable energy, semiconductors, particularly those made from silicon, are used to manufacture solar cells. These cells convert sunlight into electricity, and semiconductors are critical to their operation. Semiconductors are also used in various sensors and detectors, including temperature sensors, pressure sensors, and light detectors. The sensitivity of semiconductors to different physical phenomena makes them ideal for these applications. Finally, semiconductors create light-emitting diodes (LEDs) and solid-state lasers. These devices emit light when electric current is applied,

[13] https://www.electrical4u.com/theory-of-semiconductor/

a property made possible by using semiconductors. Semiconductors are pervasive in modern technology and critical elements for most electronic systems. They serve communications, signal processing, computing, and control applications in consumer and industrial markets. Their use continues to expand as technology advances. Semiconductor trade holds immense importance in the global economy and technological advancement. The semiconductor industry significantly impacts the economy. Despite a 3.5% contraction in the global GDP in 2020, global semiconductor sales rose 6.6% to US$440 billion.[14] Companies involved in designing, manufacturing, and distributing semiconductors are among the largest in the global stock market. In 2018, more than one trillion semiconductors were sold worldwide, accounting for $1.8 trillion in international trade.[15] Furthermore, semiconductors' ability to process and transmit information has been a critical driver of global innovation.[16]

The importance of semiconductors is also evident in their role in global supply chains. Countries like India are striving to establish themselves as critical partners in these chains, leveraging several advantages that make them promising destinations for semiconductor innovation and production. The aim for semiconductor self-reliance is also growing, with countries seeking to reduce dependence on imports and establish domestic manufacturing capabilities. With a swiftly expanding population and a rising middle class, countries like India offer a vast consumer base for semiconductor products, providing a strong demand driver for the industry.[17] Semiconductor trade is crucial for the economic growth of individual countries and the advancement of global technology and innovation.

2.2 HISTORY OF SEMICONDUCTORS

The history of semiconductors is a fascinating journey that spans over two centuries. According to G. Busch, the term "semiconducting" was first used by Alessandro Volta

[14] HOW SEMICONDUCTOR PLAYS AS A CRUCIAL ELEMENT FOR ECONOMY DELOITTE THAILAND, https://www2.deloitte.com/th/en/pages/about-deloitte/articles/semiconductor-eng.html (last visited December 25, 2023)
[15] UN Comtrade 2018 Trade Data
[16] SEMICONDUCTORS AND THE IMPACT ON THE STOCK MARKET INVESTOPEDIA, https://www.investopedia.com/semiconductor-impact-on-the-stock-market-7367723 (last visited December 25, 2023)
[17] INDIA'S NEXT 'BIG PUSH' TOWARDS SEMICONDUCTOR INDUSTRY, https://www.investindia.gov.in/team-india-blogs/indias-next-big-push-towards-semiconductor-industry (last visited December 25, 2023)

in 1782.[18] In 1833, Michael Faraday made a significant observation that furthered this understanding. He observed that the resistance of silver sulfide decreased as the temperature increased, which contrasted with the behavior typically seen in metals. This was the first recorded observation of a semiconductor effect. The late 19th and 20th centuries saw rapid advancements in semiconductor technology. In 1874, the rectifier was an early semiconductor device that converted alternating current (AC) to direct current (DC). This device paved the way for the use of semiconductors in electronic devices. The development of the point-contact transistor in 1947 by Bardeen and Brattain at Bell Laboratories in the US represented a groundbreaking achievement in the semiconductor industry. This was followed by Shockley's invention of the junction transistor in 1948. These inventions began the transistor era, which revolutionized the electronics industry. The bipolar integrated circuit (ICs) was invented by Kilby of Texas Instruments and Noyce of Fairchild Semiconductor in the US in 1959. This marked the dawn of the IC era, which saw the miniaturization of electronic circuits and led to the development of modern electronic devices.[19]

Today, the semiconductor industry has grown exponentially, with advancements in technology leading to the development of large-scale integrated circuits (LSIs), very large-scale integrated circuits (VLSIs), and ultra-large-scale integrated circuits (ULSIs). Semiconductors are now used in various applications and have become an integral part of our everyday lives.

In the early stages of transistor development, germanium was the material of choice due to the availability of purification methods developed around World War II. The electrical characteristics of semiconductors are susceptible to impurities, requiring extreme purity levels for manufacture. By the late 1950s, successful research into silicon purification led to its use in semiconductor devices from around 1960 onwards. Silicon quickly became the preferred material due to its abundance and lower cost than germanium. Additionally, silicon maintains its semiconducting properties at higher temperatures than germanium, with silicon diodes able to operate at up to 200°C

[18] G. Busch, "Early history of the physics and chemistry of semiconductors – from doubts to fact in a hundred years," Eur. J. Phys., vol. 10, no. 4, pp. 254–263, 1989.
[19] Lidia Łukasiak and Andrzej Jakubowski, *History of Semiconductors*, 1 JOURNAL OF TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY (2010)

(400°F), while germanium diodes are limited to 85°C (185°F). One key characteristic of silicon, not fully appreciated initially but crucial for the development of affordable transistors and integrated circuits, is its ability to form a durable oxide film with excellent insulating properties when heated in the presence of oxygen. This film is used as a mask during manufacturing, allowing specific impurities that alter silicon's electrical properties to be introduced. The mask pattern, created through a photolithographic process, enables the fabrication of minuscule transistors and other electronic components within the silicon.[20]

2.3 SEMICONDUCTOR INDUSTRY

"The semiconductor industry comprises firms that design, manufacture, and market semiconductor devices for original equipment manufacturers and personal computer (PC) users. Semiconductors control and amplify electrical signals in many electronic products. These include computers, TVs, VCRs, other home appliances, telecommunications equipment, industrial machinery, aircraft, and military equipment. Computers and telecommunication products consume over three-fourths of U.S.-made chips."[21]

Key players dominate the semiconductor industry. The world's largest semiconductor foundry is the Taiwan Semiconductor Manufacturing Co. Ltd. (TSM), which manufactures integrated circuits for clients. Intel Corp. (INTC) is another major player, developing processors primarily for the personal computer (PC) and enterprise server markets.[22] Samsung Electronics Co. Ltd. is a significant participant in the semiconductor industry, along with Micron Technology Inc. Qualcomm Inc. is known for its work in the semiconductor sector. Broadcom Inc. is an essential participant in the global semiconductor market. Other significant companies in the semiconductor industry include SK Hynix Inc., Texas Instruments Inc., Toshiba Corporation, and

[20] ELECTRONICS - SEMICONDUCTOR, REVOLUTION, TECHNOLOGY | BRITANNICA, https://www.britannica.com/technology/electronics/The-semiconductor-revolution (last visited December 27, 2023)
[21] Francisco A. Moris, *Semiconductors: the building blocks of the information revolution*, Vol. 119 MONTHLY LABOR REVIEW 7 (1996), https://www.jstor.org/stable/41844601
[22] 10 BIGGEST SEMICONDUCTOR COMPANIES BY REVENUE INVESTOPEDIA, https://www.investopedia.com/articles/markets/012216/worlds-top-10-semiconductor-companies-tsmintc.asp (last visited December 31, 2023)

Maxim Integrated Products Inc. These companies compete to produce smaller, cheaper, and faster chips for increasingly powerful and affordable technology products. Their semiconductor chips are a critical component for manufacturers of technology hardware and industrial equipment.[23]

Developing and manufacturing semiconductor chips involves three main stages: design, fabrication, and testing & assembly. In the design stage, the electronic circuits that will eventually be part of the chip are conceptualized and designed. This process involves creating a series of increasingly detailed abstract representations of the desired 'circuits.' The design stage is crucial as it lays the groundwork for the physical creation of the chip in the next step. The fabrication stage involves the physical composition of the chip. The circuits designed in the previous stage are constructed on the surface of a flat, circular silicon wafer. This is done in a series of steps, each adding a new circuit layer. The fabrication process is highly precise and requires a clean, controlled environment to prevent contamination of the delicate circuits.

The final stage is testing and assembly. The silicon wafer, now embedded with thousands of individual chips (or dies), is cut into these units. The number of chips obtained from a single wafer can vary greatly depending on the size of each chip. Once separated, each chip is packaged in a protective shell that safeguards the delicate internal circuits and includes connections for integrating the chip with other components.[24] This stage ensures that each chip is functional and ready for use in various electronic devices.

A semiconductor fabrication plant, often Known as a "fab," this facility specializes in the production of semiconductor devices, including integrated circuits, diodes, and transistors. Fab is short for "fabrication," which means to produce and refers to semiconductor production facilities in the semiconductor industry. "The inside of the semiconductor production line is called a clean room. If even a tiny piece of dust or particles enters the semiconductor production process, the semiconductor quality will be impacted. This is why clean rooms must maintain an extremely high level of

[23] *id*
[24] Brown Clair et al., *Offshoring in the Semiconductor Industry: A Historical Perspective*, BROOKINGS INSTITUTION PRESS (2005) https://www.jstor.org/stable/25058769 pp 280-281

cleanliness compared to other external environments."[25] The economic standards are different in each process of manufacturing semiconductor chips. The design process requires expensive EDA (electronic design automation) software, which is skill-intensive. Massive investment is needed to set up fabs with various equipment and types of machinery. Assembly also requires expensive equipment. Equipment costs dominate labor costs, especially in fabrication.

In the early days, the semiconductor companies were vertically integrated, meaning they were involved in every step of the production process, from manufacturing wafers to marketing and distributing the final products. However, as technology advanced and chips became smaller, the process of manufacturing semiconductors became more complex. Additionally, the high capital investment required for semiconductor production led to the emergence of specialized firms within the semiconductor supply chain. Today, the industry is made up of companies that specialize in specific areas of production, as well as firms that are involved in all stages of production.

There are four primary types of business models in the semiconductor supply chain. These models have evolved to meet the increasingly complex and capital-intensive demands.

Integrated device manufacturers: An Integrated Device Manufacturer (IDM) is a semiconductor firm that handles the design, production, and sale of integrated circuits (ICs). Traditional IDMs own their proprietary chips, carry out the design process internally, and have their fabrication facilities for IC manufacturing. Companies like Intel, Infineon, and Texas Instruments are examples of IDMs. Samsung is another example of an IDM, but it also offers design and foundry services to other companies in the semiconductor industry. In the early stages of the semiconductor industry, IDMs were the primary players in the supply chain. However, as the capital requirements for production increased, there was a shift in the industry structure. This led to the separation of fabrication facilities from design and assembly, packaging, and testing processes, resulting in the emergence of foundries, Outsourced Semiconductor

[25] FAB GLOSSARY.ZIP SAMSUNG SEMICONDUCTOR GLOBAL, https://semiconductor.samsung.com/support/tools-resources/dictionary/semiconductors-101-part-7-all-about-the-fab-the-birthplace-of-semiconductor-chips (last visited December 31, 2023)

Assembly and Test providers (OSATs), and design firms. In the current landscape, companies that specialize in memory and digital analog-optical (DAO) products typically follow the IDM business model. These firms primarily manufacture general-purpose components with lower capital requirements than foundries.

Fabless design firm: A fabless design firm, also known as a fabless semiconductor company, focuses on designing and selling hardware devices and semiconductor chips. However, the actual manufacturing of these designs is outsourced to a separate entity known as a semiconductor foundry. These foundries are often based in countries like the United States, China, and Taiwan. The term 'fabless' is derived from 'fabrication-less,' which signifies that the Company does not engage in the product's manufacturing process. Instead, it focuses solely on the design and marketing aspects of the semiconductor chips. This approach allows fabless companies to enjoy reduced capital costs while devoting their research and development efforts toward the end market.
In some cases, fabless companies and pure-play foundries may provide integrated circuit design services to other parties. The fabless business model emerged from the opportunity for smaller companies to design silicon but not manufacture it, depending on IDMs that had surplus production capacity. LSI Computer Systems, Inc. (LSI/CSI) was the first to adopt the fabless semiconductor model.[26]

Foundries: Fabless companies delegate manufacturing processes to specialized factories known as foundries or fabs. The substantial financial investment required for semiconductor production has given rise to these specialized fabs. The ability to spread risk is a significant advantage of specialization in the supply chain. The majority of these firms exclusively handle outsourced projects. However, a few companies with substantial capital carry out their production in addition to managing outsourced work.[27]

Outsourced assembly and test companies (OSATs): The OSATs handle assembly, packaging, and testing for IDMs and fablite business models. OSATs are known for

[26] FABLESS COMPANY: WHAT IT IS, HOW IT WORKS, EXAMPLE INVESTOPEDIA, https://www.investopedia.com/terms/f/fablesscompany.asp (last visited January 1, 2024)
[27] ULRICH NAEHER, SAKAE SUZUKI & BILL WISEMAN, THE EVOLUTION OF BUSINESS MODELS IN A DISRUPTED VALUE CHAIN, https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/semiconductors/pdfs/mosc_1_business_models.ashx.

their lower capital needs and use less skilled labor. Initially, US semiconductor companies outsourced assembly and packaging to smaller Asian firms, leading to the gradual emergence of OSATs as a specialized sector in the supply chain. The evolution of OSATs occurred following the establishment of the fab lite business model.[28]

"Semiconductors are critical technology components that drive a wide range of advanced digital devices. The global semiconductor industry is poised for sustained growth throughout the next decade, buoyed by advancements in emerging technologies like autonomous driving, AI, the Internet of Things, and 5G telecommunications, coupled with consistent spending on R&D and competition among the prominent players."[29]

2.4 SIGNIFICANCE OF THE WTO IN SEMICONDUCTOR TRADE

The World Trade Organization (WTO) has fostered growth and innovation within the semiconductor sector. Over the past quarter-century, the WTO has been pivotal in opening markets and establishing a level playing field globally, which has been crucial for the success of the worldwide semiconductor industry.

The WTO is a global institution that governs and facilitates international trade among nations. Established in 1995, it succeeded the General Agreement on Trade and Tariffs (GATT) that was formed in 1948. The WTO has six primary goals: enforcing and establishing rules for global trade, providing a platform for negotiating and monitoring Further trade liberalization, resolving trade disputes, enhancing the transparency of decision-making processes, collaborating with other significant international economic institutions involved in global financial management, and assisting developing countries to leverage the global trading system fully. The WTO aims to enable its members to utilize trade to improve living standards, generate employment, and enhance the quality of life. It manages the global system of trade rules and aids developing countries in building their trade capacity. The WTO ensures smooth,

[28] *Id.*
[29] SEMICONDUCTOR INDUSTRY - OVERVIEW, ANALYSIS & REPORT TRENDS, https://www.mordorintelligence.com/industry-reports/semiconductor-industry-landscape (last visited December 27, 2023)

predictable, free trade across borders while promoting sustainable economic growth and development.[30]

Before the WTO was formed in 1995, the semiconductor sector operated within a more segmented and less regulated global trade environment. The trade rules were not as standardized, and market access needed to be more liberalized.

The semiconductor industry, known for its intricate production process and supplier ecosystem, encountered difficulties due to the absence of a worldwide platform for resolving trade disputes, protecting intellectual property, and eliminating reciprocal tariffs. The high capital costs and short product life cycles further complicate global semiconductor trade. The inception of the WTO marked a significant milestone for the semiconductor industry. The WTO led the way in steadily opening markets and establishing a level playing field globally, which has been vital for the success of the global semiconductor industry. Key WTO agreements like the Information Technology Agreement (ITA), Trade-Related Aspects of Intellectual Property Rights (TRIPS), and the Trade Facilitation Agreement (TFA) have significantly reduced trade costs, decreased consumer prices, and broadened access to tech products that enhance productivity worldwide.[31]

The Information Technology Agreement (ITA) has been a game-changer for the semiconductor industry. Signed in 1996, the ITA is a commitment by its participants to eliminate tariffs on IT products covered by the Agreement completely. 82 WTO members are part of the ITA, representing 97% of the global trade in ITA products.[32] The ITA has significantly reduced the cost of ICT goods, increasing the availability of products like mobile phones in developing economies and promoting the broader use of new technology. Since the ITA came into effect, import prices of computers and semiconductors have dropped by 66%. Technologies enabled by semiconductors, which have greatly benefited from the ITA, have the potential to reduce greenhouse gas

[30] WTO | WHAT IS THE WTO? - WHO WE ARE, https://www.wto.org/english/thewto_e/whatis_e/who_we_are_e.htm (last visited January 1, 2024)
[31] SEMICONDUCTORS & THE WORLD TRADE ORGANIZATION HOW GLOBAL TRADE RULES HAVE SPURRED SEMICONDUCTOR GROWTH & INNOVATION THE-WTO-AND-THE-SEMICONDUCTOR-INDUSTRY-NOV-2020_2.PDF (SEMICONDUCTORS.ORG)
[32] 20 YEARS OF THE INFORMATION TECHNOLOGY AGREEMENT BOOSTING TRADE, INNOVATION AND DIGITAL CONNECTIVITY

emissions by up to 15%, nearly one-third of the reduction needed by 2030. In summary, the ITA has played a pivotal role in propelling the semiconductor trade forward by eliminating tariffs, lowering costs, and broadening market access.

The TRIPS Agreement is vital to international trade. It stands as the most comprehensive multilateral agreement on intellectual property rights and is critical in promoting 'trade' in knowledge and creativity. The 1995 WTO's TRIPS Agreement is the world's first international trade agreement to define multilateral IP rules and standards and mandate minimum national IP enforcement procedures within a single framework.[33] The TRIPS Agreement is crucial in settling trade disputes over intellectual property and ensures that World Trade Organization (WTO) members can achieve their domestic policy objectives. It shapes the intellectual property system regarding innovation, technology transfer, and public welfare. The Agreement acknowledges the importance of the connection between intellectual property and trade and the necessity for a balanced intellectual property system. It has significantly transformed the scale, diversity, and nature of cross-border commercial transactions regarding knowledge and how intellectual property is licensed and traded.

The TRIPS Agreement holds significant importance within the semiconductor industry. TRIPS is the first international trade agreement explicitly recognizing trade secrets as intellectual property and mandates members to protect confidential information.[34] This is paramount to the semiconductor industry, where trade secrets are a significant business asset. Article 35 of the TRIPS Agreement provides unique IP protection for integrated circuits (ICs) layout designs.[35] A semiconductor layout design refers to a chip's digital blueprint of transistors and other circuit components. Before 1984, existing copyright and patent laws did not adequately protect these designs, making it technically legal for a company to manufacture a chip identical to its competitor's. This situation raised fears of "chip piracy," where a company could replicate a chip design that cost the original manufacturer $100,000 for just $10,000 by merely using the

[33] Uruguay Round Agreements. WTO Legal Texts. (Available at: https://www.wto.org/english/docs_e/legal_e/legal_e.htm#TRIPs)
[34] TRIPS Article 39 calls on members to provide for the protection of "undisclosed information" that is secret and has commercial value and to protect such information from disclosure, acquisition, or use in a manner contrary to "honest commercial practices."
[35] Standards concerning the availability, scope, and use of Intellectual Property Rights. WTO. (Available at: https://www.wto.org/english/docs_e/legal_e/27-trips_04c_e.htm)

negatives of the mask design. To address this issue, the United States became the first country to enact the Semiconductor Chip Protection Act (1984) to safeguard semiconductor layout designs.[36] Following the United States' lead, other nations also began to protect semiconductor layout designs. In 1989, the "Washington Treaty on Intellectual Property in Respect of Integrated Circuits," also called the "Washington Treaty" or "IPIC Treaty," was signed, but it was never ratified.[37] Only with the introduction of the TRIPS Agreement was protection for chip layout designs extended globally.

Three critical aspects of the TRIPS agreement are of utmost importance to the semiconductor industry: They protect trade secrets, provide explicit protections for IC layout designs, and ensure protections against compulsory licensing for semiconductors. In summary, the TRIPS Agreement is instrumental in the semiconductor trade as it provides a structure for protecting intellectual property rights, a vital asset in this industry.

[36] Kasch, Steven. “The Semiconductor Chip Protection Act: Past, Present, and Future.” High Technology Law Journal, Vol. 7, No 1 (Spring 1992).
[37] Treaty on Intellectual Property in Respect of Integrated Circuits. World Intellectual Property Organization, 1989. (Available at: https://wipolex.wipo.int/en/text/294976)

CHAPTER 3
CURRENT GLOBAL CHIP CRISIS

3.1 INTRODUCTION

Semiconductors are crucial in modern society, influencing everything from computing and telecommunications to household appliances and healthcare. These chips form the backbone of modern computing, enabling the functionality of smartphones, laptops, and a wide range of electronic devices.[38] In telecommunications, they control functions in devices like smartphones and the infrastructure that supports the internet. Additionally, semiconductors are essential in household appliances, sustainability initiatives such as wind turbines and solar farms, and medical devices, including pacemakers and insulin pumps.[39]

From 2020 to 2023, the semiconductor industry faced significant challenges due to a global chip shortage. This shortage disrupted manufacturing across more than 169 industries worldwide, leading to increased prices, delayed product launches, and production slowdowns.[40] The COVID-19 pandemic primarily triggered this crisis by causing significant disruptions in supply chains and a spike in demand for PCs as the world shifted to remote work and learning.[41]

The shortage has had widespread repercussions, including inflated prices for consumer electronics and vehicles, delayed production in the automotive industry, and heightened inflation rates.[42] Manufacturers are working to increase production, but the complexities of semiconductor manufacturing mean the shortfall will persist for some time. This crisis underscores the indispensable role of semiconductors in the global economy and the urgent need for more resilient supply chains.

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[38] 8 Reasons Why Semiconductors Are Important to Modern Living MUO, https://www.makeuseof.com/why-semiconductors-important/ (last visited Jun 12, 2024)
[39] *id*
[40] The Impact of Semiconductor Chip Shortages on the Global Economy, https://www.knowledgeridge.com/blog/the-impact-of-semiconductor-chip-shortages-on-the-global-economy (last visited Jun 12, 2024)
[41] Decoded | Impact of semiconductor chip shortage on global economy India Today, https://www.indiatoday.in/business/story/decoded-how-chip-shortage-has-hurt-global-economy-1828911-2021-07-16 (last visited Jun 12, 2024)
[42] *Id* at 39

3.2 CAUSES AND EFFECTS OF CHIP CRISIS

In December 2019, a novel coronavirus case was reported in Wuhan, China. The initial outbreak was linked to the Hunan Seafood market. On 31st December 2019, China alerted WHO about several instances of Pneumonia in Wuhan. In January 2020, Chinese scientists identified the new virus. Evidence of human-to-human transmission emerged as the number of cases increased. The World Health Organization officially declared the ongoing outbreak as an International Public Health Emergency on January 30, 2020. This declaration underscored the global significance and urgency of addressing the situation. From February 2020 onwards, COVID-19 cases appeared in several countries outside China, including Italy, Iran, and South Korea. From March onwards, Countries worldwide imposed lockdowns, travel restrictions, and social distancing measures to curb the spread. The pandemic caused significant economic imbalances, leading to global job losses and financial instability.

COVID-19 pandemic: The COVID-19 pandemic is one of the reasons for the Global Chip crisis. It accelerated the chip crisis by disrupting global supply chains and causing factory shutdowns and labor shortages. The geopolitical tensions between the US and China have boosted supply chain issues along with the pandemic. The virus outbreak affected production as it resulted in labor challenges. The health and safety of workers during the pandemic is important. The global lockdown and the emergence of a work-from-home culture led to a high demand for personal computers. Chips are the brains of computers, and the high demand for personal computers leads to a high demand for chips. The semiconductor industries could not meet the computer manufacturers' needs as the social distancing and lockdowns have adversely affected the labor force, transportation, manufacture, and distribution. All of these were interconnected with each other. The breakdowns in transportation delayed the delivery of raw materials and manufactured chips. It badly affected international trade and services.

The automotive industries increased the demand for chips during the post-pandemic period. Modern automobiles require a lot of chips. Today, all the cars are equipped with

numerous Engine Control Units.[43] These ECUs use chips to analyze sensor data, adjust the fuel injection and ignition timing, and control the emissions.[44] ECUs are required to enhance fuel efficiency and to reduce the environmental impact.[45] The connectivity features: The touch screen in a car is a computer that requires many semiconductor chips to function.[46] The era of electric vehicles has just begun. The net-zero goal boosted the production of EVs. The EVs require a lot of chips to function correctly. The semiconductor chips in EVs assist in controlling the battery and powertrain. The different vehicle modes are controlled by the computers inside, which are made using semiconductors.

The modern vehicles are equipped with different types of safety features. Different nations mandate different standards of safety features in cars for the manufacturers to sell them in that nation. Advanced Driver Assistance system is a term for various driver assistance systems. Forward Collision Warning, forward collision avoidance assist, Lane Departure Warning, and Lane Keeping Assist are some of the ADAS used in modern vehicles.[47] Image sensors that are capable of converting light into electrical signals use semiconductor technologies to guarantee safety. The Airbag deployment systems, Antilock Braking System, and Stability Control system also use semiconductor technologies.[48]

From the above, it is understandable that semiconductors are crucial in the automotive industry. As the manufacture of vehicles increased, the need for semiconductor chips also increased to incorporate various features in their cars by the manufacturers to meet the requirements of the standards of the different nations. Therefore, this high demand for chips in the automotive industry led to the current chip crisis.

Trade barriers between the US and China and the geopolitical tensions: The trade barriers between the US and China and the geopolitical tensions showed the industry's

[43] How Many Semiconductors Are in a Car? [Infographic] | Polar Polar Semiconductor, LLC, https://polarsemi.com/blog/blog-semiconductor-chips-in-a-car/ (last visited Jun 13, 2024)
[44] *Id*
[45] *Id*
[46] What Do Semiconductor Chips Do in Cars? MotorBiscuit, https://www.motorbiscuit.com/what-do-semiconductor-chips-do-in-cars/ (last visited Jun 13, 2024)
[47] *Id*
[48] *Id*

globalized supply chains' complexity, resulting in production delays and shortages.[49] For many years, the United States has had a bipartisan consensus that China is a strategic rival.

Through the Federal Acquisition Regulatory Council (FAR Council), the US government has implemented prohibitions on procuring semiconductor products and services from certain Chinese companies. This is outlined in Section 5949 of the National Defense Authorization Act for Fiscal Year 2023 (NDAA FY23). The prohibitions cover the procurement of electronic products or services that include covered semiconductor products or services and the procurement of electronic products that use covered semiconductor products or services when used in critical systems.[50] The Bureau of Industry and Security (BIS) has imposed export restrictions on products, materials, equipment, technology, and software that could advance China's semiconductor capabilities. These restrictions aim to delay or limit the development of advanced semiconductors in China.[51]

The U.S.'s determination to increase the local manufacturing of semiconductors and to deny China advanced semiconductor chips to avoid their use for military purposes and China's desire to be the leader in the semiconductor technology and trade disrupted the global semiconductor supply chains.

Texas Winter Storm: Texas is the center of semiconductor manufacturing in the US. Major chip makers like Samsung and NXP have manufacturing plants in Texas. The extreme winter storm that happened in February 2021 in Texas had a significant impact on chip manufacturing facilities.[52] The chip factories must run 24 hours a day to be economically viable.[53] However, the extreme storm caused power outages across the

[49] Semiconductor: The new driver of geopolitical balance KPMG, https://kpmg.com/in/en/blogs/home/posts/2024/01/semiconductor-new-driver-of-geopolitical-balance.html (last visited Jun 13, 2024)
[50] US Government Continues Coordinated Efforts to Place Restrictions on Chinese Semiconductors Lexology, https://www.lexology.com/library/detail.aspx?g=5f4d81d0-12cc-4813-883b-83cac3bb36c1 (last visited Jun 13, 2024)
[51] *Id*
[52] Historic Winter Storm Shuts Texan Chip Factories, Worsening Global Chip Shortage - Lowyat.NET, https://www.lowyat.net/2021/233012/historic-winter-storm-shuts-texan-chip-factories-worsening-global-chip-shortage/ (last visited Jun 13, 2024)
[53] *Id*

state, a headache for semiconductor manufacturers. Even though the storm and power outrage had only a tiny effect on the chip crisis, this event highlighted the vulnerability of global semiconductor supply chains to unfortunate disruptions.

Russia v Ukraine: Russia and Ukraine are significant producers of materials used in semiconductor manufacturing. These materials are Neon, Palladium, Nickel, Gold, Silver, etc. Neon is used in the deep ultraviolet Lithography process. Ukraine produces about 70-80 percent of the global supply of neon. Palladium plays a critical role in semiconductor production, particularly in plating applications, and is indispensable for catalytic converters in automotive applications. Other materials, such as Nickel, Gold, Silver, etc., are also crucial in semiconductor manufacturing.[54] The short-term crisis is manageable. The Russian invasion of Crimea caused shortages that lasted 18 to 24 months, but many companies have used risk mitigation plans to overcome the shortage.[55] However, the mitigation plan can only prevent production disruption for two to three months. But the long term can be more serious. The semiconductor supply chain is highly interconnected, and depending on the events, there may be severe consequences with production, an increase in price, and decreased output, revenues, and profits.[56]

The Global Chip Crisis, due to a confluence of factors like the COVID-19 pandemic, trade disputes, and unexpected surges in demand, has rippled through various industries and caused worldwide disruptions. The current semiconductor shortage has affected the production of electronic goods and broader sectors such as automotive manufacturing and consumer appliances. This led to significant economic disruptions.

Production Slowdowns and Shortages: The most immediate effect of the chip shortage has been widespread production slowdowns in industries heavily reliant on semiconductors. The automotive sector has been particularly hard-hit, with major manufacturers like Ford and General Motors forced to idle production lines and extend

[54] Lincoln Clark & Scott Jones, *Russia-Ukraine war: Impact on the semiconductor industry*,
[55] *Id*
[56] *Id*

wait times for new vehicles.[57] This lack of availability has resulted in higher car prices for consumers. The shortage has also impacted the production of consumer electronics. Laptops, smartphones, and even gaming consoles have become more difficult to find, and those available often come with inflated price tags.[58] This has significantly impacted individuals and businesses as reliance on technology grows.

The global electronic components shortage has caused significant delays and disruptions across various industries. Analogue's Pocket, a highly anticipated gadget, is the latest victim of these delays.[59] The shortage has also impacted significant tech companies, with reports indicating that the production of iPads and MacBooks has been affected. Additionally, the street prices of Nvidia and AMD GPUs have skyrocketed, reflecting the severe supply constraints.[60] The automotive industry is not immune either; some new GM trucks are expected to pollute more due to the lack of microchips required for emission control systems.[61] Furthermore, the rollout of Gogo's 5G network has stalled, demonstrating the widespread impact of the chip shortage on technological advancements and product launches.[62]

Disruptions in Global Supply Chains: The chip shortage has exposed vulnerabilities within global supply chains, previously optimized for efficiency and cost-effectiveness. The over-reliance on a limited number of chip manufacturers, particularly those concentrated in Asia, has proven problematic.[63] This realization has spurred

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[57] A GLOBAL CHIP SHORTAGE IS HITTING CARMAKERS AT THE WORST POSSIBLE TIME | CNN BUSINESS CNN, https://www.cnn.com/2021/01/13/business/global-chip-shortages-carmakers/index.html (last visited Jun 15, 2024)

[58] THE LATEST IN THE GLOBAL SEMICONDUCTOR SHORTAGE THE VERGE, https://www.theverge.com/2021/4/2/22363232/global-semiconductor-chip-shortage-pandemic-consoles-cpus-graphics-cards-cars (last visited Jun 15, 2024)

[59] ANALOGUE'S POCKET IS THE LATEST GADGET DELAYED DUE TO THE ONGOING GLOBAL ELECTRONIC COMPONENTS SHORTAGE THE VERGE, https://www.theverge.com/2021/3/31/22361017/analogue-pocket-handheld-delayed-electronic-component-shortage (last visited Jun 15, 2024)

[60] THE STREET PRICES OF NVIDIA AND AMD GPUS ARE UTTERLY OUT OF CONTROL - THE VERGE, https://www.theverge.com/2021/3/23/22345891/nvidia-amd-rtx-gpus-price-scalpers-ebay-graphics-cards (last visited Jun 15, 2024)

[61] SOME NEW GM TRUCKS WILL POLLUTE MORE THANKS TO MICROCHIP SHORTAGE THE VERGE, https://www.theverge.com/2021/3/15/22331766/gm-pickups-semiconductor-shortage-fuel-economy-emissions (last visited Jun 15, 2024)

[62] GOGO'S 5G NETWORK LAUNCH HAS STALLED DUE TO THE CHIP SHORTAGE - THE VERGE, https://www.theverge.com/2021/3/11/22325999/gogo-5g-network-delay-chip-shortage (last visited Jun 15, 2024)

[63] WHEN THE MICROCHIPS ARE DOWN | COUNCIL ON FOREIGN RELATIONS, https://www.cfr.org/podcasts/when-microchips-are-down (last visited Jun 15, 2024)

manufacturers to explore diversification of their supply chains, seeking alternative sources for critical chips.

Impact on Innovation: The limited availability of chips has also had a chilling effect on technological innovation. Companies developing new products across various sectors, from healthcare and AI to renewable energy and autonomous vehicles, are facing delays in bringing them to market due to chip shortages. This can stifle economic growth and hinder progress in critical areas. For instance, the development of new medical devices and diagnostics equipment that rely on advanced chips might be stalled, potentially impacting patient care, and similarly, advancements in AI, a field with vast potential for improving efficiency and automation across industries, could be slowed by chip limitations. The chip shortage is essentially putting a brake on technological progress, with the potential to delay breakthroughs that could improve our lives in countless ways.

Labor Market: The global chip shortage has had a complex and uneven impact on the labor market. While some chip manufacturers have seen increased profits due to high demand, other industries facing production slowdowns have been forced to implement temporary layoffs or furloughs, leaving workers in limbo and causing uncertainty about their job security. The current chip shortage has also highlighted the importance of a skilled workforce in the semiconductor industry. The complex design and manufacturing processes require a highly trained workforce, and the shortage has exacerbated existing talent gaps. This has increased competition for skilled workers in the chip industry, driving wages and potentially leading to poaching between companies. In the long term, the chip shortage could spur investment in workforce development programs to close the skills gap and ensure a more robust talent pipeline for the semiconductor industry.

Impact on Trade Regulations and Policies: The U.S. has taken steps to address the semiconductor shortage through legislative measures such as the CHIPS Act enacted in 2022. This act aims to bolster domestic semiconductor manufacturing and reduce dependency on foreign suppliers. Additionally, the Semiconductor Technology Pilot Program has been introduced to expedite the examination of patent applications related to semiconductor manufacturing.

Beyond the Immediate: Long-Term Repercussions of the Chip Crisis

The global chip crisis has far-reaching implications that extend beyond the current shortage and are expected to significantly influence the technological landscape for years to come. Some additional noteworthy effects are:

Increased Investment in Chip Production: Governments and companies worldwide invest heavily in building new chip manufacturing facilities and bolstering domestic production capabilities. This shift could potentially reshape the global chip market landscape. Previously, chip production was concentrated in a few countries, particularly Asia. The chip shortage has highlighted the risks associated with this over-reliance and spurred efforts to diversify production geographically. This could lead to a more geographically balanced chip industry, with new chip fabs built in regions like North America and Europe.

Focus on Self-Reliance: The chip shortage has prompted many countries to prioritize self-reliance in chip production, potentially leading to a less centralized and more geographically diverse supply chain. This could have geopolitical implications as nations strive to secure their technological independence. For instance, the United States has taken steps to bolster its domestic chip manufacturing capabilities to reduce its reliance on foreign suppliers. This trend towards self-reliance could lead to increased competition between countries in the chip industry, with potential implications for international relations.

Geopolitical Tensions: The importance of chip production has been underscored by the current shortage, potentially becoming a point of contention between countries vying for technological dominance. This could further complicate international relations. Semiconductor chips are essential in various technologies, from consumer electronics to military equipment. The control of chip production gives a country a significant advantage in technological innovation and economic power. As the global chip shortage continues, tensions between countries competing for dominance in the chip industry could escalate, potentially leading to trade or geopolitical conflicts.

3.3 PROTECTIONISM AND TRADE BARRIERS IN THE GLOBAL CHIP CRISIS

The global chip crisis is a complex web of factors triggered by the COVID-19 pandemic and other events worldwide. It has exposed vulnerabilities in the globalized semiconductor industry and its trade. In response, some countries embrace protectionist policies to bolster domestic chip production. Many nations used the protectionist strategy in various cases. Protectionism is an economic policy restricting imports from other nations through tariffs on imported goods, import quotas, and other regulations. The main objective of such economic policy is to protect domestic goods, services, and industries from foreign competition. Sometimes, it also helps preserve jobs and maintain financial stability within that nation. While it helps in short-term benefits, such as the growth of local businesses by supporting them and reducing trade deficits, it may have adverse effects in the long term. It may lead to trade wars and increased consumer costs in the long run.

The 'America First' policy of the Trump administration marked a significant shift in U.S. trade and economic strategy. It was predicated on the belief that reindustrializing the nation and prioritizing American interests would lead to greater economic prosperity and security. The policy led to the U.S. withdrawing from international agreements like the Trans-Pacific Partnership, renegotiating existing trade deals like NAFTA, and imposing tariffs to protect domestic industries. Protectionism can offer tangible benefits, particularly in strategic sectors such as semiconductor manufacturing. By implementing protective measures, nations can bolster national security, ensuring self-reliance in producing critical components like semiconductor chips, which are vital for defense and communication systems.[64] This reduction in dependency on foreign suppliers serves as a safeguard against geopolitical risks. Additionally, protectionist policies such as subsidies and import tariffs can stimulate domestic production, leading to job creation within the semiconductor industry.[65] This can be a significant advantage for countries grappling with economic downturns and seeking to reduce unemployment.

[64] *Id*
[65] *Id*

The Trump administration of the U.S. adopted a protectionist approach to trade, viewing it as a zero-sum competition over jobs. This led to tariffs on Chinese imports, including semiconductors, to prevent the export of U.S.-made and designed semiconductors to China. The primary goal was to bring manufacturing jobs back to the United States. The Biden administration has primarily maintained these tariffs, continuing protectionist policies that influence U.S. trade decisions. This persistent stance underscores the importance of protecting domestic semiconductor manufacturing and technology industries. These measures taken by the U.S. have affected the global supply chain of semiconductors, as many components and raw materials are sourced internationally. The U.S. has implemented stringent export controls on semiconductor technology to prevent foreign adversaries from using advanced technologies. This has impacted international collaborations and the global semiconductor market. To reduce dependency on foreign semiconductor manufacturing, the U.S. has introduced incentives for domestic production. This includes subsidies and tax breaks for companies that manufacture semiconductors within the United States.

In a display of protectionist measures, the Netherlands and Japan imposed controls on the export of advanced chip-making machines. In response, China placed export restrictions in early July 2023 on gallium and germanium, two critical metals used in chipmaking and communication equipment. These metals are essential for producing chips, fiber-optic cables, other telecom products, and electric vehicles. Additionally, they play significant roles in the defense and renewable energy industries, including solar cells and LEDs. As the leading producer of both metals, China accounts for about two-thirds of the world’s germanium production and approximately 80% of global gallium production. The leading importers of these metals include Japan, South Korea, India, and Taiwan. In early August 2023, India implemented another set of surprise restrictions on the technology sector, immediately placing controls on the import of laptops and tablets. This move is part of the "Make in India" initiative, promoting domestic hardware manufacturing. Companies need a "restricted imports" license to ship such devices to India. This measure could increase prices for these products in the country due to anticipated scarcity. The restriction primarily impacts companies that do

not assemble their devices in India, such as Apple and ASUS, thereby underscoring India's protectionist strategy to bolster its domestic manufacturing industry.[66]

3.4 ENERGY TRANSITION AND CHIP CRISIS

The urgent necessity to confront climate change is pushing for a shift from reliance on fossil fuels in the energy sector to prioritizing renewable energy sources. The energy sector stands as the most significant contributor to greenhouse gas emissions. (GHGs). Meeting the targets of the Paris Agreement necessitates a quick reduction of greenhouse gas emissions from the energy sector to reach the ultimate goal of complete elimination by mid-century. The Paris Agreement adopted in 2015 has laid down several goals to tackle climate change, limiting global warming by pursuing efforts to limit the temperature increase to 1.5 degrees Celsius.

Semiconductor Chips play a significant role in energy transition. It enables the development of intelligent and efficient technologies. Semiconductors are critical components in renewable energy systems like solar panels and wind turbines. The solar panel is a semiconductor that converts solar energy into electrical energy. The semiconductor chips help optimize energy capture and conversion. In EVs, the chips manage battery usage and improve the driving range. Chips also enable advanced features like autonomous driving and safety features like ADAS, ABS, and Infotainment systems. Modern vehicles have a ‘drive by wire’ system, which uses electrical signals to accelerate, brake, steer, etc., for which advanced chips are used.

As energy transition requires lots of semiconductors, its shortage will adversely affect the energy transition. The global chip crisis and the energy transition are interconnected in two main ways: chips are essential for renewable energy, and energy is needed to make chips. As already discussed, clean energy technologies like solar panels, wind turbines, EVs, etc., require lots of semiconductors for control and efficiency, and the shortage of semiconductors will slow down the production of these clean energy technologies and hinder the progress of the energy transition. The shortage will also

[66] *Id*

affect the feasibility of energy transition projects, and the high price will disincentivize the energy transition.

Moreover, chip manufacturing is an energy-intensive process requiring a lot of electricity, water, other raw materials, etc. The energy shortage and the price hikes will adversely affect chip production, worsening the chip crisis. Climate change and natural phenomena that affect the availability of water and raw materials will affect the manufacturing of new and advanced chips, directly affecting the energy transition and adding an extra challenge to the existing chip crisis.

The semiconductor shortage has significantly affected the UK's energy transition goals, particularly in achieving net zero. Achieving net zero carbon involves balancing the amount of greenhouse gas emissions produced by removing the same amount from the atmosphere, which is crucial for controlling climate change impacts and achieving sustainable environmental goals. Reaching net zero is essential to meeting the objectives laid down by the Paris Agreement to limit global warming by reducing emissions as much as possible through transitioning to renewable or green energy sources and also improving energy efficiency or implementing sustainable practices. The COVID-19 pandemic and its aftereffects in international trade, the limited supply, and the increased demand for semiconductors in various sectors adversely affected the production of essential technologies, such as smart meters, vital for energy efficiency and management.[67] The shortage is further compounded by geopolitical tensions and Russia's invasion of Ukraine, which disrupted neon supply from two major Ukrainian producers critical for semiconductor chip manufacturing.[68] These highlight the importance of semiconductors in energy transition and the UK's vulnerabilities in energy and technology supply chains, emphasizing the need for a strategic approach to securing semiconductor supply to ensure unbreakable energy transition and enhance energy security.

The UK government's net-zero strategies, aimed at decarbonizing the electricity system by 2035 and achieving net zero carbon emissions by 2050, heavily depend on modern

[67] SEMICONDUCTOR SUPPLY PUTS THE UK'S ENERGY TRANSITION AT RISK, https://rusi.orghttps://rusi.org (last visited Jun 16, 2024)
[68] *Id*

digital technologies that require a steady supply of semiconductors.[69] Semiconductors that conduct electricity under specific conditions have been essential for creating microchips for various instruments, machines, appliances, etc., since the mid-20th century.[70] Microchips are found in almost all electronic devices, including those vital for the net zero transition. Solar panels, wind turbines, smart meters, EVs, and advanced computer systems managing energy transmission and distribution require semiconductors.[71] Silicon is the primary component of many microchips; it is abundant on earth, but the production of microchips involves a complex, complicated, energy-consuming multi-step process encompassing design, manufacturing, fabrication, assembly, testing, and packaging.[72] The UK excels in semiconductor design, backed by substantial investments in research and development of new and alternative materials. However, its role in semiconductor fabrication is limited.[73] A massive amount of advanced semiconductor fabrication is conducted by the Taiwan Semiconductor Manufacturing Company, which is responsible for over half of the world's microchip production.

3.5 DIFFERENT NATIONS AND SEMICONDUCTOR SUPPLY CHAIN

The semiconductor supply chain comprises six key regions: the United States, South Korea, Japan, Mainland China, Taiwan, and Europe. According to recent data, each of these regions plays a significant role, contributing at least 8% or more to the overall value addition in the supply chain.

The United States is known for its leadership in semiconductor design and innovation, housing significant companies that develop cutting-edge technologies. South Korea excels in semiconductor manufacturing and memory chip production, with companies like Samsung and SK Hynix at the forefront. Japan contributes through its expertise in semiconductor materials and equipment, supplying essential components needed for

[69] *Id*
[70] *Id*
[71] *Id*
[72] *Id*
[73] *Id*

chip fabrication. Mainland China has rapidly expanded its semiconductor capabilities, investing heavily in manufacturing and aiming for greater self-sufficiency. Taiwan is a critical player, home to the Taiwan Semiconductor Manufacturing Company (TSMC), which accounts for a significant portion of global microchip production. Europe also plays a crucial role, with strengths in research and development, design, and specialized manufacturing.

The United States is home to the majority of semiconductor design firms, making it a central hub for innovation in the industry. In 2019, semiconductors emerged as the fifth largest export from the U.S., underscoring their economic importance. To capitalize on cost-effective skilled labor, numerous American design firms have recently expanded their reach by creating joint ventures or establishing wholly-owned subsidiaries in countries like India. This strategic move is significant because over 20% of the world's semiconductor design engineers are based in India.[74] This expansion into India not only leverages the available talent but also enhances the global footprint of U.S. firms, fostering international collaboration and growth in the semiconductor industry.

The majority of semiconductor manufacturing is concentrated in Taiwan at the Taiwan Semiconductor Manufacturing Company (TSMC). Additionally, South Korea hosts several highly efficient fabrication plants. Europe specializes in the semiconductor supply chain for automotive and industrial automation sectors. Japan excels in consumer electronics and plays a significant role in automotive and industrial automation. Similarly, South Korea has established a strong presence in manufacturing smartphones and consumer electronics.[75] This diverse specialization across different regions highlights the global nature of the semiconductor industry, with each area contributing unique strengths and expertise to the supply chain.

From this, it is evident that factors like pandemic-induced supply chain disruptions drive the current chip crisis, surging demand for semiconductors in various fields, and

[74] ANTONIO VARAS et al., STRENGTHENING THE GLOBAL SEMICONDUCTOR SUPPLY CHAIN IN AN UNCERTAIN ERA (2021), https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era/

[75] Nathan Associates Inc., BEYOND BORDERS THE GLOBAL SEMICONDUCTOR VALUE CHAIN (2016), https://www.semiconductors.org/wp-content/uploads/2018/06/SIA-Beyond-Borders-Report-FINAL-June-7.pdf.

geopolitical tensions. It had widespread effects across multiple industries. This shortage has led to delays in the supply of vehicles, gaming consoles, and healthcare technologies. It has implications for the global energy transition, where semiconductors are crucial for devices like smart meters and renewable energy technologies. The protectionist measures and trade barriers such as export controls and import restrictions imposed by significant semiconductor traders like the U.S. and China have further complicated the supply chain. Each region, be it Taiwan’s manufacturing dominance, the U.S. design expertise, or South Korea's efficiency in fabrication, plays a vital role in the semiconductor supply chain. Addressing the chip crisis requires a strategic approach to protect and bolster the semiconductor supply chain, ensuring stability and supporting the global transition towards sustainable energy solutions.

CHAPTER 4
INDIA'S ROLE IN SEMICONDUCTOR TRADE

4.1 INTRODUCTION

India's role in the semiconductor trade has gained significant importance within the context of international trade. After the COVID-19 pandemic, the world is going through a Global Chip Crisis. As the demand for semiconductors rises, India has emerged as a critical participant, especially in design and development. Today, over 20 percent of the world's semiconductor design engineers are located in India. Today, the country is trying to become an attractive destination for multinational semiconductor firms seeking to utilize cost-effective and skilled labor.

India's strategic initiatives include the "Make in India."[76] The campaign aims to enhance domestic manufacturing capabilities and reduce reliance on imports. Government policies and bilateral trade agreements are designed to foster an advantageous environment that promotes investment and stimulates innovation within the semiconductor industry. As international trade law continues to evolve to address the complexities of the global semiconductor supply chain, India's contribution and regulatory strategy will play a substantial role in influencing the future of this vital industry. India is actively trying to boost its semiconductor trade for several strategic and economic reasons. First and foremost, enchanting domestic semiconductor capabilities are crucial for achieving technological self-reliance. The global semiconductor shortage has underscored the vulnerabilities of relying on foreign suppliers, prompting India to invest in building its robust semiconductor ecosystem. Economically, the semiconductor industry represents a significant growth opportunity. By developing this sector, India will create high-skilled job opportunities for its citizens, attract foreign investment, and promote innovation across various industries, including automotive, telecommunications, and consumer electronics. The "Make in India" initiative seeks to establish India as a leading global manufacturing hub, and the semiconductor industry is a crucial component of this vision.

[76] MAKE IN INDIA, https://www.makeinindia.com/ (last visited Jun 17, 2024)

Like the world's superpower nations, national security is a big concern for India. India has geopolitical tensions with its neighboring nations. Therefore, national security is something that cannot be ignored. Therefore, from a national security perspective, having a strong domestic semiconductor industry is essential for maintaining control over critical technologies and reducing dependency on other nations. Additionally, the increasing integration of semiconductors in defense and cybersecurity systems makes it imperative for India to secure its supply chain.

Finally, boosting the semiconductor trade aligns with India's broader economic goals, such as improving trade balances, enhancing export capacities, and integrating more into the global supply chain. India can improve its position in the global economy and drive significant economic growth by becoming a major player.

4.2 INDIA'S SEMICONDUCTOR INDUSTRY

India's semiconductor industry presents a compelling growth narrative. Despite its current reliance on chip imports, the nation is poised for a strategic transformation. Driven by a rapidly expanding domestic electronics market and a government actively fostering domestic production through financial incentives, India is meticulously building a comprehensive semiconductor ecosystem. This ambitious undertaking is motivated by a two-pronged strategy: to lessen dependence on foreign chip suppliers and establish itself as a key player on the global chip design and manufacturing stage. The Indian semiconductor industry is still developing, particularly in its early stages. There is a significant demand for electronic communication devices such as smartphones in India, driven by an increasing population that has become more reliant on these devices, particularly during the COVID-19 pandemic. India‘s economy is projected to be the second-fastest-growing economy globally,[77] Which witnessed a growth rate of about 7% in 2019.[78] India boasts a significant talent pool with over 2.6 million STEM graduates. Additionally, the nation is undergoing substantial infrastructure development, evidenced by the expansion of international airports and

[77] Gayatri Nayak, *India to be the second fastest growing economy after China this year*, THE ECONOMIC TIMES, Jun. 29,2021,https://economictimes.indiatimes.com/news/economy/indicators/india-to-be-the-second-fastest-growing-economy-after-china-this-year/articleshow/83953637.cms (last visited Jun 17, 2024)
[78] EY, Tapping into the globally-competitive Indian manufacturing opportunity (2020)

well-maintained road networks, which bolsters domestic and global connectivity. Furthermore, India enjoys political stability and fosters positive trade relations with key partners such as Japan, South Korea, and the USA.[79] India's trade landscape is bolstered by a network of Comprehensive Economic Partnership Agreements and Free Trade Agreements with various countries. These agreements enable India to offer preferential trade terms to its partners, often including reduced or eliminated customs duties. This is particularly advantageous for the nation's burgeoning electronics industry, which is currently experiencing the fastest growth rate domestically. Furthermore, India boasts one of the world's highest consumption rates for electronic devices, witnessing a remarkable surge from USD 69.6 billion in 2012 to USD 400 billion in 2020. Notably, mobile phones reign supreme as the most popular electronic goods among Indian consumers.

India's second-largest import, following crude oil and preceding gold. India is the world's second-largest importer of semiconductor chips, with imports increasing by 92% in the last three years. In 2021, according to OEC, India imported $5.38 billion worth of semiconductor devices, ranking as the 7th largest importer globally. Most of these imports were from China, amounting to $4.2 billion. This large scale of imports indicates a heavy reliance on foreign semiconductor sources.[80] The substantial expenditure on semiconductor imports significantly impacts the Indian economy. To reduce these import expenses and boost GDP, the Indian government has invited major private sector participants, both domestic and international, to invest in semiconductor manufacturing within the country. India has implemented various government initiatives to attract foreign enterprises to establish manufacturing facilities. This is especially advantageous compared to countries like China, which currently faces political tensions with the USA, Japan, and other international entities.

The Indian government has initiated the India Semiconductor Mission (ISM) as a strategic initiative to cultivate a resilient semiconductor ecosystem. “India Semiconductor Mission (ISM) is a specialized and independent Business Division

[79] *Id*
[80] INDIA’S SEMICONDUCTOR MANUFACTURING AMBITION NEEDS A DECADAL PLAN, https://www.electronicsb2b.com/eb-specials/indias-semiconductor-manufacturing-ambition-needs-decadal-plan/ (last visited Jun 17, 2024)

within the Digital India Corporation that aims to build a vibrant semiconductor and display ecosystem to enable India's emergence as a global hub for electronics manufacturing and design."[81] It was launched on 15th December 2022. "This initiative, housed under the Digital India Corporation, is tasked with catalyzing India's semiconductor manufacturing, packaging, and design capabilities."[82] By forging strategic partnerships with industry leaders, academia, and research institutions, the initiatives aim to strengthen India's position in the global semiconductor industry. Through targeted investments in infrastructure, skill development, and research and development (R&D), the initiative aims to enhance India's competitiveness and attractiveness as a leading destination for semiconductor manufacturing and innovation. This proactive approach reflects the government's commitment to promoting technological self-sufficiency and fostering sustainable economic growth in the semiconductor sector. In December 2022, the initiative received substantial financial backing through a Rs. 76,000-crore incentive package. This funding was announced to incentivize the establishment of semiconductor and display fabrication plants in India.[83] This financial initiative aimed to attract major industry stakeholders and promote investments in India's semiconductor infrastructure. The Indian government has approved significant investments in semiconductor facilities, including Tata Electronics Private Limited's (TEPL) groundbreaking semiconductor fabrication plant in Gujarat, representing the country's first commercial semiconductor fabrication facility.[84] This project, valued at ₹91,000 crore, is part of a broader effort to enhance India's semiconductor manufacturing capabilities.[85] Additionally, TEPL is establishing an Outsourced Semiconductor Assembly and Test (OSAT) facility in Morigaon, Assam, with an investment of ₹27,000 crore to advance indigenous semiconductor packaging technologies.[86] Similarly, CG Power and Industrial Solutions Limited, in collaboration with Renesas Electronics Corporation from Japan and Stars

[81] HOME | INDIA SEMICONDUCTOR MISSION, https://www.ism.gov.in/ (last visited Jun 17, 2024)
[82] INDIA TO EMERGE AS A GLOBAL SEMICONDUCTOR HUB? KOTAK SECURITIES, https://www.kotaksecurities.com/articles/india-to-emerge-as-a-global-semiconductor-hub/ (last visited Jun 17, 2024)
[83] *Id*
[84] TATA ELECTRONICS BREAKS GROUND FOR RS 91,000 CRORE SEMICONDUCTOR PLANT IN GUJARAT BUSINESS TODAY, https://www.businesstoday.in/tech-today/news/story/tata-electronics-breaks-ground-for-rs-91000-crore-semiconductor-plant-in-gujarat-421357-2024-03-13 (last visited Jun 17, 2024)
[85] *Id*
[86] TATA TIES UP WITH TAIWAN'S PSMC TO SET UP SEMICONDUCTOR FAB, https://www.fortuneindia.com/enterprise/tata-ties-up-with-taiwans-psmc-to-set-up-semiconductor-fab/115977 (last visited Jun 17, 2024)

Microelectronics from Thailand, is setting up another semiconductor unit in Sanand, Gujarat, focusing on consumer, industrial, automotive, and power applications.[87]

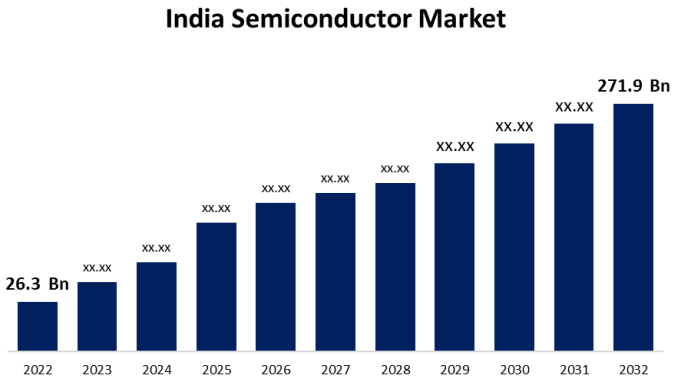
India prioritizes fortifying strategic partnerships, exemplified by its collaboration with the United States. This collaborative effort specifically targets the semiconductor industry, aiming to bolster domestic production and navigate the current supply chain challenges. The US-India Semiconductor Supply Chain and Innovation Partnership reflects a shared commitment to fostering a more resilient and diversified global semiconductor ecosystem. "On May 24, 2022, India and the United States announced the joint initiative on Critical and Emerging Technology (iCET), which committed the two countries to expand strategic technology partnerships and defense industrial cooperation between their nations' businesses, academic institutions, and government agencies. As part of the inaugural meeting of the iCET in January 2023, the Semiconductor Industry Association (SIA) in the United States and the India Electronics and Semiconductor Association (IESA) agreed to develop a "readiness assessment" to identify near-term industry opportunities to facilitate the longer-term strategic development of their complementary semiconductor ecosystems, and make recommendations to the U.S. Department of Commerce and the Government of India Semiconductor Mission (ISM)."[88] The U.S.-India Semiconductor Supply Chain and Innovation Partnership, established through a Memorandum of Understanding (MOU) in March 2023, is partially informed by an assessment conducted by the Information Technology and Innovation Foundation (ITIF). ITIF, a Washington, D.C.-based science and technology policy think tank, was commissioned by the Semiconductor Industry Association (SIA) and the Indian Electronics and Semiconductor Association (IESA) to undertake this crucial evaluation.[89] To gather comprehensive data, ITIF representatives conducted fact-finding visits to India in May and October of 2023. These visits included interviews with various stakeholders, encompassing government officials, industry leaders, associations, and research institutions. The findings from these interviews, along with other data, contributed to the assessment's conclusions. A

[87] *Id*
[88] STEPHEN EZELL, ASSESSING INDIA'S READINESS TO ASSUME A GREATER ROLE IN GLOBAL SEMICONDUCTOR VALUE CHAINS (2024), https://itif.org/publications/2024/02/14/india-semiconductor-readiness/ (last visited Jun 17, 2024)
[89] *Id*

preliminary report summarizing these findings was delivered to both the Indian and U.S. governments in June 2023.

The Indian semiconductor industry is anticipated to significantly enhance the global value chain, with projections estimating the market to reach USD 85 billion and create employment for approximately 600,000 people by 2030.[90] The anticipated growth is fueled by rising demand for semiconductors across diverse sectors such as consumer electronics, automotive, telecommunications, and healthcare. The industry's expansion is further supported by government initiatives aimed at reducing dependency on imports and encouraging domestic manufacturing.

FIGURE 4.1 INDIA SEMICONDUCTOR MARKET[91]



Despite ranking among the world's leading consumers of electronics, India relies heavily on imports to fulfill its semiconductor needs. This dependence stems primarily from the absence of a robust domestic fabrication ecosystem crucial for semiconductor production. Notably, a significant portion of India's established electronics industry focuses on software development and chip design, where it has emerged as a major player in VLSI technology and embedded software. Recognizing the strategic importance of electronics and semiconductors, the Indian government has actively implemented policies and incentive programs, including the Modified Special Incentive Package Scheme (M-SIPS) and the Electronics Development Fund (EDF), to stimulate domestic growth in these sectors.[92]

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[90] INDIAN SEMICONDUCTOR MARKET TO REACH US$ 55 BILLION BY 2026: DELOITTE INDBIZ | ECONOMIC DIPLOMACY DIVISION, https://indbiz.gov.in/indian-semiconductor-market-to-become-us-55-billion-by-2026-deloitte/ (last visited Jun 17, 2024)

[91] INDIA SEMICONDUCTOR MARKET SIZE, SHARE, FORECAST REPORT - 2032 SPHERICAL INSIGHTS, https://www.sphericalinsights.com/reports/semiconductor-market (last visited Jun 17, 2024)

[92] *Id*

4.3 INTERNATIONAL TRADE AGREEMENTS OF INDIA IN RELATION TO SEMICONDUCTOR TRADE

India is a major consumer of electronics with ambitions for domestic chip production. The nation is strategically reshaping its trade environment. International trade agreements and domestic regulations are crucial instruments in this endeavor. These policies pursue a dual objective to attract foreign investment and technology transfer for semiconductor fabrication, fostering a competitive domestic ecosystem that cultivates local chip design and manufacturing capabilities. These trade agreements and regulations are paramount for companies seeking to navigate and contribute to India's growing semiconductor industry.

ASEAN-India Free Trade Area (AIFTA): The ASEAN-India Free Trade Area (AIFTA) presents a strategic economic partnership for India's growing semiconductor industry. It was established in 2010, and AIFTA fosters enhanced trade and economic ties between India and the Association of Southeast Asian Nations (ASEAN). This agreement, encompassing trade in goods, services, and investment (through the AITIGA, AITISA, and AIIA, respectively), offers several advantages.[93] It facilitates duty reductions on chip imports from ASEAN nations, potentially lowering production costs for Indian chip manufacturers. Additionally, AIFTA could incentivize collaboration between Indian and ASEAN companies in chip design and fabrication, fostering a more robust regional ecosystem. In the context of the global semiconductor competition, particularly between the US and China, AIFTA positions India to leverage ASEAN's technological advancements and production capabilities, potentially accelerating its domestic chip development.

India-Japan Comprehensive Economic Partnership Agreement (CEPA): The India-Japan Comprehensive Economic Partnership Agreement (CEPA), signed in 2011, aimed to eliminate tariffs on most goods traded between the two nations. This

[93] AIFTA CAMBODIAN CORNER, https://cambodiancorner.com/ftas/cambodias-ftas/aifta/ (last visited Jun 17, 2024)

agreement has successfully boosted sectors like textiles, pharmaceuticals, and electronics by removing import duties on a wide range of products.[94]

Overall, trade between India and Japan has grown by 38% since CEPA's implementation, with projections that a total value of $24 billion will be achieved by March 2013. However, the benefits haven't been evenly distributed. Japan's exports to India have nearly doubled, while India's exports to Japan haven't shown significant growth.[95] India has called for a review of CEPA to address this imbalance, particularly the rules of origin (ROO) and product-specific rules (PSRs). These changes aim to improve India's market access in Japan and create a more balanced trading environment.[96] CEPA has facilitated increased trade, but India seeks adjustments to ensure both countries benefit equally.[97] While the India-Japan CEPA removes tariffs on a large number of products, it likely doesn't directly impact India's semiconductor trade. This agreement focuses more on sectors like textiles and pharmaceuticals. Additionally, India's current strategy emphasizes building its own domestic semiconductor industry rather than solely relying on imports or exports influenced by trade agreements. There could be some indirect benefits. Lower tariffs on electronics, in general, might make it slightly cheaper for Indian companies to import equipment or components needed for domestic semiconductor production.

Comprehensive Economic Partnership Agreement (CEPA) signed between India and South Korea: The CEPA signed between India and South Korea in 2009 functions as a free trade agreement, and this agreement aims to streamline foreign direct investment restrictions and grant the Indian service industry, encompassing IT and engineering, improved access to the South Korean market.[98] The terms were finalized in August 2009, and the CEPA came into effect in January 2010. The agreement

[94] India's International Free Trade Agreements - India Guide | Doing Business in India, https://www.india-briefing.com/doing-business-guide/india/why-india/india-s-international-free-trade-and-tax-agreements (last visited Jun 18, 2024)
[95] India-Japan FTA: Rules of origin, product specific rules to be reviewed BusinessLine, https://www.thehindubusinessline.com/economy/india-japan-fta-rules-of-origin-product-specific-rules-to-be-reviewed/article67569856.ece (last visited Jun 18, 2024)
[96] *Id*
[97].A Review Of India-Japan CEPA Agreement | Department of Chemicals and Petrochemicals, https://chemicals.gov.in/latest-news/review-india-japan-cepa-agreement (last visited Jun 18, 2024)
[98] INDIA-KOREA-CEPA-2009.PDF, https://commerce.gov.in/wp-content/uploads/2023/05/INDIA-KOREA-CEPA-2009.pdf (last visited Jun 23, 2024)

negotiations spanned for four years, commencing in February 2006. Both the South Korean and Indian parliaments approved the agreement within a week of each other in November 2009. The CEPA significantly reduces tariffs on nearly 90% of goods traded between the two nations, including electronics and semiconductors. This liberalization of trade resulted in a substantial rise in bilateral trade, with the total volume reaching $15.6 billion by 2008. The agreement also facilitates foreign direct investments by permitting companies to hold a majority stake (up to 65%) in subsidiaries within the other country. Additionally, the CEPA grants the Indian service sector, particularly IT and engineering, improved access to the South Korean market, encompassing a more comprehensive range of service offerings like finance and legal services. While the CEPA has demonstrably boosted trade, it has also led to an increased trade deficit for India, rising from $1.76 billion in 2007 to $14.57 billion in the 2023 fiscal year. India has initiated discussions on renegotiating the CEPA to address this imbalance and achieve greater fairness. These negotiations are ongoing and expected to conclude in 2024. In conclusion, the CEPA has played a crucial role in fostering trade and investment between India and South Korea, particularly emphasizing the Indian service sector. However, ongoing talks aim to address concerns regarding trade imbalances.

Comprehensive Economic Cooperation Agreement (CECA) between India and Singapore: The Comprehensive Economic Cooperation Agreement (CECA), signed in 2005, is a cornerstone for a dynamic and mutually beneficial economic partnership between India and Singapore. By eliminating tariffs and streamlining regulations, the CECA greases the wheels of trade, ensuring a smooth flow of goods across borders. This contributes to benefits for consumers, offering them greater access to a variety of products at competitive prices while also bolstering the economies of both countries through increased trade volumes. This free trade agreement streamlines trade by eliminating tariffs and simplifying regulations, allowing for the free flow of goods between the two nations. Furthermore, the CECA fosters a more attractive environment for cross-border investments and financial transactions by eliminating double taxation and duplicative processes. This has increased Singaporean investment in Indian infrastructure projects and information technology hubs. The agreement also encourages collaboration across various service sectors, including education, science and technology, intellectual property, aviation, information technology, and finance. Tourism has also seen a significant boost, with India becoming a major source of

visitors for Singapore, with over 650,000 Indian tourists in 2006 alone. The CECA undergoes periodic reviews to ensure it remains relevant. The most recent review in 2018 focused on enhancing trade facilitation, e-commerce, and customs procedures, with a third review launched in September 2018. However, the agreement has not been without controversy. Singapore has raised concerns regarding the movement of Indian professionals in specific sectors, fearing potential job competition. Despite these concerns, the CECA serves as a foundation for a robust economic relationship between India and Singapore, fostering collaboration across various sectors.

The India-Singapore Comprehensive Economic Cooperation Agreement (CECA) is a comprehensive free trade agreement designed to eliminate tariffs, avoid double taxation, and streamline processes to strengthen bilateral trade and investment relations between India and Singapore. However, it does not explicitly target the semiconductor industry. While the CECA has facilitated increased trade and investment overall between the two nations, it has not notably influenced India's semiconductor trade, which relies heavily on imports. India's semiconductor sector remains at an early stage of development, prompting the country to pursue additional free trade agreements with entities such as the US, EU, and Israel to attract technology and investments necessary for its growth. The CECA's periodic reviews have concentrated on trade facilitation, e-commerce, and customs issues rather than addressing the specific needs of the semiconductor industry. While the CECA supports broader trade liberalization objectives, it has not directly bolstered India's semiconductor capabilities, which require more focused policy interventions and international collaborations to advance domestic production capabilities.

South Asian Free Trade Area (SAFTA): Established in 2004 under the South Asian Association for Regional Cooperation (SAARC), The South Asian Free Trade Area (SAFTA) aims to enhance trade and economic cooperation among its eight member countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. SAFTA's primary objective is to phase out customs duties on all traded goods, including electronics and semiconductors, to reduce tariffs to zero by 2016. The agreement includes provisions for trade in goods, services, and investment, emphasizing tariff reduction and other trade barrier eliminations among member states. It offers special measures for the Least Developed Countries (LDCs) within the region,

such as Bangladesh, Bhutan, and Nepal, providing preferential treatment and extended timelines for tariff reductions. SAFTA's implementation involves various mechanisms such as the Trade Liberalization Programme, Rules of Origin, and Safeguard Measures. While intra-regional trade within SAFTA has shown growth, challenges remain in realizing its full potential, attributed to disparities in economic development and trade imbalances among member countries. Overall, SAFTA aims to enhance regional trade, promote economic cooperation, alleviate poverty, reduce inequality, and improve member countries' competitiveness in the global marketplace.

In conclusion, India's semiconductor trade is significantly influenced by a network of international trade agreements and regulations that aim to foster economic cooperation and reduce barriers across regions. The ASEAN-India Free Trade Area (AIFTA) has played a pivotal role by creating a vast market with liberalized tariffs, benefiting electronics and semiconductor sectors by facilitating smoother trade flows. The India-Japan Comprehensive Economic Partnership Agreement (CEPA) has likewise contributed by eliminating duties on a wide array of products, including electronics, thereby enhancing bilateral trade prospects. Additionally, the India-Republic of Korea Comprehensive Economic Partnership Agreement has eased investment restrictions and bolstered opportunities for Indian service industries in South Korea, particularly in IT and engineering. The India-Singapore Comprehensive Economic Partnership Agreement has streamlined trade processes and eliminated tariff barriers, fostering collaboration between the financial institutions of both nations. Furthermore, the South Asian Free Trade Area (SAFTA) has aimed ambitiously to reduce customs duties to zero on all traded goods, including electronics and semiconductors, among its member countries. These agreements collectively underscore India's commitment to integrating into global supply chains and leveraging international partnerships to bolster its semiconductor industry's growth and competitiveness in the worldwide market.

CHAPTER 5

ANALYSIS OF INDIAN POLICIES AND LEGISLATIONS AS EFFECTING INDIA'S PROSPECTS OF BECOMING GLOBAL SEMICONDUCTOR HUB

5.1 INTRODUCTION

The global semiconductor market is witnessing exponential growth, driven by advancements in AI, 5G technology, and the Internet of Things (IoT). In this dynamic landscape, India aspires to carve out a niche for itself as a dominant player in the global semiconductor industry. This ambition reflects India's recognition of the strategic importance of semiconductors and their centrality to the future of technology. A robust domestic semiconductor industry would empower India to meet its growing demand for chips and position it as a critical supplier in the international market. However, bridging the gap between India's aspiration and its realization necessitates a careful examination of the existing legislative and policy framework. This framework aids as the foundation upon which India's semiconductor industry can be built. A supportive legislative and policy environment can incentivize investments, foster innovation, and create a level playing field for domestic and international players. Conversely, an ineffective or restrictive framework can create bottlenecks that stifle progress. These bottlenecks can manifest in various ways, from hindering the ease of doing business to impeding the capacity to attract and hold top talent. A complex and maze-like regulatory environment can lengthen approval processes for setting up fabs. At the same time, a lack of clarity or consistency in policies can create uncertainty for investors. Additionally, an underdeveloped ecosystem of supporting industries can create logistical challenges and limit the domestic availability of critical raw materials and components. All of these factors can combine to slow down the growth of the Indian semiconductor industry and deter its capacity to strive on the global stage.

The global chip crisis, triggered by pandemic disruptions and surging demand for electronics, has underscored the strategic importance of semiconductors. These tiny

engineering marvels are the invisible backbone of modern technology, powering everything from smartphones and laptops to medical equipment and AI. Recognizing this geopolitical and economic imperative, India aspires to become an international hub for chip manufacturing. A robust domestic semiconductor industry would not only ensure India's self-sufficiency in meeting its ever-growing demand for chips but also empower it to participate in the global semiconductor supply chain, reducing its vulnerability to external shocks and potential geopolitical tensions. Furthermore, an established domestic industry would position India as a strategic partner to other countries seeking to diversify their chip sources and mitigate risks associated with overdependence on a restricted number of providers. This diversification is becoming increasingly crucial as geopolitical rivalries and trade wars threaten to disrupt the flow of critical technology. By developing a domestic semiconductor industry, India has the potential to not only secure its own technological future but also emerge as a significant player in the global semiconductor market, shaping the geopolitical landscape of this essential technology.

Its legislative framework and policy initiatives significantly influence India's determination to become a global semiconductor hub. The government's strategic policies aim to create a conducive environment for semiconductor manufacturing, attract foreign investments, and enhance domestic capabilities. Key legislation and policies, such as the Production Linked Incentive (PLI) Scheme and establishing the India Semiconductor Mission (ISM), are designed to support the semiconductor ecosystem through financial incentives, infrastructure development, and R&D investments. This chapter delves into a critical analysis of how these regulations and policy instruments shape India's prospects of becoming a global semiconductor hub.

5.2 NATIONAL POLICY ON ELECTRONICS 2019

The Government of India's National Policy on Electronics 2019 (NPE 2019) outlines a comprehensive strategy for the nation's electronics sector. This policy comes at a time when the global semiconductor market is experiencing explosive growth driven by progressions in AI, 5G technology, and the Internet of Things (IoT). Recognizing the strategic importance of semiconductors, India desires a prominent role in the global

trade of these essential components. The NPE 2019 serves as a roadmap to achieve this goal. It outlines a series of strategic initiatives designed to cultivate domestic capabilities in semiconductor design and manufacturing, attract investments, and establish a supportive environment for the industry as a whole. By analyzing the NPE 2019's provisions concerning the semiconductor trade, we can evaluate its effectiveness in propelling India's ambitions within this critical sector.

"The Policy envisions positioning India as a global hub for Electronics System Design and Manufacturing - (ESDM) by encouraging and driving capabilities in the country for developing core components, including chipsets, and creating an enabling environment for the industry to compete globally."[99]

The National Policy on Electronics (NPE) 2019 intends to establish a globally competitive ecosystem for India's ESDM sector. Key features of the policy include promoting domestic manufacturing and exports across the entire ESDM value chain and providing incentives and support for the production of core electronic components. It also offers special incentive packages for mega projects, including semiconductor facilities and display fabrication, that are highly advanced and require significant investments. The policy is designed to encourage the establishment of new units and the expansion of existing ones through various schemes and incentive mechanisms.

Moreover, NPE 2019 emphasizes industry-led R&D and innovation across all electronic sub-sectors, fostering grassroots innovations and early-stage startups in emerging technology areas such as 5G, IoT/Sensors, AI, Machine Learning, Virtual Reality, Drones, Robotics, Additive Manufacturing, Photonics, and nano-based devices. The policy also aims to significantly enhance the availability of skilled workforce through targeted incentives and support, including re-skilling initiatives.

Additionally, NPE 2019 places particular emphasis on the fabless chip design industry, medical electronic devices industry, automotive electronics, and power electronics for mobility and strategic electronics. It proposes the creation of a Sovereign Patent Fund

[99] Cabinet approves the proposal of National Policy on Electronics 2019, https://pib.gov.in/pib.gov.in/Pressreleaseshare.aspx?PRID=1565285 (last visited Jun 18, 2024)

(SPF) to support the development and acquisition of intellectual properties in the ESDM sector. It promotes trusted electronics value chain initiatives to bolster national cybersecurity.

The implementation strategy for the National Policy on Electronics (NPE) 2019 involves developing various schemes, initiatives, projects, and measures aimed at enhancing the ESDM sector in India, following the roadmap laid out in the policy. The primary target is to boost domestic manufacturing and export across the entire ESDM value chain to drive economic growth, with a goal of reaching a turnover of USD 400 billion (approximately INR 26,00,000 crore) by 2025. This ambitious target includes the production of 1.0 billion (100 crore) mobile handsets valued at USD 190 billion (approximately INR 13,00,000 crore), with 600 million (60 crore) units valued at USD 110 billion (approximately INR 7,00,000 crore) designated for export.[100]

The implementation of the NPE 2019 will drive the creation of numerous schemes, initiatives, and projects, developed in collaboration with relevant Ministries and Departments, to bolster the ESDM sector in India. This policy will attract significant investment and technological advancements, enhancing the value addition of domestically manufactured electronic products. It aims to boost electronics hardware manufacturing within the country and increase exports while simultaneously creating substantial employment opportunities.[101]

The Ministry of Electronics and Information Technology (MeitY) has issued the National Policy on Electronics 2019 (NPE 2019), intending to position India as a global leader in ESDM. This policy aims to enhance domestic capabilities in developing essential components, including chipsets, and to foster an environment conducive to global competitiveness. To attract significant investments and promote exports in the electronics value chain, the following schemes have been introduced:[102]

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[100] *Id*
[101] *Id*
[102] Cabinet approves the proposal of National Policy on Electronics 2019, https://pib.gov.in/pib.gov.in/Pressreleaseshare.aspx?PRID=1565285 (last visited Jun 18, 2024)

On December 15, 2021, the Union Cabinet, presided over by Prime Minister Narendra Modi, agreed to a comprehensive program with an allocation of INR 76,000 crore (over USD 10 billion) to develop a sustainable semiconductor and display ecosystem in India. The schemes introduced under this program include:[103]

- Semiconductor & Display Fabs Scheme: This scheme offers fiscal support to establish semiconductor wafer fabrication facilities and display panels, aiming to attract significant investments and build a reliable value chain.[104]
- Compound Semiconductors / Silicon Photonics / Sensors Fab and ATMP / OSAT Facilities Scheme: This provides fiscal support of 30% of the capital expenditure for setting up facilities in these sectors.[105]
- Design Linked Incentive Scheme: This scheme provides monetary incentives and design infrastructure backing across various stages of semiconductor design development for Integrated Circuits (ICs), Chipsets, Systems on Chips (SoCs), Systems & IP Cores.[106]

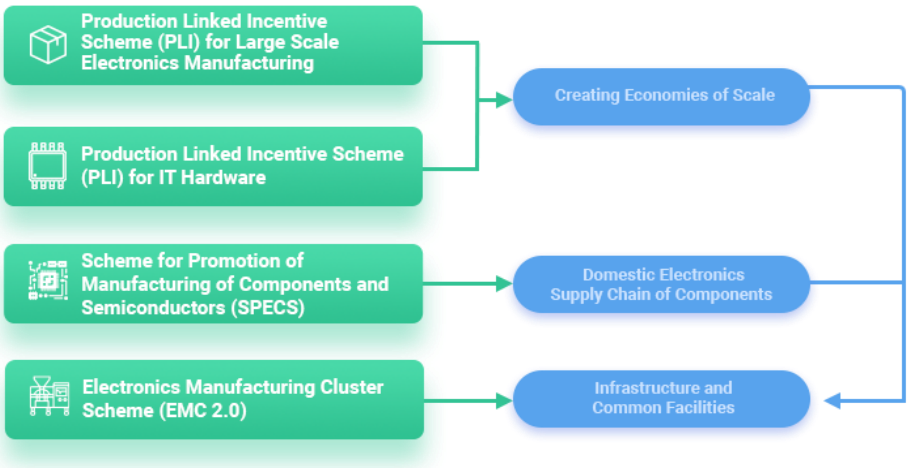
The establishment of the India Semiconductor Mission (ISM) as an Independent Business Division within the Digital India Corporation was also approved. ISM, envisioned to be led by global semiconductor and display industry experts, will operate with administrative and financial autonomy.[107] It will serve as the central agency to ensure effective and coordinated implementation of the semiconductor and display ecosystem schemes, working closely with government ministries, industry stakeholders, and academia.[108]

"To position India as a global hub for ESDM and push further the vision of the National Policy on Electronics (NPE) 2019, three schemes, namely the **Production Linked Incentive Scheme (PLI)**, **Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors** (SPECS) and Modified Electronics Manufacturing Clusters Scheme (EMC 2.0) were notified in April 2020. A fourth scheme, the

[103] *Id*
[104] *Id*
[105] *Id*
[106] *Id*
[107] *Id*
[108] *Id*

Production Linked Incentive Scheme (PLI) for IT Hardware, was notified in March 2021."[109]

FIGURE 5.1 SCHEMES FOR ELECTRONICS MANUFACTURING[110]



5.3 PRODUCTION LINKED INCENTIVE SCHEME (PLI) FOR LARGE-SCALE ELECTRONICS MANUFACTURING

The Production Linked Incentive (PLI) Scheme for Large Scale Electronics Manufacturing is designed to incentivize domestic production and attract substantial investments in the electronics sector, including mobile phones, electronic components, and ATMP (Assembly, Testing, Marking, and Packaging) units. Under this scheme, financial incentives totaling up to INR 40,951 crores will be distributed over a span of five years.[111] This initiative aims to bolster the electronics manufacturing ecosystem in India by providing significant financial support to encourage large-scale investments and enhance the domestic value chain.

The PLI Scheme for Large Scale Electronics Manufacturing aims to enhance India's electronics production capabilities significantly. Its primary goals include boosting domestic manufacturing to reduce reliance on imports, attracting substantial investments to the sector, and strengthening global competitiveness by offering financial incentives. Additionally, the scheme focuses on creating employment

[109] Incentive Schemes for Electronics Manufacturing | Invest India, https://www.investindia.gov.in/schemes-for-electronics-manufacturing (last visited Jun 18, 2024)
[110] *Id*
[111] *Id*

opportunities and increasing the export of electronic products from India.[112] By targeting these objectives, the PLI Scheme seeks to build a robust electronics manufacturing ecosystem that can thrive domestically and internationally.

The PLI Scheme for Large Scale Electronics Manufacturing offers financial incentives ranging from 3% to 5% on incremental sales of goods mass-produced in India over the base year. It specifically targets segments of specified electronic components to encourage their domestic production.[113] To qualify for these incentives, entities must meet certain thresholds of incremental investment and sales of manufactured goods. The scheme is set to run for a tenure of four years, effective from April 1, 2021, aiming to bolster local manufacturing capabilities and support the growth of the electronics industry in India.[114]

TABLE 5.1 THE PLI SCHEME TARGET SEGMENTS[115]

S.No	Description of Goods
1	Specified Electronic Components
1.1	SMT components
1.2	Discrete semiconductor devices including transistors, diodes, thyristors, etc.
1.3	Passive components including resistors, capacitors, etc. for electronic applications
1.4	Printed Circuit Boards (PCB), PCB laminates, prepregs, photopolymer films, PCB printing inks
1.5	Sensors, transducers, actuators, crystals for electronic applications
1.6	System in Package (SIP)
1.7	Micro / Nano-electronic components such as Micro Electromechanical Systems (MEMS) and Nano Electromechanical Systems (NEMS)
1.8	Assembly, Testing, Marking and Packaging (ATMP) units

The PLI Scheme targets specific segments within the electronics manufacturing industry. These segments include specified electronic components such as Surface Mount Technology (SMT) components and discrete semiconductor devices, including

[112] What is Production linked Incentive (PLI) Scheme? TaxGuru, https://taxguru.in/finance/production-linked-incentive-pli-scheme.html (last visited Jun 18, 2024)
[113] *Supra* note 111
[114] *Id*
[115] Production Linked Incentive Scheme, https://pli.ifciltd.com/ (last visited Jun 19, 2024)

transistors, diodes, and thyristors.[116] It also covers passive components like resistors and capacitors used in electronic applications. Other targeted segments are Printed Circuit Boards (PCB), PCB laminates, prepregs, photopolymer films, and PCB printing inks. Additionally, the scheme includes sensors, transducers, actuators, crystals for electronic applications, System in Package (SIP) technologies, micro/nano-electronic components such as Micro Electromechanical Systems (MEMS) and Nano Electromechanical Systems (NEMS), and Assembly, Testing, Marking, and Packaging (ATMP) units. This comprehensive coverage aims to bolster the domestic production capabilities of these essential components.[117]

The PLI Scheme is anticipated to transform India's semiconductor trade by increasing domestic manufacturing and drawing significant investments into the electronics sector. By providing financial incentives for incremental sales and investment, the scheme will encourage the production of essential electronic components, such as semiconductors, within the country. This initiative aims to decrease dependence on imports, enhance India's role in the global value chain, and create a competitive manufacturing environment. Additionally, the PLI scheme is expected to generate numerous employment opportunities, contributing to the nation's economic growth and development. With targeted support for segments like SMT components, discrete semiconductors, and PCBs, the scheme will drive technological advancements and innovation within India's semiconductor industry. Ultimately, this initiative is projected to boost exports, improve self-reliance in electronics manufacturing, and position India as a significant player in the global semiconductor market.

5.4 INDIA SEMICONDUCTOR MISSION

“India Semiconductor Mission (ISM) is a specialized and independent Business Division within the Digital India Corporation that aims to build a vibrant semiconductor and display ecosystem to enable India’s emergence as a global hub for electronics manufacturing and design.”[118]

[116] Supra note 114
[117] *Id*
[118] *Supra* note 81

The Vision: "The vision of ISM is to build a vibrant semiconductor and display design and innovation ecosystem to enable India's emergence as a global hub for electronics manufacturing and design in a more structured, focused, and comprehensive manner through various mechanisms."[119]

Objectives: The India Semiconductor Mission (ISM) is a strategic initiative to propel India on the global stage as a significant semiconductor and display industry player. Established in 2021, the ISM has charted a course with five distinct objectives, each designed to cultivate a robust domestic ecosystem for these critical technologies. The five objectives of ISM focusing on are Strategy, Supply Chain, Design & Startup, Intellectual Property, and Partnership.[120]

1. Strategic Planning: The foundation of the ISM's strategy lies in collaborative planning. Working alongside government ministries, industry leaders, and academic institutions, the mission prioritizes formulating a comprehensive long-term strategy. This strategy goes beyond just establishing semiconductor and display manufacturing facilities. It envisions a thriving domestic ecosystem for semiconductor design, emphasizing a comprehensive approach that encompasses every facet of the industry, from raw materials to the end products.

2. Supply Chain Security: Establishing a secure and dependable supply chain for semiconductors and displays is crucial for the ISM. This objective focuses on facilitating the adoption of "trusted electronics." This translates to ensuring a steady and reliable supply of essential elements like raw materials, specialty chemicals, and gases alongside the advanced manufacturing equipment required for domestic production. By mitigating dependence on external sources, the ISM aims to build resilience within the Indian electronics sector, safeguarding it from potential disruptions in the global supply chain.

3. Design and Startup Assistance: Recognizing the immense potential of the Indian semiconductor design industry, the ISM prioritizes empowering domestic design

[119] *Id*
[120] *Id*

companies, particularly early-stage startups. The mission provides crucial support mechanisms to nurture this potential. This includes access to Electronic Design Automation (EDA) tools, which are the software foundation for chip design. Additionally, the ISM facilitates access to foundry services and the physical manufacturing capabilities that bring these designs to life. The mission explores further avenues to support startups, nurturing an environment that encourages innovation and entrepreneurial spirit within the Indian semiconductor design landscape.

4. Intellectual Property (IP) Development:

The ISM acknowledges genuine self-reliance in the semiconductor industry hinges on a robust domestic intellectual property (IP) ecosystem. To cultivate this environment, the mission actively promotes the generation of indigenous IP within the domestic semiconductor industry. This not only incentivizes innovation but also empowers Indian companies to compete on the global stage with their own unique technologies. Furthermore, the ISM fosters a culture of innovation by providing incentives and support programs that encourage the transfer of technologies (ToT) from international partners. By facilitating the acquisition of cutting-edge knowledge and expertise, the mission aims to accelerate India's technological advancement in the semiconductor sector.

5. Collaboration and Partnership:

The final objective underscores the importance of collaboration across various stakeholders. The ISM actively works to establish and facilitate partnerships between national and international agencies, industries, and academic institutions. These partnerships serve a multifaceted purpose. They can catalyze collaborative research efforts, leading to groundbreaking advancements in the field. Additionally, partnerships can accelerate the commercialization of innovations, ensuring promising ideas translate into tangible products and services that benefit the Indian economy. Finally, collaboration fosters skill development programs, equipping India's workforce with the expertise necessary to compete in the ever-evolving semiconductor industry.

By pursuing these five objectives, the ISM lays the groundwork for India's transformation into a global leader in the semiconductor and display industry. This

transformation promises to empower India's technological capabilities, contribute significantly to its economic growth, and solidify its self-reliance in the years to come.

5.5 SCHEME FOR PROMOTION OF MANUFACTURING OF ELECTRONIC COMPONENTS AND SEMICONDUCTORS (SPECS)

"Government of India's goal is to make India a significant design and manufacturing hub in the Global Value Chain for Electronics as part of its Atmanirbhar Bharat Economic policies. To establish India as a global leader in electronics manufacturing, the Government of India has launched many flagship schemes that are aimed at "Atmanirbhar Bharat – A self-reliant India" under the aegis of National Policy on Electronics 2019 (NPE 2019). The Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) is a step in this direction."[121]

The Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) is an initiative by the Ministry of Electronics and Information Technology (MeitY) aimed at enhancing India's electronic components and semiconductor manufacturing capabilities. SPECS provides financial incentives to promote domestic production and attract significant investments in this sector.[122] The scheme targets the manufacturing of essential electronic components and semiconductors to reduce reliance on imports and improve India's competitive edge in the global electronics market.[123] By encouraging local manufacturing and technological advancements, SPECS aspires to strengthen India's position in the electronics industry, contributing to economic growth and technological self-sufficiency.

The Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) aims to enhance domestic production and attract significant investments in the electronics value chain, mainly focusing on electronic components and semiconductors.[124] SPECS offers financial incentives to support the establishment

[121] Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1812283 (last visited Jun 19, 2024)
[122] *Id*
[123] *Id*
[124] *Supra* note 117

of new units and the expansion, modernization, or diversification of existing units.[125] The target segments include electronic components, semiconductors, specialized sub-assemblies, and the necessary capital goods for manufacturing these items.[126] The scheme was initially open for applications for three years from its notification date, April 1, 2020. Applications are appraised continuously, and implementation proceeds according to the approved plans. SPECS is open for applications for three years. Investments made within five years from the date of acknowledgment will qualify for receiving the incentive.[127] This framework ensures that new and expanding manufacturing units can benefit from the financial support offered under the scheme, provided they meet the specified investment timelines. This approach aims to encourage long-term planning and sustained investment in the Indian electronics and semiconductor manufacturing sector.

Launched in 2020, the SPECS scheme was designed to last three years and extended until March 31, 2024. It offered a 25% financial incentive on capital expenditure for the manufacturing of various goods, such as discrete semiconductor devices (including transistors and diodes), USB/data cables, HDMI cables, sensors, transducers, actuators, crystals for electronic applications, and printed circuit boards (PCBs).[128] The government received applications from 42 companies under SPECS, proposing investments totaling Rs 11,690 crore. The government's committed incentive amounts to Rs 1,612 crore, and as of the end of February, Rs 378.37 crore had been disbursed to applicants.[129]

This initiative aimed to catalyze significant investments and promote the growth of the electronics manufacturing sector in India, enhancing the country's global competitiveness in the semiconductor and electronic components industry.

The government is set to introduce a new production-linked incentive (PLI) scheme for component manufacturing after the upcoming elections. This new scheme will follow the model of existing PLI schemes, where incentives are tied to achieving specified

[125] *Id*
[126] SPECS Portal, https://specs.ifciltd.com/ (last visited Jun 19, 2024)
[127] *Id*
[128] Curtains for Rs 3,300-crore SPECS scheme; new PLI after polls Financialexpress, https://www.financialexpress.com/business/industry-curtains-for-rs-3300-crore-specs-scheme-new-pli-after-polls-3442375/ (last visited Jun 19, 2024)
[129] *Id*

incremental production and sales targets. The primary focus of the new scheme will be to enhance domestic value addition in the electronics sector as exports increase. This initiative aims to further boost the local manufacturing ecosystem and reduce import dependency by encouraging significant investments in producing critical electronic components.

5.6 THE CHIPS TO STARTUP (C2S) PROGRAMME

"Chips to Startup (C2S) Programme aims to train 85,000 Specialized Manpower over a period of 5 years in the area of VLSI and Embedded System Design and leapfrog in ESDM space by way of inculcating the culture of System-on-Chip (SoC)/ System Level Design at Bachelors, Masters and Research level and act as a catalyst for growth of Start-ups involved in fabless design."[130]

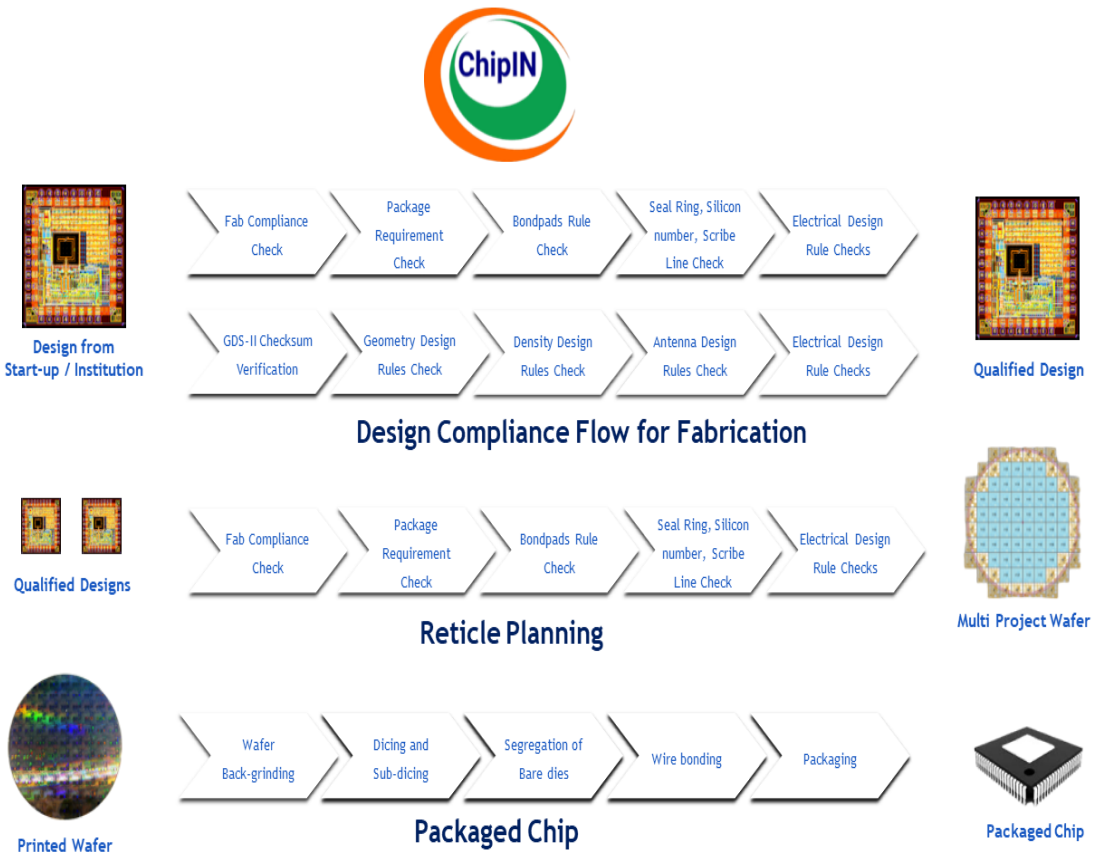
The Chips to Startup (C2S) Programme is an innovative initiative launched by the Indian government, aiming to enhance the country's semiconductor design and manufacturing capabilities. The programme targets the creation of 85,000 skilled engineers through comprehensive training in semiconductor technologies. By promoting start-ups and encouraging collaborations between academia and industry, C2S seeks to build a strong foundation for semiconductor research and development. This initiative aspires to position India as a competitive player in the global semiconductor value chain, meeting the growing technological demands and fostering an environment conducive to innovation and growth in the electronics sector.

The Chips to Startup (C2S) Programme aims to create a robust ecosystem for semiconductor design in India. Key objectives include generating industry-ready professionals in the System/SoC design sector to support a dynamic fabless chip design environment. The initiative promotes industry-led research and development, encourages translational research, and strengthens collaborations between industry and academia.[131] It also focuses on developing reusable IP cores and designing ASIC/SoC systems for societal and strategic applications. Additionally, the programme seeks to

[130] C2S, https://c2s.gov.in/index.jsp (last visited Jun 19, 2024)
[131] *Id*

expand the base of ASIC/IC design in the country by engaging more academic institutions and start-ups in IP/ASIC/SoC design.[132] Protecting the intellectual property generated and fostering an entrepreneurial culture among students and researchers through incubating start-ups are also critical objectives of the C2S Programme.[133]

FIGURE 5.2 PROCESS FLOW - DESIGN COMPLIANCE FLOW & RETICLE PLANNING TO PACKAGED CHIP[134]



The Ministry of Electronics and Information Technology (MeitY) has established the ChipIN Centre at C-DAC Bangalore to support the semiconductor design community in India. "The Centre for Development of Advanced Computing (C-DAC) is an autonomous scientific society in India under the Ministry of Electronics and Information Technology. It was established in November 1988 as the Centre for Development of Advanced Computing Technology (C-DACT) when the US government refused to sell a Cray supercomputer to India 1988 over concerns that it

[132] *Id*
[133] *Id*
[134] C2S, https://c2s.gov.in/chipin.jsp (last visited Jun 19, 2024)

would be used to manufacture nuclear weapons. This led to India's decision to develop its own supercomputer, leading to the birth of C-DAC. In 2003, C-DAC merged with the National Centre for Software Technology, the Electronic Research and Development Centre, and CEDTI."[135]

This facility serves as a comprehensive resource for fabless chip designers from startups, MSMEs, and academia, offering access to semiconductor design tools, fabrication facilities, and virtual prototyping hardware labs. As a centralized cloud-supported design center, ChipIN hosts advanced Electronic Design Automation (EDA) tools for the entire chip design cycle and facilitates the fabrication of designs at both Indian and international foundries, such as SCL foundry.[136]

ChipIN Centre aims to stimulate the chip design ecosystem in India by providing Multi-Project Wafer (MPW) support, thereby enabling academic institutions, startups, and MSMEs to access foundry services. The center offers centralized access to EDA design tools from Synopsys, Cadence, and Siemens-EDA, along with services like fab compliance checks, design validation, and integration. It coordinates with firms for chip packaging, characterization, and prototyping. Additionally, the facility focuses on creating a repository of reusable IP cores and offers training on EDA tools. It also features a Virtual Prototyping Lab at NIELIT Calicut for VLSI design training.[137]

The Chips to Startup (C2S) Programme is a strategic initiative launched by the Ministry of Electronics and Information Technology (MeitY) to enhance India's semiconductor design and manufacturing capabilities. The program aims to develop industry-ready talent, support industry-led research, and facilitate collaboration between academia and industry. By creating reusable IP cores, supporting startups, and expanding the base of ASIC/IC design, the C2S Programme is designed to reduce dependence on imports, protect intellectual property, and encourage entrepreneurship among students and researchers. This initiative is a significant step towards establishing India as a critical

[135] Chips to Startup (C2S) Program - India's Initiative to Boost Semiconductor and Display Manufacturing Testbook, https://testbook.com/articles/chips-to-startup-program (last visited Jun 19, 2024)
[136] Supra note 134
[137] *Id*

player in the global semiconductor market, contributing to technological advancement and economic growth.

5.7 THE DESIGN LINKED INCENTIVE (DLI) SCHEME

"The Ministry of Electronics and Information Technology has announced the Design Linked Incentive (DLI) Scheme to offset the disabilities in the domestic industry involved in semiconductor design to move up in value-chain and strengthen the semiconductor chip design ecosystem in the country. CDAC is responsible for implementing the DLI Scheme as a Nodal Agency. The Design Linked Incentive (DLI) Scheme aims to offer financial incentives as well as design infrastructure support across various stages of development and deployment of semiconductor design(s) for Integrated Circuits (ICs), Chipsets, Systems on Chips (SoCs), Systems & IP Cores and semiconductor linked design(s) over a period of 5 years."[138]

FIGURE 5.3 DLI BENEFICIARIES[139]

The DLI Scheme is a significant initiative to enhance innovation and competitiveness within India's electronics sector. This scheme aims to incentivize and support domestic companies, startups, and MSMEs, focusing on accelerating the development and indigenization of semiconductor content and intellectual properties (IPs) critical for electronic products. The DLI Scheme aims to strengthen the sector's capabilities by encouraging import substitution and bolstering value addition. It also seeks to enhance

[138] Design Linked Incentive Scheme, https://chips-dli.gov.in/DLI/HomePage (last visited Jun 19, 2024)
[139] *Id*

access to semiconductor design infrastructure, empowering smaller enterprises to thrive in a globally competitive market landscape.

The DLI Scheme sets out comprehensive objectives aimed at strengthening India's electronics sector. Firstly, it seeks to nurture and facilitate the growth of domestic companies, startups, and MSMEs by providing essential support and incentives. Secondly, the scheme targets significant indigenization of semiconductor content and intellectual properties (IPs) crucial for electronic products deployed within the country. This strategic focus on local production aims to reduce reliance on imports, thereby promoting import substitution and increasing value addition in the electronics industry.[140] Moreover, the DLI Scheme strives to bolster access to semiconductor design infrastructure explicitly tailored for startups and MSMEs, empowering them with the necessary technological resources to innovate and excel in a competitive global market.

Eligibility for the Design Linked Incentive (DLI) Scheme encompasses financial incentives and design infrastructure support directed towards domestic companies, startups, and MSMEs engaged in semiconductor design or related activities. Approved applicants claiming incentives under the scheme must maintain their domestic status, with more than 50% of their capital beneficially owned by resident Indian citizens or Indian companies ultimately controlled by resident Indian citizens, for a minimum of three years post-claiming incentives.[141] Applicants must satisfy specified Threshold and Ceiling Limits to qualify for the disbursement of incentives, as outlined in the scheme's guidelines.

5.8 MAKE IN INDIA INITIATIVE

The Make in India initiative is a national program launched by the Government of India with the aim of transforming the country into a global manufacturing hub. It was

[140] *Id*
[141] *Id*

introduced in September 2014 with the objective of encouraging both multinational corporations and domestic companies to manufacture their products within India.[142]

Designed to position India as a leading global center for design and manufacturing, the Make in India initiative was a strategic response to a critical period. By 2013, the once-promising growth of emerging markets had slowed, causing India to experience its lowest economic growth rate in ten years. The BRICS Nations (Brazil, Russia, India, China, and South Africa) no longer held the promise they once did, and India was identified among the 'Fragile Five'. Global investors debated whether the world's largest democracy presented a risk or an opportunity. With a population of 1.2 billion, India faced significant questions about its potential for success or vulnerability to failure on a large scale. India urgently needed a substantial initiative to address its economic challenges at this crucial juncture. One of the key challenges was the need to enhance the manufacturing sector's contribution to GDP, which stood at around 15%. The government aimed to increase this to 25%, like other developing Asian nations, to generate jobs, attract foreign direct investment, and establish India as a preferred global manufacturing hub. Additionally, India's infrastructure was seen as inadequate, with poor logistics and a bureaucratic approach that hindered timely production and efficient manufacturing processes.[143]

The Make in India initiative has introduced several policies that are particularly advantageous for India's semiconductor trade, aiming to enhance the sector's growth and establish the nation as an important player in the global market. Key among these are financial incentives such as tax breaks, subsidies, and grants, which substantially reduce the costs associated with establishing and operating semiconductor manufacturing facilities in India, making the country a more attractive destination for investment. Furthermore, the initiative focuses on developing world-class infrastructure, including special economic zones (SEZs) and semiconductor parks, which are critical for the efficient functioning of semiconductor plants, supported by improved logistics and transportation networks.

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[142] India's Emerging Prominence as a Semiconductor Superpower, https://www.investindia.gov.in/team-india-blogs/indias-emerging-prominence-semiconductor-superpower (last visited Jun 19, 2024)
[143] ABOUT US | Make In India, https://www.makeinindia.com/about (last visited Jun 19, 2024)

The initiative also emphasizes research and development (R&D) through funding and partnerships with academic institutions and research organizations, encouraging the advancement of sophisticated semiconductor technologies. Addressing the industry's skill gap is another priority, with Make in India including training programs and collaborations with educational institutions to create a workforce that meets the sector's needs. Simplifying regulatory procedures, reducing bureaucratic red tape, and implementing business-friendly policies improve the overall ease of doing business in India, facilitating the setup and expansion of semiconductor companies.

Moreover, the initiative allows 100% Foreign Direct Investment (FDI) in the semiconductor sector under the automatic route, encouraging international firms to invest in India without requiring prior government approval. These combined policies are expected to significantly increase domestic semiconductor production, reducing reliance on imports and enhancing self-sufficiency. Favorable FDI policies and an improved business environment will likely attract global investments, bringing in capital, technology, and expertise. Enhanced manufacturing capabilities and improved quality standards can boost India's semiconductor exports, positioning the country as a competitive player in the global market.

Additionally, the semiconductor industry's growth under these policies is anticipated to create substantial employment opportunities, contributing to economic development and improving living standards. R&D and skill development support will encourage innovation in semiconductor technologies, enabling India to develop advanced solutions and maintain a competitive edge in the global industry. By implementing these policies, the Make in India initiative aims to transform India into a central hub for semiconductor manufacturing and trade, driving economic growth and technological advancement.

5.9 INDIAN ENERGY POLICY

India’s energy policy aims to ensure energy access for all, improve energy security, and promote sustainable development. The government expects that diversifying the energy

mix, increasing the use of renewables, and improving energy efficiency will meet the growing energy demands of its population and economy while minimizing environmental impact. India's renewable energy policy is closely related to the semiconductor trade through several mechanisms that ensure a stable, cost-effective, and sustainable energy supply, which is crucial for the semiconductor manufacturing industry. “The Ministry of New and Renewable Energy envisions advancing the development of renewable energy technologies, processes, and materials that align with international standards and performance benchmarks. The goal is to position the country as a net foreign exchange earner in this sector. Additionally, it aims to deploy domestically developed and manufactured products and services to support the national objective of energy security.”[144]

The National Solar Mission's emphasis on developing extensive solar power generation capacity and associated infrastructure offers a dependable and sustainable power supply for semiconductor manufacturing facilities. Enhanced energy infrastructure and increased access to renewable energy enable semiconductor companies to minimize their carbon footprint and achieve sustainability targets. Affordable and consistent solar power can reduce operational expenses for semiconductor manufacturers in India, boosting their competitiveness in the global market.

Furthermore, government financial incentives and policy support for the solar energy sector can further lower electricity costs for semiconductor fabs. By focusing on renewable energy, the National Solar Mission aids the semiconductor industry in reducing its carbon footprint and complying with environmental regulations, making it more appealing to international customers. Utilizing sustainable energy sources also helps semiconductor manufacturers mitigate the risk of power disruptions, vital for the industry’s reliability and competitiveness.

The semiconductor industry is known for its high electricity demands and significant environmental impact and stands to benefit significantly from the country's renewable energy policies and projects. India has been expanding its renewable energy capacity,

[144] VISION & MISSION | MINISTRY OF NEW AND RENEWABLE ENERGY | INDIA, https://mnre.gov.in/about-department/vision-mission/ (last visited Jun 21, 2024)

focusing on solar and wind power, through initiatives like the National Solar Mission, which aims to achieve 100 GW of solar power. This increase in renewable energy provides a substantial and reliable electricity supply crucial for the energy-intensive processes in semiconductor manufacturing. Additionally, the shift towards renewable energy sources helps reduce the carbon footprint of semiconductor companies, aligning with their sustainability goals and environmental regulations. Government incentives and policy support make renewable energy more affordable, thus lowering operational costs for semiconductor fabs and improving their global competitiveness. Moreover, the integration of renewable energy ensures a more decentralized and resilient power supply, mitigating risks of power disruptions critical for maintaining production quality and efficiency in the semiconductor industry. By leveraging these renewable energy resources and supportive policies, India can enhance its semiconductor sector's sustainability, reliability, and competitiveness.

5.10 INTELLECTUAL PROPERTY LAWS IN SEMICONDUCTOR TECHNOLOGY

"Semiconductor chips are fundamental to technological advancement, prompting nations to recognize the necessity of protecting the innovation involved in their creation. In 1984, the United States led by enacting the Semiconductor Chip Protection Act (SCPA), which had a significant global impact. This legislation ultimately led to forming the Intellectual Property in Respect of Integrated Circuit (IPIC) treaty in 1989 under WIPO's auspices, later incorporated into the TRIPS Agreement. Under the TRIPS Agreement, India introduced the Semiconductor Integrated Circuit Layout Design Act, 2000, which aims to protect the layout design of integrated circuits and support the manufacturing of semiconductor chips."[145]

The Semiconductor Integrated Circuits Layout-Design Act 2000 is a critical legislation providing exclusive protection for original and distinctive semiconductor integrated circuit layout designs. This act ensures that India complies with its obligations under

[145] INDIAN IP REGIME IN SEMICONDUCTOR CHIP, https://ipbulletin.in/indian-ip-regime-in-semiconductor-chip/ (last visited Jun 21, 2024)

the TRIPS agreement, specifically Articles 35-38, regarding the protection of semiconductor integrated circuit layout designs.

The Act defines key terms crucial to its scope, such as "integrated circuit," which is described as a product comprising active and passive elements intended for electronic functions.[146] Additionally, "layout design" is specified as the three-dimensional arrangement of elements and their interconnections within an integrated circuit, emphasizing the spatial configuration that contributes to its functionality.[147] The Act safeguards "original layout designs," defined as those resulting from the creator's intellectual effort and not commonplace among designers at the time of creation.[148] These definitions underscore the Act's intent to protect innovative layout designs, encouraging investment and creativity in India's semiconductor sector. Key sections include provisions for registration with the Semiconductor Integrated Circuits Layout-Design Registry, granting creators exclusive rights for ten years from registration or first commercial exploitation.[149] Exemptions from infringement, such as private and non-commercial use, are also outlined.[150] By providing legal certainty and protection, the Act promotes a conducive environment for semiconductor innovation, which is essential for technological advancement and industry growth in India.

The Act is crucial for India's semiconductor trade for several compelling reasons. Firstly, it provides robust protection to layout designs of integrated circuits, incentivizing domestic and international semiconductor companies to invest in research and development within India. This protection ensures that innovators can reap the benefits of their creations without the risk of unauthorized use or exploitation. Secondly, by adhering to international standards, particularly those outlined in the TRIPS Agreement, the Act facilitates smoother trade relations and collaborations with global semiconductor entities. It assures foreign investors and partners that their intellectual property rights will be respected in India, thus fostering a conducive environment for technology transfer and joint ventures. Thirdly, the Act supports semiconductor manufacturing by safeguarding proprietary layout designs crucial for

[146] Semiconductor Integrated Circuits Layout Design Act, 2000, § 2(a)
[147] Semiconductor Integrated Circuits Layout Design Act, 2000, § 2(h)
[148] Semiconductor Integrated Circuits Layout Design Act, 2000, § 2(c)
[149] Semiconductor Integrated Circuits Layout Design Act, 2000, § 11(1)
[150] Semiconductor Integrated Circuits Layout Design Act, 2000, § 14

producing advanced integrated circuits. This protection is instrumental in attracting investments in semiconductor fabrication plants and bolstering India's capabilities in indigenous manufacturing. Moreover, the Act provides legal certainty through clear definitions and provisions, which are essential for business planning, investment decisions, and effective resolution of intellectual property disputes. Overall, by promoting innovation and protecting intellectual property, the Act contributes significantly to India's position as a competitive player in the global semiconductor market, driving economic growth and technological advancement.

5.11 LEGISLATIVE SUPPORT FOR SEMICONDUCTOR WAFER FABRICATION UNITS IN INDIA

The legislative framework supporting semiconductor wafer fabrication manufacturing units in India includes the Income-tax (14th Amendment) Rules, 2014, Section 35AD of the Income-tax Act, 1961, and Rule 11-OB of the Income-tax Rules. Section 35AD of the Income-tax Act provides investment-linked deductions for specified businesses, including semiconductor wafer fabrication units.[151] The Income-tax (14th Amendment) Rules, 2014, detail guidelines for the notification of semiconductor wafer fabrication manufacturing units as specified businesses under Section 35AD.[152] Rule 11-OB of the Income-tax Rules further elaborates on the application process and conditions for approval of semiconductor wafer fabrication units, facilitating their establishment and operation in India.[153] This legislative framework aims to incentivize investment, promote technological development, and enhance India's semiconductor manufacturing capabilities.

The analysis of Indian policies and legislation reveals a strategic framework aimed at establishing India as a global semiconductor hub. The National Policy on Electronics 2019 outlines a cohesive strategy to promote innovation and attract investments in the electronics sector, which is crucial for semiconductor manufacturing. The Production Linked Incentive (PLI) Scheme for Large Scale Electronics Manufacturing, along with initiatives like the India Semiconductor Mission and Scheme for Promotion of

[151] Income-tax Act, 1961, § 35AD
[152] Income-tax (14th Amendment) Rules, 2014
[153] Income-tax Rules, Rule 11-OB

Manufacturing of Electronic Components and Semiconductors (SPECS), enhances India's manufacturing capabilities by incentivizing local production and research in semiconductor technologies. Programs such as the Chips to Startup (C2S) Programme and the Design Linked Incentive (DLI) Scheme support startups and entrepreneurs in the semiconductor industry, fostering an ecosystem of innovation and entrepreneurship. These initiatives align with the Make in India initiative, aimed at promoting domestic manufacturing and reducing dependence on imports. Supported by a robust Indian Energy Policy ensuring a stable and sustainable power supply, these efforts create an attractive environment for semiconductor manufacturing. Furthermore, strong intellectual property laws in semiconductor technology protect innovation and facilitate technology transfer, positioning India to expand its global semiconductor presence and drive economic growth and technological advancement in the foreseeable future.

CHAPTER 6
CHALLENGES AND OPPORTUNITIES FOR INDIA IN SEMICONDUCTOR MANUFACTURE AND TRADE.

6.1 INTRODUCTION

Semiconductors, the invisible engines driving technological progress found in everything from smartphones to medical equipment, are crucial to the global economy. In light of India's growing IT prowess, there is a pressing need to address the overreliance on imported semiconductors. This chapter delves into India's potential in semiconductor manufacturing and trade, highlighting the challenges and opportunities.

The expanding demand for semiconductors presents India with a productive market opportunity. India is strategically positioned to develop a domestic chip-making industry, boosting innovation and economic growth by leveraging its strengths in IT and software services. A self-sufficient semiconductor industry would enable India to meet its domestic market's evolving needs with cutting-edge technologies. However, achieving self-sufficiency in semiconductor production comes with significant hurdles, requiring substantial investments in infrastructure and R&D. Cultivating a skilled workforce in chip design, fabrication, and testing is crucial. These areas represent the actual test of India's ambitions in this domain. Overcoming these obstacles will allow India to establish itself as a key player in global semiconductor production. A thriving domestic semiconductor industry promises not only economic prosperity but also technological independence. This would give India a significant strategic advantage on the international stage, enabling it to exert greater influence in the global technological ecosystem.

6.2 CHALLENGES

India faces several challenges in establishing itself as a significant player in semiconductor manufacturing. Historically, the country has not been significantly involved in chip manufacturing and has not been able to develop the necessary talent or technical education in this field. While India does have a substantial pool of design

engineers, there is a shortage of skilled workers for specialized semiconductor manufacturing processes. It will be necessary to rely on experts from abroad to train local talent initially, but long-term success will require developing domestic expertise. In addition, securing a stable supply of rare earth elements and critical minerals, many of which are dominated by China, remains a significant hurdle, as India still heavily relies on imports for these essential materials.

"The U.S. semiconductor industry faces several challenges that are also relevant to India as both countries strive to enhance their semiconductor manufacturing capabilities. Tax incentives are crucial, as a competitively awarded federal incentives program can support investments by companies and consortia in establishing, expanding, and modernizing semiconductor manufacturing facilities and infrastructure. Workforce development is another critical area; the federal government must address gaps in the current semiconductor manufacturing and R&D workforce by ensuring that every segment of the industry chain has adequately skilled workers supported by appropriate curricula and training programs. Furthermore, advanced semiconductor packaging capabilities require federal support to maintain state-of-the-art tools, facilities, expertise, and infrastructure, along with a skilled workforce and robust operational support for characterization, intellectual property protection, and international collaborations. Finally, creating a public-private National Semiconductor Technology Center (NSTC) can help integrate existing research, design, and manufacturing capabilities, addressing gaps in the microelectronics infrastructure and coordinating research and investment to tackle unprecedented technological challenges. These issues apply similarly to India, which also needs to incentivize investments, develop a skilled workforce, enhance packaging capabilities, and coordinate research efforts to establish a strong semiconductor industry."[154]

India's Challenges in Semiconductor Manufacturing

1. **Lack of Manufacturing Legacy**
2. **Skilled Workforce Shortage**
3. **Need for Training**

[154] SUJAI SHIVAKUMAR ET AL., THE PILLARS NECESSARY FOR A STRONG DOMESTIC SEMICONDUCTOR INDUSTRY (Center for Strategic and International Studies (CSIS)) (2022), https://www.jstor.org/stable/resrep41419 (last visited Jun 21, 2024)

4. **Material Supply Dependence**
5. **Reliance on Imports**
6. **Infrastructure Deficits**
7. **R&D Coordination Needed**
8. **Advanced Packaging Capabilities**
9. **Technology Transfer Restrictions**
10. **Water Demand of Semiconductor Production**

Lack of Manufacturing Legacy: India's historical lack of involvement in semiconductor manufacturing has significantly impacted its ability to develop a competitive semiconductor industry. The absence of a legacy and experience in this field means that India must build its manufacturing capabilities from the ground up, requiring substantial time and investment. This gap in development also hinders the attraction of skilled professionals and the creation of a specialized workforce, as local expertise and training infrastructure are limited. Furthermore, establishing a reliable supply chain and infrastructure for semiconductor production is challenging without a robust manufacturing base.

Skilled Workforce Shortage: The Indian semiconductor industry is currently facing a severe shortage of qualified workers who are proficient in specialized semiconductor manufacturing processes. This shortage presents a significant challenge, as the industry requires highly trained professionals well-versed in intricate techniques essential for semiconductor fabrication. The lack of skilled labor impedes the scaling of operations, hinders swift innovation, and makes it difficult for companies to meet global standards. Additionally, the shortage is a barrier to establishing new semiconductor manufacturing facilities and modernizing/expanding existing ones. Furthermore, it restricts India's ability to effectively compete in the international semiconductor market, where precision and efficiency are crucial.

Need for Training: India initially needs to bring experts from abroad to train local talent in specialized semiconductor manufacturing processes. However, it is crucial to develop a solid indigenous pool of skilled workforce for the long term. This two-pronged approach is essential for bridging the current skills gap and creating sustainable expertise within the Indian semiconductor industry. While foreign expertise provides

immediate training and knowledge transfer, nurturing local talent ensures continuity and self-reliance in meeting future industry demands. Developing a skilled workforce domestically reduces dependence on external trainers and strengthens India's competitiveness in semiconductor manufacturing. It fosters innovation, speeds up technological advancements, and supports the growth of indigenous semiconductor capabilities. By investing in specialized training programs and tailored educational initiatives for semiconductor manufacturing, India can effectively address its skills shortage and position itself as a significant player in the global semiconductor market.

Material Supply Dependence: Semiconductor manufacturing heavily relies on rare earth elements and critical minerals to produce high-performance chips. However, the global supply chain for these materials is dominated by China, which controls a significant portion of their production and distribution. This dependency poses substantial challenges for the Indian semiconductor industry. India's reliance on imports for these essential materials not only subjects its supply chain to potential geopolitical tensions and price fluctuations but also exposes it to supply disruptions, as seen during global crises like the COVID-19 pandemic. Moreover, China's dominance in rare earth elements and critical minerals limits India's strategic autonomy and ability to scale up semiconductor manufacturing independently.[155] Addressing these material supply challenges is crucial for India to secure a stable and sustainable supply chain, reduce dependence on external sources, and strengthen its semiconductor industry's resilience and competitiveness in the global market.

Reliance on Imports: India continues to depend significantly on imports to fulfill its semiconductor manufacturing needs despite ongoing efforts to explore and develop critical minerals domestically. This reliance on external sources for essential materials crucial to semiconductor production presents a substantial challenge to India's semiconductor industry. The dependence on imports exposes the industry to risks such as supply chain disruptions, price volatility, and geopolitical tensions. For instance, fluctuations in global supply or trade restrictions imposed by exporting countries can directly impact semiconductor manufacturing operations in India. Moreover, the

[155] RARE EARTHS: NEW CHALLENGES FOR THE SEMICONDUCTOR MARKET? - SI ELECTRONICS, https://si-electronics.de/en/rare-earths-new-challenges-for-the-semiconductor-market/ (last visited Jun 21, 2024)

reliance on imports hinders India's ability to control production costs and maintain competitiveness in the global semiconductor market. To mitigate these challenges, India needs to accelerate its efforts to explore and extract critical minerals within its borders while diversifying its sources through strategic partnerships and collaborations with other mineral-rich nations. Developing a resilient and self-sufficient supply chain for critical minerals is crucial for India to strengthen its semiconductor industry's resilience and ensure sustainable growth in the long term.

Infrastructure Deficits: India's semiconductor industry faces significant challenges due to a lack of advanced manufacturing infrastructure required for semiconductor fabrication plants. The absence of robust infrastructure capable of supporting complex semiconductor manufacturing processes hinders the country's ability to attract investments and establish state-of-the-art semiconductor facilities. This deficit impacts various aspects of semiconductor production, including the availability of clean rooms, specialized equipment, and reliable power supply, which are critical for producing high-quality chips. Moreover, inadequate infrastructure limits India's capacity to scale up semiconductor manufacturing operations and compete effectively in the global market. Addressing these infrastructure deficits is essential for India to enhance its semiconductor industry's competitiveness, attract foreign investments, and foster technological advancements. By investing in infrastructure development tailored to semiconductor manufacturing needs, India can strengthen its position as a critical player in the global semiconductor supply chain and drive economic growth through enhanced domestic production capabilities.

R&D Coordination Needed: The effective coordination of research and development (R&D) is crucial for addressing critical gaps in India's microelectronics infrastructure and advancing its semiconductor industry. Currently, India's semiconductor sector experiences fragmented efforts across research, design, and manufacturing domains. This fragmentation hinders synergies and collaborative innovation. By integrating existing capabilities in R&D, efforts can be streamlined towards overcoming technological challenges, enhancing product development, and fostering indigenous semiconductor technologies. A coordinated approach would enable India to leverage its software services and design strengths while bolstering semiconductor manufacturing capabilities. Aligning research priorities and pooling resources would

allow India to accelerate the development of cutting-edge technologies, reduce import dependency, and strengthen its position in the global semiconductor market. Moreover, enhanced coordination would attract investments in advanced manufacturing facilities and talent development, paving the way for sustainable growth and competitiveness in semiconductor manufacturing.

Advanced Packaging Capabilities: Developing advanced semiconductor packaging capabilities is crucial for the growth and competitiveness of the Indian semiconductor industry in the global market. This effort requires substantial support regarding specialized tools, state-of-the-art facilities, expert knowledge, and a skilled workforce. Advanced packaging plays a pivotal role in enhancing semiconductor performance, improving reliability, and reducing overall size, which is crucial for meeting evolving consumer demands and technological advancements. Furthermore, ensuring robust operational support for characterization, intellectual property protection, and international collaborations is equally essential. Adequate packaging safeguards semiconductor integrity and enhances its functionality and market appeal. For India, investing in advanced packaging capabilities enhances domestic production, attracts foreign investments, and reinforces its role in the global semiconductor supply chain. By fostering an environment conducive to innovation and collaboration, India can accelerate its journey towards becoming a pivotal player in the semiconductor industry while promoting sustainable growth and technological leadership.

Technology Transfer Restrictions: Prominent companies in the global semiconductor market often impose limitations on technology transfer, making it challenging for India to gain access to crucial expertise and know-how. These restrictions hinder India's ability to acquire advanced technologies and intellectual property needed to develop competitive semiconductor manufacturing capabilities. As a result, India faces obstacles in growing its semiconductor industry as it must independently build its own capabilities to close the technology gap. This highlights the need to invest in domestic R&D, encourage innovation, and cultivate a skilled workforce with expertise in cutting-edge semiconductor technologies. By prioritizing the development of indigenous capabilities, India can reduce its reliance on external technology transfers, enhance its technological self-sufficiency, and strengthen its position in the global semiconductor market. Additionally, overcoming technology transfer restrictions is vital for India to

create an environment conducive to innovation, attract foreign investments, and drive sustainable growth in its semiconductor industry.

Water Demand of Semiconductor Production: Water demand in semiconductor production is a critical yet often underestimated factor with significant implications for the Indian semiconductor industry. Semiconductor manufacturing processes, particularly in fabrication plants or "fabs," are highly water-intensive, with a single silicon wafer requiring up to 3,000 liters of ultrapure water to meet stringent production standards. This demand translates into substantial daily water consumption at semiconductor plants, exerting immense pressure on local water treatment and supply systems. In the context of global challenges such as water scarcity and heightened environmental awareness, efficient water management practices are crucial. For India, which already faces water scarcity issues in various regions, managing the water demand for semiconductor production becomes a critical concern. It necessitates investments in sustainable water management technologies, recycling and reuse strategies, and stringent regulatory frameworks to ensure responsible water usage in semiconductor manufacturing. Addressing these challenges effectively will mitigate environmental impacts and support the long-term sustainability and growth of India's semiconductor industry, enabling it to meet global standards while minimizing resource constraints.

6.3 OPPORTUNITIES

India is currently at a crucial point with significant semiconductor manufacturing and trade prospects due to the increasing global demand for advanced electronic devices and the country's growing technological capabilities. As an important player in software services and information technology, India has the potential to use its strengths to establish a strong semiconductor ecosystem. The expanding domestic market for electronics provides an excellent opportunity for India to improve local manufacturing capabilities and reduce dependence on imports. Furthermore, initiatives such as the National Policy on Electronics 2019 and programs like the Production Linked Incentive (PLI) Scheme highlight India's commitment to creating a favorable environment for semiconductor manufacturing. India is strategically investing in infrastructure, research

and development, and skill enhancement to establish a significant presence in the global semiconductor supply chain. Embracing these opportunities positions India as a hub for semiconductor production and drives economic growth, technological innovation, and employment generation in the country.

Memorandum Of Understanding On Working Arrangements On Semiconductors Ecosystem, Its Supply Chain And Innovation Under The Framework Of Eu-India Trade And Technology Council (TTC).[156] The Memorandum of Understanding (MoU) between the EU and India on semiconductors represents a substantial opportunity for India in the realm of semiconductor manufacture and trade. This agreement facilitates sharing experiences and best practices, enabling India to glean insights into efficient semiconductor ecosystem management from the EU.[157] Collaboration in research, development, and innovation with EU universities, research organizations, and businesses promises to accelerate technological advancements in India's semiconductor sector.[158] Moreover, the MoU promotes skills development tailored to semiconductor industry needs, addresses India's talent shortages, and enhances workforce capabilities.[159] By ensuring transparency in public subsidies and promoting a level playing field, the agreement aims to attract increased investment in India's semiconductor infrastructure.[160] This strategic engagement, coupled with broader initiatives in strategic technologies and resilient value chains under the EU-India Trade and Technology Council, positions India to strengthen its semiconductor manufacturing capabilities and expand its global trade footprint in this critical industry.

India has the potential to benefit significantly from semiconductor manufacturing and trade opportunities through Free Trade Agreements (FTAs) with various countries or blocs. In general, FTAs help by reducing tariffs or providing duty-free access to partner markets, which can lower costs for semiconductor components and equipment imports. This cost reduction can make Indian semiconductor manufacturing more competitive globally by minimizing input costs. Also, FTAs often include trade facilitation and

[156] MEMORANDUM OF UNDERSTANDING ON SEMICONDUCTORS WITH INDIA | SHAPING EUROPE'S DIGITAL FUTURE, https://digital-strategy.ec.europa.eu/en/library/memorandum-understanding-semiconductors-india (last visited Jun 21, 2024)
[157] *Id*
[158] *Id*
[159] *Id*
[160] *Id*

regulatory cooperation provisions, streamlining customs procedures, and regulatory barriers that can hinder semiconductor exports.

In addition, FTAs can promote deeper economic integration and supply chain linkages with partner countries, enhancing India's access to advanced semiconductor technologies and materials. This access can boost innovation and technology transfer, which is crucial for upgrading India's semiconductor manufacturing capabilities. By participating in FTAs, India can expand its market reach for semiconductor products, reach new consumer bases, and diversify its export destinations. Moreover, FTAs encourage investment flows by providing more predictable and favorable business environments. This can attract foreign direct investment (FDI) into India's semiconductor sector, bolstering infrastructure development, skills enhancement, and technological advancements.

India has adopted a comprehensive strategy to bolster its semiconductor manufacturing and trade. The National Policy on Electronics 2019 aims to position India as a global hub for ESDM. The policy encourages the development of essential components like semiconductors and promotes domestic production to reduce reliance on imports and drive technological innovation.

The Production Linked Incentive Scheme (PLI) for Large Scale Electronics Manufacturing provides financial incentives to boost domestic production. This benefits semiconductor manufacturers by attracting investments, increasing production capacities, and creating a robust supply chain ecosystem.

The India Semiconductor Mission focuses on developing a sustainable semiconductor and display ecosystem through collaborations with global companies, strategic investments, and technological partnerships. The Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) offers financial incentives to establish manufacturing units, which are crucial for developing a domestic supply chain, reducing dependence on imports, and promoting innovation.

The Chips to Startup (C2S) Programme supports semiconductor design startups and companies by providing funding, infrastructure, and mentorship to create a vibrant

design and innovation ecosystem. The Design Linked Incentive (DLI) Scheme offers financial incentives for research and development in chip design, aiming to establish India as a hub for semiconductor design, complementing its manufacturing capabilities.

The Make in India initiative aims to position India as a global manufacturing hub by encouraging both multinational corporations and domestic companies to establish fabrication plants and critical infrastructure within the country. India's energy policies focus on ensuring a stable power supply and promoting renewable energy sources to support the energy-intensive semiconductor manufacturing industry.

Robust intellectual property laws protect innovations in semiconductor technology, encouraging investment in research and development and fostering a culture of innovation. By leveraging these policies and initiatives, India aims to attract substantial investments, enhance its manufacturing and technological capabilities, and establish itself as a significant player in the global semiconductor market. This comprehensive ecosystem supports everything from initial design to final production, creating a sustainable and competitive industry.

CHAPTER 7
INDIA'S ROLE IN TACKLING GLOBAL CHIP CRISIS

7.1 INTRODUCTION

The global semiconductor shortage has become a significant challenge, causing disruptions in industries such as automotive and consumer electronics. Countries around the world are working to secure their chip supplies and strengthen their domestic production capabilities. The PLI scheme offers substantial financial incentives to enhance domestic manufacturing and attract major investments in the electronics value chain, encompassing electronic components and semiconductor packaging, financial incentives, and international collaborations. This has positioned India as a critical player in the semiconductor industry. The country's comprehensive approach includes the National Policy on Electronics 2019, the Production Linked Incentive (PLI) Scheme, and the India Semiconductor Mission, among others. These efforts are aimed at boosting domestic semiconductor manufacturing, promoting innovation, and reducing reliance on imports, thus helping to stabilize global chip supplies. This chapter explores India's multifaceted strategy to alleviate the chip crisis and its potential to reshape the global semiconductor landscape.

7.2 DIFFERENT POLICIES AND SCHEMES IN TACKLING THE GLOBAL CHIP CRISIS

India's role in addressing the global chip shortage is greatly supported by the objectives outlined in the 2019 National Policy on Electronics. This policy provides strong support and special incentives for capital-intensive semiconductor projects, ensuring the development and expansion of domestic manufacturing capabilities. A primary goal is to promote microchip production in critical infrastructure sectors such as defense, space, atomic energy, telecommunications, broadcasting, aviation, and power within India, reducing the country's reliance on imports and boosting its strategic

independence.[161] The policy also emphasizes the importance of research and innovation in areas such as packaging, interconnects, and microphotonics, addressing long-term challenges posed by the limitations of silicon technology.[162] This includes encouraging the industry to explore alternatives to silicon to overcome issues like scaling limits and dark silicon. Additionally, the policy incentivizes the Transfer of Technology (ToT) for core technologies, making it easier for Indian manufacturers to acquire and integrate advanced global semiconductor technologies.[163]

India's **National Policy on Electronics 2019** outlines strategic measures to address the global chip crisis. The policy incentivizes advanced and capital-intensive projects, such as semiconductor facilities, display fabrication, photonics, and LED chip fabrication units.[164] India aims to attract investments and facilitate the establishment and expansion of cutting-edge manufacturing facilities according to the infrastructure status of these units.[165] The policy also encourages investment in mega facilities abroad, including supporting the acquisition of existing semiconductor facilities and establishing research and development units in locations with well-developed ecosystems for specific technologies.[166] These international investments and collaborations can enhance India's technological capabilities and integrate global best practices into its domestic semiconductor industry.

India’s role in tackling the global chip crisis has advanced significantly through the objectives of the **Production Linked Incentive (PLI) Scheme for Large Scale Electronics Manufacturing.** The PLI scheme offers substantial financial incentives to enhance domestic manufacturing and attract major investments in the electronics value chain, encompassing electronic components and semiconductor packaging.[167] By targeting key segments such as discrete semiconductor devices (transistors, diodes, thyristors), micro and nano-electronic components (MEMS and NEMS), and essential materials for Printed Circuit Boards (PCBs) such as laminates, prepregs, photopolymer

[161] EGAZETTE_NOTIFICATION_NPE 2019_DATED 25022019.PDF, https://www.meity.gov.in/writereaddata/files/eGazette_Notification_NPE%202019_dated%2025022019.pdf (last visited Jun 21, 2024)
[162] *Id*
[163] *Id*
[164] *Id*
[165] *Id*
[166] *Id*
[167] *Supra* note 115

films, and printing inks, the scheme aims to create a robust infrastructure for semiconductor manufacturing in India.[168] These incentives encourage companies to set up and expand their operations in India, fostering an environment conducive to high-tech manufacturing and innovation.

India is actively addressing the global chip crisis by backing initiatives like the India Semiconductor Mission, which provides strategic support for semiconductor fabs. The scheme provides significant fiscal incentives, covering up to 50% of the project cost for approved applicants across different segments on an equal basis.[169] This support is aimed at Semiconductor Fabs, Display Fabs, Compound Semiconductors including Silicon Photonics and Sensors (including MEMS), and Discrete Semiconductors, Fab and Semiconductor Packaging (ATMP / OSAT) facilities. The goal is to encourage investments and promote the development of advanced manufacturing capabilities within India.[170] By offering financial support for these crucial infrastructure projects, India seeks to reduce its reliance on imports, strengthen its semiconductor ecosystem, and contribute to stabilizing global chip supplies. These initiatives stimulate local manufacturing and position India as a competitive hub for semiconductor production, essential for meeting the increasing demand in critical sectors worldwide.

The **Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS)** is crucial for strengthening India's manufacturing ecosystem. The initiative aims to address the global chip crisis by promoting domestic production of electronic components and semiconductors. It provides a 25% financial incentive on capital expenditure for manufacturing electronic components, semiconductor/display fabrication units, ATMP units, specialized sub-assemblies, and capital goods.[171] The goal is to increase value addition, meet domestic demand, and create employment opportunities.[172] As of November 2022, the scheme had received 32 applications with a total project cost of INR 11,130 crore, indicating strong industry

[168] *Id*
[169] *Supra* note 81
[170] *Id*
[171] PROMOTION OF SPECS, https://pib.gov.in/pib.gov.in/Pressreleaseshare.aspx?PRID=1881407 (last visited Jun 22, 2024)
[172] *Id*

interest. Incentives of up to INR 3,285 crore will be awarded over eight years to boost domestic production capacity and reduce reliance on imports.[173]

The SPECS initiative aligns with India's National Policy on Electronics 2019, which aims to make India a global hub for ESDM. This policy is a cornerstone of the AtmaNirbhar Bharat (Self-Reliant India) economic strategy, aiming to increase domestic manufacturing capabilities and position India as a critical player in the global electronics value chain. Given the global chip crisis and the vulnerabilities in the semiconductor supply chain, India's efforts under SPECS and related schemes could play a crucial role in diversifying the global supply base. By enhancing its manufacturing ecosystem, India can provide an alternative to the traditional semiconductor manufacturing hubs, contributing to stabilizing global supply chains and mitigating future disruptions.

India's **"Chips to Startup" (C2S) Programme** aims to alleviate the global chip shortage by developing expertise in VLSI and Embedded System Design. The program seeks to train 85,000 specialized professionals over five years, boosting India's capabilities in semiconductor and electronic systems design.[174] This initiative aims to address the global demand for skilled personnel in the semiconductor industry and caters to both domestic and international markets. The program also emphasizes the creation of a repository of reusable intellectual properties (IPs) to expedite the design process, supporting fabless startups that drive innovation without owning fabrication facilities.[175] Furthermore, the C2S initiative targets critical societal areas such as energy, environment, healthcare, agriculture, and disaster management, promoting technological advancements that tackle significant societal issues.[176] By fostering collaboration between academia, industry, and R&D organizations, the C2S programme strengthens the electronics ecosystem, making it more resilient and capable of handling global supply chain challenges.[177] This holistic approach positions India as a key player in addressing the global chip crisis, contributing to a more balanced and robust semiconductor supply chain.

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[173] *Id*
[174] *Supra* note 139
[175] C2S, https://c2s.gov.in/about_c2s.jsp (last visited Jun 22, 2024)
[176] *Id*
[177] *Id*

India's **Design Linked Incentive (DLI) Scheme** is overseen by the Ministry of Electronics and Information Technology and implemented by CDAC. This scheme addresses the global chip shortage by enhancing the country's semiconductor design capabilities.[178] It aims to offset the challenges faced by the domestic semiconductor design industry by offering financial incentives and infrastructure support for developing Integrated Circuits (ICs), Chipsets, Systems on Chips (SoCs), and Systems & IP Cores over a period of five years. The DLI Scheme promotes innovation and reduces import dependency, thereby helping build a robust local design ecosystem. This will contribute to the global semiconductor supply chain's resilience and diversity. Overall, this initiative positions India as a significant player in mitigating the global chip crisis through strengthened local capabilities and sustained innovation.

The **"Make in India" initiative** focuses on four key pillars to address the global chip shortage. It aims to strengthen India's manufacturing and semiconductor capabilities by simplifying business procedures, reducing licensing and regulatory burdens, and creating a favorable environment for investment in semiconductor manufacturing.[179] These efforts are expected to increase India's chip production and help alleviate global supply shortages. The initiative also emphasizes the development of modern infrastructure, such as industrial corridors and smart cities, with advanced technology and integrated logistics. Upgrading existing infrastructure in industrial clusters is intended to support efficient production and distribution of semiconductors, addressing supply chain issues contributing to the global chip crisis.[180] Furthermore, "Make in India" promotes 25 key sectors, including manufacturing, infrastructure, and services, by encouraging significant Foreign Direct Investment (FDI) in areas like Defense Production, Construction, and Railway infrastructure.[181] This approach contributes to building a robust chip production industry in India, helping to mitigate the chip shortage.

[178] *Supra* note 138
[179] MAKE IN INDIA | PRIME MINISTER OF INDIA, https://www.pmindia.gov.in/en/major_initiatives/make-in-india/ (last visited Jun 22, 2024)
[180] *Id*
[181] *Id*

In addition, the initiative encourages the government to shift its role from regulator to facilitator of economic development. This collaborative approach promotes innovation and growth in semiconductor manufacturing, ensuring policies align with industry needs and enhance production capabilities to address the chip crisis effectively. Overall, the "Make in India" initiative can strengthen India's position in the global semiconductor supply chain by improving business processes, modernizing infrastructure, encouraging sectoral growth, and fostering government-industry collaboration. These efforts aim to expand production, reduce supply chain vulnerabilities, and position India as a key player in resolving the global chip crisis.

Semiconductor fabrication facilities (fabs) are notorious for their substantial energy consumption, with the industry devouring 149 billion kWh in 2021 alone, capable of powering a city of over 25 million people for a year.[182] This high energy demand stems from intricate processes like a material deposition, circuit etching, doping, and maintaining stringent cleanroom conditions. As semiconductor technology advances to smaller node sizes, such as the current 3 nm, energy use per square millimeter rises.[183] The primary energy sources for semiconductor manufacturing are grid electricity and fossil fuels, accounting for 95.8% of total consumption, while renewable energy constitutes only 2.7%. Concerns over escalating electricity demands led to projections suggesting that by 2030, the industry could require 237 terawatt-hours, surpassing Australia's 2021 national consumption and potentially intensifying greenhouse gas emissions. In response, major semiconductor players like TSMC, Intel, and Samsung have committed to transitioning their manufacturing operations to 100% renewable energy within the next decade.[184] This shift is crucial as the industry confronts energy security and environmental sustainability challenges.

India's energy policies play a pivotal role in the global semiconductor trade, particularly amidst efforts to address the ongoing chip shortage. Aligned with its National Action Plan on Climate Change[185], India aims to significantly increase renewable energy's

[182] Qi Wang et al., *Environmental data and facts in the semiconductor manufacturing industry: An unexpected high water and energy consumption situation*, 4 WATER CYCLE 47–54 (2023)
[183] RESOURCE CONSUMPTION IN THE SEMICONDUCTOR INDUSTRY AZONANO, https://www.azonano.com/article.aspx?ArticleID=6658 (last visited Jun 22, 2024)
[184] *Id*
[185] CLIMATE CHANGE PROGRAMME | DEPARTMENT OF SCIENCE & TECHNOLOGY, https://dst.gov.in/climate-change-programme (last visited Jun 22, 2024)

share in its energy mix, targeting 175 GW by 2022 and 450 GW by 2030. Such initiatives bolster India's appeal as a favorable destination for semiconductor investments and manufacturing, offering stable, cost-effective, and sustainable energy supplies crucial for fabs.

By integrating more renewable energy into its grid, India supports its semiconductor sector and aligns with global trends towards greener manufacturing practices. This strategic approach enhances India's capacity to attract investments, expand production capabilities, and contribute positively to the global semiconductor supply chain. Consequently, India's proactive energy policies are set to play a crucial role in alleviating the chip crisis by fostering a sustainable and reliable manufacturing environment for semiconductors.

7.3 SUMMING UP

India is strategically set to address the global semiconductor shortage through a combination of comprehensive policies and initiatives. The National Policy on Electronics 2019 aims to transform India into a worldwide hub for ESDM. To support this goal, the Production Linked Incentive (PLI) Scheme for Large Scale Electronics Manufacturing and the Design Linked Incentive (DLI) Scheme offer financial incentives to improve manufacturing and design capabilities. Additionally, the India Semiconductor Mission and the Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) aim to build the necessary infrastructure and component ecosystem for semiconductor production. The "Chips to Startup" (C2S) Programme also plays a crucial role by promoting innovation and talent development in semiconductor design and manufacturing. The "Make in India" initiative further enhances the attractiveness of India's manufacturing sector. Furthermore, India's energy policies, which focus on increasing renewable energy capacity, provide a sustainable and reliable energy supply for the energy-intensive semiconductor industry. Together, these policies and initiatives create a favorable environment for expanding production capacity, attracting global investments, and positioning India as a prominent participant in the global semiconductor supply chain, thereby contributing substantially to resolving the semiconductor crisis.

CHAPTER 8
FINDINGS, CONCLUSION AND SUGGESTIONS

8.1 INTRODUCTION

Semiconductors are the backbone of modern technology; they have experienced a significant transformation since their initial development. These tiny electronic components are crucial in powering various devices, from everyday consumer electronics to advanced computing systems and critical infrastructure. The evolution of semiconductors began with the development of the first transistors and integrated circuits in the mid-20th century by John Bardeen, Walter Brattain, and William Shockley, who invented the first working transistors at Bell Labs, the point-contact transistor in 1947. and has since progressed to creating highly sophisticated microchips that drive the digital age. However, this advancement has not been without its challenges, as evidenced by the current global chip crisis.

The global semiconductor shortage, intensified by the COVID-19 pandemic and geopolitical tensions, has exposed vulnerabilities in the supply chain and underscored the urgent need for increased production capacity. Semiconductors are indispensable in modern life; without them, the functionality of smartphones, computers, medical devices, automobiles, and countless other technologies would be severely compromised. Our reliance on semiconductors means that living without them is not a feasible option in today's interconnected and digital world.

India's role in the semiconductor trade has become increasingly significant in this context. The country's strategic initiatives and legislative measures, such as the National Policy on Electronics 2019 and the Production Linked Incentive (PLI) Scheme, aim to enhance domestic semiconductor manufacturing and position India as a critical player in the global market. A thorough analysis of these policies was necessary to assess their effectiveness in enabling India to become a global semiconductor hub.

This conclusion emphasizes the critical importance of semiconductors in today's technology-driven world and outlines India's strategic role and future prospects in this essential industry. Through a comprehensive evaluation, the chapter provides insights into how India can continue to grow and lead in the global semiconductor landscape, ultimately contributing to a more resilient and sustainable semiconductor supply chain.

8.2 FINDINGS

In today's interconnected world, semiconductors play an indispensable role across diverse industries, underpinning the functionality of modern electronics and technological advancements. These tiny yet powerful components are fundamental to the operation of computers, smartphones, and a plethora of digital devices. They enable the processing, storage, and transmission of data with unprecedented speed and efficiency, supporting critical applications in telecommunications, healthcare, transportation, and beyond. As society continues to embrace digital transformation, semiconductors remain pivotal in driving innovation, enhancing productivity, and shaping the trajectory of technological progress worldwide.

History and Evolution of Semiconductors and their Significance in the Modern World: The history of the semiconductor trade dates back to the mid-20th century, characterized by pivotal breakthroughs in materials science and electronics. Semiconductors were first used in early transistors and later integrated circuits, revolutionizing computing and communication technologies. The invention of the first working transistor by John Bardeen, Walter Brattain, and William Shockley at Bell Labs in 1947 marked a transformative milestone in the electronics industry.

Before establishing the World Trade Organization (WTO) in 1995, the semiconductor sector operated within a segmented and less regulated global trade environment, facing varying trade rules and challenges related to liberalization. The landscape changed significantly with the Information Technology Agreement (ITA) signed in 1996. This landmark agreement, involving 82 members and covering 97% of global trade in IT products, committed participants to eliminate tariffs on specified IT products, including

semiconductors. The ITA has played a crucial role in facilitating more straightforward global trade and fostering growth within the semiconductor industry.

In addition, the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), also adopted as part of the WTO agreements, provides a framework for protecting intellectual property rights crucial to the semiconductor sector. This framework establishes strong legal mechanisms to protect intellectual property rights associated with semiconductor designs and technologies. Such protections are essential for encouraging innovation, attracting investment, and promoting fair competition in the global semiconductor market.

Today, the semiconductor industry thrives in a more interconnected and regulated global trade environment. Major players such as Taiwan Semiconductor Manufacturing Co. Ltd. (TSMC), Intel Corp. (INTC), Samsung Electronics Co. Ltd., Micron Technology Inc., Qualcomm Inc., Broadcom Inc., SK Hynix Inc., Texas Instruments Inc., Toshiba Corporation, and Maxim Integrated Products Inc. lead the industry, leveraging technological advancements and benefiting from supportive international trade agreements like the ITA and TRIPS. Semiconductors remain indispensable in a wide array of applications, spanning industries such as smartphones, computers, medical equipment, and renewable energy systems. They enable advanced functionalities, enhance connectivity, and drive innovation across various sectors. As global demand for electronics continues to grow, the semiconductor trade remains indispensable in powering the ongoing digital revolution and shaping the future of technology.

Causes of Global Chip Crisis: The global chip crisis has resulted from complex factors affecting semiconductor production and supply chains worldwide. The COVID-19 pandemic caused shortages in labor and disruptions in logistics, which impacted semiconductor manufacturing at a time when demand was rising due to the shift to remote work and increased dependence on personal computers. At the same time, the automotive industry, which relies on advanced chips for modern vehicles equipped with numerous Engine Control Units, saw increased demand for chips after the pandemic. Geopolitical tensions, especially in relations involving the US and China, introduced trade barriers that complicated global supply chains, leading to additional delays and

shortages in semiconductor production. The US's efforts to promote domestic semiconductor manufacturing and restrict chip exports to China, with the goal of preventing military use, clashed with China's aspirations to lead in semiconductor technology. External disruptions such as the Texas Winter Storm and geopolitical unrest involving key semiconductor material producers like Russia and Ukraine worsened the crisis. As a result, the global chip shortage disrupted various industries and hindered technological innovation due to limited chip availability.

Challenges of India in its quest to become a Global semiconductor: India faces significant challenges in establishing itself as a major player in the global semiconductor industry. One of the main obstacles is the lack of a well-established legacy and experience in semiconductor manufacturing, which requires significant investments and time to build manufacturing capabilities. The shortage of skilled labor further complicates this, hindering expansion and innovation. Due to these constraints, India also struggles to establish new semiconductor manufacturing facilities and upgrade existing ones. To tackle these issues, India must initially rely on importing expertise from abroad to train local talent in specialized semiconductor manufacturing processes. Additionally, the semiconductor industry heavily relies on rare earth elements and critical minerals, most of which are controlled by China in the global supply chain. This dependence exposes India to risks such as supply chain disruptions, price volatility, and geopolitical tensions, which pose significant challenges to achieving self-sufficiency in semiconductor production. Furthermore, the lack of advanced manufacturing infrastructure and the substantial water demands of semiconductor production further complicate India's ambitions in this sector. These challenges underline the complexities India must navigate to establish a competitive position in the global semiconductor market.

Policies and schemes to tackle the global chip crisis: India has implemented a series of strategic policies and schemes aimed at mitigating the global chip crisis and bolstering its semiconductor manufacturing capabilities. The National Policy on Electronics 2019 focuses on incentivizing advanced projects such as semiconductor facilities, display fabrication, photonics, and LED chip units. A cornerstone initiative, the Production Linked Incentive (PLI) Scheme, offers substantial financial incentives to boost domestic manufacturing across the electronics value chain, strongly

emphasizing electronic components and semiconductor packaging. The India Semiconductor Mission provides significant fiscal support, covering up to 50% of project costs for approved applicants in segments like Semiconductor Fabs and Display Fabs. The Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) plays a crucial role by providing a 25% financial incentive on capital expenditure for electronic components and semiconductor fabrication units. Additionally, the "Chips to Startup" (C2S) Programme aims to train 85,000 professionals in VLSI and Embedded System Design over five years, enhancing India's capabilities in semiconductor technology. Complementing these efforts, the "Make in India" initiative aims to streamline business procedures and create a conducive environment for semiconductor manufacturing investment, thereby reinforcing India's commitment to tackling the global chip shortage and nurturing a thriving semiconductor sector.

8.3: SUGGESTIONS AND CONCLUSION

India has made significant progress in developing its legal framework and policies to establish itself as a global semiconductor hub. However, there are several challenges that still need to be addressed. The National Policy on Electronics 2019 serves as a strategic plan, providing incentives to promote semiconductor projects and attract investments in critical areas such as display fabrication, photonics, and LED chip manufacturing. The Production Linked Incentive (PLI) Scheme plays a crucial role by offering substantial financial incentives to boost domestic manufacturing in the electronics sector, including essential semiconductor components for global supply chains. Additionally, initiatives like the India Semiconductor Mission provide important fiscal support for semiconductor fabs and related facilities to enhance India's manufacturing capabilities in this high-tech sector.

Nevertheless, challenges persist, particularly in addressing the need for a skilled workforce capable of meeting the demands of semiconductor production. While the "Chips to Startup" (C2S) Programme aims to develop expertise in VLSI and Embedded System Design through training initiatives, scaling and deepening this expertise nationwide remains a significant challenge. Moreover, India's reliance on rare earth

elements and critical minerals, controlled mainly by China, poses risks to its semiconductor ambitions, necessitating strategies to diversify supply chains and establish international partnerships to ensure secure access to essential materials. Furthermore, the effectiveness of policies such as SPECS, which incentivizes electronic component manufacturing, depends on their implementation and operational efficiency. The "Make in India" initiative, while creating an attractive investment climate, needs ongoing refinement to simplify regulatory processes and reduce bureaucratic complexities.

Several strategic initiatives can be implemented to strengthen India's supply chain resilience for critical materials such as rare earth elements and semiconductor-grade silicon. Firstly, India should invest in developing domestic capabilities for extracting, refining, and manufacturing these materials by identifying viable sources within the country and building the necessary infrastructure. At the same time, forging strategic partnerships with resource-rich nations possessing abundant reserves can diversify supply sources and reduce dependency on single suppliers. Long-term supply agreements should be negotiated to ensure consistent access to these essential materials. Moreover, investing in research and development is crucial to exploring alternative materials or technologies that can decrease reliance on rare earth elements and improve sustainability in extraction and processing. Government support through financial incentives, tax breaks, and subsidies can incentivize private sector investments in domestic production facilities, fostering a conducive business environment. Infrastructure development is equally vital, encompassing robust transportation networks, storage facilities, and efficient power and water management systems to sustain operations. Skill development programs should focus on training a competent workforce proficient in advanced mining and processing technologies, tailored through collaboration with educational institutions and industry experts. Lastly, international collaborations and technology transfers with countries possessing advanced expertise can elevate India's domestic capabilities and competitiveness in rare earth elements and semiconductor-grade silicon production, aligning with global best practices. These integrated efforts aim to strengthen India's supply chain resilience and secure its position in the semiconductor manufacturing landscape.

Simplifying India's regulatory framework for semiconductor manufacturing is crucial to fostering a more conducive business environment and stimulating industry growth. By digitalizing regulatory processes through user-friendly online platforms and portals, we aim to enhance accessibility and transparency while providing real-time updates on application statuses. Clear and regularly updated guidelines ensure stakeholders understand and comply with regulatory requirements efficiently, reflecting current standards in the semiconductor sector. Establishing a centralized single window clearance mechanism streamlines approvals, minimizing bureaucratic delays and optimizing operational efficiency for businesses. Standardizing processes across India's diverse regions promotes consistency in compliance with environmental, safety, and operational regulations, which is crucial for sustaining semiconductor manufacturing operations nationwide. Training programs for regulatory officials and stakeholders are essential to equip them with the necessary skills and knowledge, enabling smoother application processing and effective resolution of industry-specific challenges. Regular consultation with industry experts and stakeholders ensures that regulatory frameworks evolve dynamically, addressing emerging issues and fostering collaborative solutions. Introducing performance metrics holds regulatory bodies accountable, driving continuous process efficiency and effectiveness improvement. Encouraging self-certification empowers semiconductor manufacturers to proactively meet regulatory standards, reducing administrative burdens and facilitating faster business operations. Simplifying the regulatory framework aims to create a supportive environment that promotes innovation, investment, and competitiveness in India's semiconductor industry.

In conclusion, significant policy initiatives and legal frameworks support India's efforts to become a global semiconductor powerhouse. However, persistent efforts are required to overcome existing challenges, including skill shortages, supply chain vulnerabilities, and policy implementation hurdles, to realize India's full potential in this strategically vital industry.

CHAPTER 9

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9.5 LIST OF FIGURES & TABLES

CHAPTER 1 to 3

by Vishakh K A

General metrics

83,463	11,426	691	45 min 42 sec	1 hr 27 min
characters	words	sentences	reading time	speaking time

Score

98

This text scores better than 98% of all texts checked by Grammarly

Writing Issues

119	6	113
Issues left	Critical	Advanced

Plagiarism

1 %

5 sources

1% of your text matches 5 sources on the web or in archives of academic publications

CHAPTER 4 to 6

by Vishakh K A

General metrics

98,438	12,914	664	51 min 39 sec	1 hr 39 min
characters	words	sentences	reading time	speaking time

Score

This text scores better than 96% of all texts checked by Grammarly

Writing Issues

198	9	189
Issues left	Critical	Advanced

Plagiarism

52 sources

7% of your text matches 52 sources on the web or in archives of academic publications

CHAPTER 7 to 8

by Vishakh K A

General metrics

32,059	4,189	208	16 min 45 sec	32 min 13 sec
characters	words	sentences	reading time	speaking time

Score

This text scores better than 96% of all texts checked by Grammarly

Writing Issues

63	4	59
Issues left	Critical	Advanced

Plagiarism

6 sources

1% of your text matches 6 sources on the web or in archives of academic publications