Pakistan National Semiconductor Plan

January 2022

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Foreword

Semiconductors are the key enablers of modern electronics and are responsible for the advances made in communications, healthcare, agriculture, transportation, energy, computing, and so much more. Today's semiconductor technology has greatly affected our world and increased our quality of life in countless ways. We now have the Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), and 5G to name just a few. There are infinite applications where these can be applied to not only improve our lives but to save our lives.

Availability and access to semiconductors is critical to economic growth, national sovereignty, and global competitiveness. Pakistan has much to gain by pursuing and achieving semiconductor independence.

It is a great pleasure and honour to present the Pakistan National Semiconductor Plan (PNSP).

This plan has been prepared as a roadmap for Pakistan to build a strategic capability over a long period of time such that all semiconductor needs of the nation are either met by local indigenous design and/or manufacturing, or by creating access to a secure supply of design and/or manufacturing capability of these critical components.

We would like to thank all who contributed to creating the Pakistan National Semiconductor Plan and for providing their expertise in the various subcommittees. We would also like to thank all of the colleagues in various Pakistani universities and diaspora in silicon for their contributions.

Finally, we would like to especially thank the President of Pakistan, the Honorable Dr. Arif Alvi, for his encouragement to develop such a plan.

We are looking forward to working with each and every key stakeholder to further develop this plan. Thank you for your trust and confidence in Global Semiconductor Group (GSG).

Sincerely,

Dr. Naveed Sherwani
Chairman, GSG
On Behalf of the PNSP Team

Authors and Subcommittees

This plan is the collaborative effort of a team of experts in various disciplines across many geographies. We have professors, researchers, business executives, and other practitioners with vast and diverse experience in the semiconductor field. Without the effort of this team, it would not have been possible to put together such a comprehensive proposal in such a short time.

We thank all of our authors for their contributions and timely turn around of various content when required.

Dr. Naveed Sherwani
Chairman, Global Semiconductor Group

Dr. Naveed Sherwani is a well-known semiconductor industry veteran with over 30 years of entrepreneurial, engineering, and management experience. He is widely recognized as an innovator and leader in the field of design automation of ASICs and microprocessors. Naveed has founded or co-founded over eleven silicon companies and raised over $850M over 15 funding rounds from marquee venture capital firms over the course of his career. For his services in Pakistan, Dr. Naveed Sherwani was awarded Sitara-e-Quaidazam in 2019, by President Arif Alvi.

Dr. Sajid Baloch
Director General at NECOP

Dr. Sajid Baloch is an eminent personality in IC design and has 30 years of vast experience of working with IC design related industry and academia. He has been awarded ‘EPSON UK’ award and has been conferred Sitara-e-Imtiaz and Tamgha-e-Imtiaz by the President of Pakistan. Dr. Baloch is currently heading National Electronics Complex of Pakistan (NECOP) as Director General. Dr. Baloch is also heading IC Design center at NECOP with more than 100 IC design engineers. Dr. Baloch has tapped out Pakistan’s First Digital Chip which is currently being used successfully in several products.

Prof. Dr. Ahmed Shuja Syed
Vice President (Research & Enterprise) & Founding Executive Director, Centre for Advanced Electronics & Photovoltaic Engineering, International Islamic University Islamabad Pakistan

Prof. Shuja is the Vice President of International Islamic University (IIU), Islamabad. As Founding Executive Director of the Centre for Advanced Electronics & PV Engineering at IIU, he developed a pioneering teaching and research program of Advanced Electronics in Pakistan supported by state-of-the-art facilities including an IS0-5 Cleanroom. Prof. Shuja is also Visiting Professor at James Watt School of Engineering at University of Glasgow, UK. Prof. Shuja holds MS and Ph.D. degrees from Sweden and UK; respectively, and maintained very close collaborative linkages with some of the world’s most renowned scientific facilities and semiconductor industries including the Lawrence Berkeley National Laboratory, Department of Energy, USA. Prof. Shuja is reflected on many national and international committees on scientific planning and policy interventions.

Dr. Roomii Naqvi

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Dr. Roomi Naqvi is the silicon architect and process technologist at Intel Foundry Services, Intel Corporation. He has over 28 year of experience in IC/SoC design. He is also professor of practice at Usman Institute of Technology University and is the director of the Microelectronics Research Lab leading research on RISC-V based cores/SoC for IoT/ML.

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Professor, Director of IC Design Lab, FAST-NUCES, Islamabad

Dr. Rashad Ramzan received an M.Sc. degree from the Royal Institute of Technology, Stockholm, Sweden, and his Ph.D. degree from Linkoping University, Sweden in 2003 and 2009 respectively. He has worked in industry in the US, Germany, and Pakistan for more than 10 years. He has authored over 80 US patents journals and conference papers. One of his designed LNA was published in ISSCC 2007. He is a recipient of two best paper awards and two chancellor innovation awards. His current research interests include VLSI design, RFICs, and RF sensors.

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Principal & Dean, Research Institute for Microwave & Millimeter-Wave Studies (RIMMS), National University of Sciences & Technology (NUST)

Dr. Hammad M. Cheema is a professor of electrical engineering and dean of an interdisciplinary graduate school at NUST, Islamabad. He has more than 12 years of teaching and research experience in analog & RF IC design, and has published books on 60GHz CMOS PLLs and on-chip antennas. He has written more than 70 peer reviewed publications and has 12 granted/pending patents.

Mr. Farhat Jahangir

Partner, Chief Manufacturing Officer, GSG

25 years of experience in semiconductor manufacturing, operations, and business development. Farhat is known in the industry for his semiconductor IC manufacturing & operations skills for delivering rapid and substantial change & growth. He has deep operational expertise in leading Foundry, Assembly & Test technology. Farhat played a critical role in transforming semiconductor manufacturing operations to profitability in many companies resulting higher margins, successful growth, and IPOs in Nasdaq. His last IPO was at Quantenna Communications in 2016 which was later acquired by Onsemi for $1.1B in 2019.

Farhat is also the CEO of GS Microelectronics. Previously he was responsible for managing $2B+ revenue line at Onsemi's 300mm Fab.

Dr. Syed Arsalan Jawed

Professor / HoD, Department of Avionics Engineering (D.AV.E)
Director - Electronic Devices, Circuits and Systems (EDCAS) Group

Dr. Syed Arsalan Jawed received his bachelor's degree in electrical engineering from NED University, Karachi in 2001. From 2001 to 2003, he worked as a digital design engineer at Avaz Networks, a company working on high-density media processors. He completed his master's degree in SoC engineering from Linkoping University, Sweden, and carried out his master's thesis on Sigma-Delta ADCs at Fraunhofer Institute, Germany. He completed his Ph.D. in 2009 from the University of Trento, Italy, and mainly worked on the development of readout interfaces for MEMS capacitive microphones in collaboration with ST Microelectronics, Italy, and Analog Devices, Denmark. From 2009-2014, he worked at the Institute of Applied Technologies, Islamabad as senior analog IC designer where he was involved in the development of integrated sensor readouts including readouts for MEMS and imaging sensors. He holds several patents and has written for international publications. Since 2014, he has been working as the head of department and director of the Advanced Research Center-Electronic Devices, Circuits and Systems at KIET University, Karachi, Pakistan.

Dr. Muhammad Fahim Ul Haque

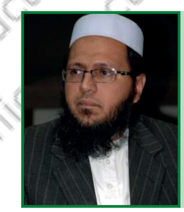
Assistant Professor, Telecommunications Engineering Department at NED University of Engineering and Technology

Dr. Muhammad Fahim Ul Haque has taped out multiple RF power amplifiers and transmitters on various CMOS nodes. He also developed multiple architectures of all-digital transmitters for sub-micron CMOS IC and FPGAs. His research interests are wideband transceiver architecture, RF IC, hardware security, complexity reduction, and deep learning hardware.

Dr. Muhammad Yasir Qadri

Project Director at NECOP

Dr. Muhammad Yasir Qadri obtained his PhD in electronic systems engineering from University of Essex, UK. He has over 18 years of practical experience in the fields of computer architecture, high-end embedded systems, and FPGA-based designs. He has been teaching advanced computer architecture for several years in renowned national institutes at the postgraduate level. He is the editor of a book on multicore technology by CRC Press, USA, and has a US patent granted in the area of computer architecture. His area of specialization is microprocessor design, IC failure analysis and characterization, and energy/performance optimization in reconfigurable MPSoC architectures.



Dr. Saad Ahmed Qazi

Meritorious Professor and Dean of Faculty of Electrical and Computer Engineering, NED University

Dr. Saad Ahmed Qazi is an electrical engineer by profession. He is also the principal investigator at the Neurocomputation Lab under the National Centre of Artificial Intelligence. He earned his M.S. degree from Lancaster University, U.K. in digital signal processing applications in 2002, and completed his Ph.D. at Brunel University, U.K. in 2006. He leads several national and international R&D projects and has worked with World Bank, GCRF, UNDP, UNESCO, HEC and Planning Commission among others. He is the author of several

Dr. Ali Ahmed

Assistant Professor of Electrical Engineering, UITU
Head Micro Electronics Research Laboratory at UITU (MERL-UITU)

Dr. Ali Ahmed's current broader research interests are in computer architecture (RISC-V), IoT, and information security. He has 10+ years of experience in the complete product development cycle of CoTs (hardware and software). His undergraduate students at MERL- UIT have taped out collectively nine RISC-V- based SoCs and other custom designs in open source Google Shuttle.

Mr. Ali Sana

Director of Corporate Development, GSG

Ali currently manages corporate development and investor relations at GSG and its portfolio companies. He has assisted in and led venture capital raises in semiconductor companies totaling over $320M over the past four years. Ali has helped to establish and then lead strategic cross-border development of eight corporate groups from founding and early stage to a combined enterprise value of over $3.2 billion over the past 5 years. Ali evangelizes open source and has over 10 years of industry experience. Prior to GSG, Ali worked at a boutique investment firm and Citibank. Ali holds an honors law degree from University of Kent, UK.

Mr. Aly Fahd

Head of Sourcing (Strategic Silicon), KeepTruckin

Aly Fahd has 15+ years experience in engineering, partnership and business development, and supply chain management of semiconductors for technology companies such as KeepTruckin, Amazon, Calix, Juniper and Hitachi. He has 20+ global patents granted and/or in filing. Aly holds an MBA from Cornell University and an MS in mechanical engineering with a focus on design and manufacturing from Southern Methodist University.

Dr. Hashim Raza Khan

Associate Professor, Electronic Engineering Department at NED University of Engineering and Technology

Dr. Hashim Raza Khan has hands-on experience designing RF power amplifiers on various CMOS nodes. He develops multiple power-efficient RF power amplifier architectures for sub-micron CMOS ICs. His research interests are power amplifiers, IoT devices, power electronics, and neuromorphic ICs.

Mr. Kashif Inayat

PhD Researcher at System on Chips Lab, Incheon National University

Kashif Inayat received his M.S. degree in electronics and computer engineering in 2019 from Hongik University, South Korea. He is currently a registered researcher at Samsung Electronics and pursuing his Ph.D. in electronics engineering at Incheon National University on Samsung Research Funding and Incubation Center for Future Technology (SamsungFTF) funded projects related to hardware-software co-design for AI SoCs. His current research interests include neuromorphic computing, machine learning accelerators, computer arithmetics, and information security.

Subcommittees

In order to develop the Pakistan National Semiconductor Plan, the team of authors created four subcommittees:

1. Academic and Research Subcommittee:

The focus of the academic and research subcommittee is to identify programs that can strengthen the ability of Pakistan's universities and to support the PNSP. The contributing members include:

- Dr. Ali Ahmed
- Dr. Hammad M. Cheema
- Dr. Muhammad Fahim Ul Haque
- Mr. Kashif Inayat
- Dr. Syed Arsalan Jawed
- Dr. Hashim Raza Khan
- Dr. Muhammad Yasir Qadri
- Dr. Rashad Ramzan
- Dr. Ahmed Shuja Syed

2. Development of Human Resource Subcommittee:

The focus of the human resource subcommittee is to identify programs that ensure graduates become productive members of the design centres. They will be provided distinct training for jobs with specific skill set requirements. The contributing members include:

- Dr. Sajid Baloch
- Dr. Roomii Naqvi
- Dr. Saad Ahmed Qazi
- Dr. Naveed Sherwani
- Dr. Ahmed Shuja Syed
- Dr. Ali Ahmed

3. Industry Incentives Subcommittee:

The focus of the industry incentive subcommittee is to put together an incentives plan that attracts US and Chinese chip companies to open their design centres in Pakistan. The contributing members include:

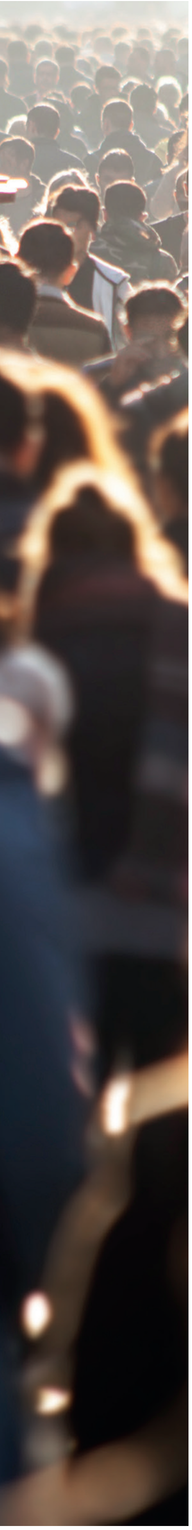
- Dr. Sajid Baloch
- Mr. Aly Fahd
- Dr. Naveed Sherwani

4. Manufacturing & OSAT Subcommittee:

The focus of the manufacturing & OSAT subcommittee is to identify low-cost semiconductor manufacturing opportunities for Pakistan. The contributing members include:

- Mr. Farhat Jahangir
- Dr. Muhammad Yasir Qadri
- Dr. Ahmed Shuja Syed
- Dr. Ali Ahmed

Acknowledgements



Contributions to this report are not limited to just our authors but to a large supporting network of visionaries who each played a crucial role in the final outcome.

Here we acknowledge the contributions of our ambassadors - past and presently serving, consulate officers, and various ministers and secretaries in different departments at both the federal and provincial level. We also acknowledge the contributions of various semiconductor institutions that helped us shape this plan. We apologize for simply listing the names and not the contributions due to the short time frame.

Honorable Mr. Mohammad Sarwar, Governor, Punjab
Mr. Fawad Chaudhry, Federal Minister of Information, Pakistan
Mr. Yassir Humayun, Provincial Minister of Education & IT, Punjab, Pakistan
Honorable Mr. Asad Majeed Khan, Pakistan Ambassador to USA
Honorable Mr. Moin Ul Haque, Pakistan Ambassador to China
Honorable Mr. Aizaz Ahmad Chaudhry, Former Pakistan Ambassador to USA
Mr. Amer Hashmi, Chairman, STZA, Pakistan
Mr. Jamal Ansari, Chairman, Lahore Technopolis
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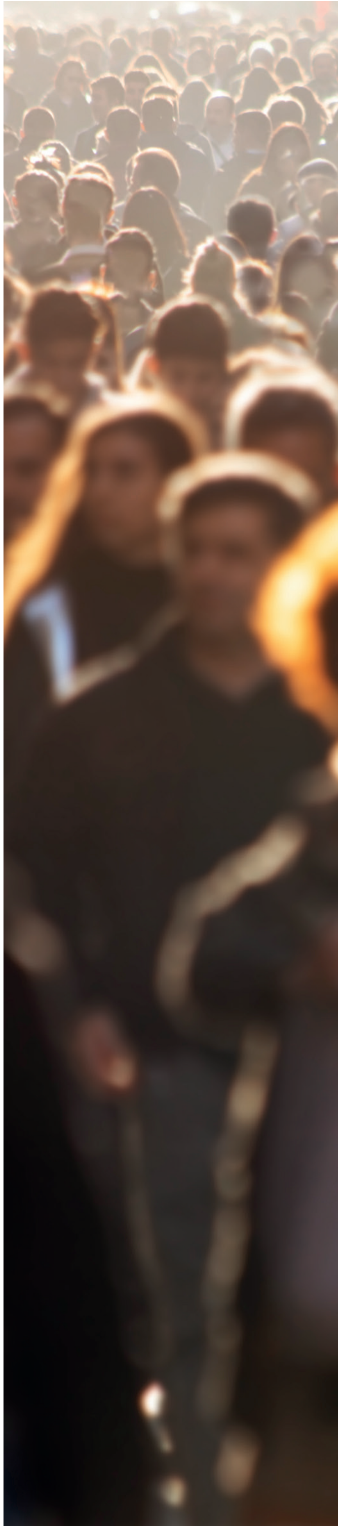


1. Executive Summary

Semiconductor technologies have now become essential to all aspects of modern society. No country can sustain its economy or grow without such technologies. In addition, since such technologies play a crucial role in defense, the availability and command on the use of such technologies become an issue of sovereignty.

In this document, we present the Pakistan National Semiconductor Plan (PNSP). Our eight recommendations consist of three broader policies and five specific short-term (2025 plan) recommendations, which propose investments of approximately $240M, including private, public, and private-public partnership (PPP) into the semiconductor sector.

We hope that these recommendations will go a long way to establish Pakistan's semiconductor industry on a firmer footing, grow our human resources, strengthen our research institutions, and increase our collaboration with companies in China, the US, and elsewhere. This will help ensure that Pakistan is on a path to accelerate its semiconductor accessibility and national sovereignty.

The three broad recommendations include:

1. Establish the national semiconductor goal that Pakistan must ensure accessibility to all critical semiconductor technologies by 2050
2. Establish a cabinet-level task force, headed by a czar, to implement these goals with short (2025), medium (2030), and strategic long-term plans (2050).
3. Establish offices at key consulates headed by special officers with a specific mandate of growing semiconductor businesses in Pakistan

The five specific recommendations include:

4. Establish a private nonprofit association, the Pakistan Semiconductor Association (PSA), to work with all stakeholders and promote Pakistan's semiconductor businesses both within and outside of the country
5. Invest in universities to upgrade semiconductor education and research with PNSP-focused programs in six hubs
6. Invest in Advanced Training Institutes (ATI) to train the human resources so that it can productively work in international level design centres
7. Invest to incentivise Chinese and US companies to establish design centres in Pakistan
8. Invest in a package and test business as the first step into semiconductor manufacturing

2. Objectives and Approach

This study, conducted by the Pakistan National Semiconductor Plan team, examines Pakistan's semiconductor sector capabilities, needs, and opportunities, and is based on over hundreds of hours of research and group interviews with the industry sector and academic leaders.

The primary objective of the study was to determine if, where, and how Pakistan might more meaningfully participate in the global semiconductor value chain. The methodological approach was to establish two primary streams of questions:

1. The first set of questions and analysis focused on ascertaining Pakistan's current participation in the sector across the whole value chain and where inhibitors to semiconductor-related business addition and growth arise, including barriers to entry.

2. The second set of questions and analysis sought to evaluate, place and project Pakistan's existing and potential participation in the semiconductor sector in terms of global competitiveness. This included assessing capability, global market dynamics across a range of value chain positions and end markets, and prospective global market discontinuities where Pakistan may be well-positioned to carve out a niche or leading position.

A synthesis of the findings, guided by these two primary questions, suggested underlying themes, or 'levers', around which actionable policy and implementation initiatives could be undertaken. This included evaluating international case studies for policy options and alternatives. There is a wide range of potential initiatives, each with its own benefits, costs, and risks. The benefits can be maximised where a more comprehensive set of initiatives is adopted.

The analysis of needs and challenges considered the root causes for Pakistan's present low relative standing within the global semiconductor sector. Specifically, we examines the factors that have inhibited Pakistan's participation in this sector.

To accomplish the plan outlined in this study, Pakistan needs a clear semiconductor policy. Such a policy must identify all critical semiconductor technologies and provide a clear plan for ensuring complete access to all such technologies in the future.

3. What are Semiconductors

Semiconductors, often referred to as 'chips', are the electronic 'engines' underlying almost all technology applications, and hence a significant proportion of regional, national and global industry development, economic performance and growth. Chips perform all the calculations in computers (digital logic), industrial control systems in manufacturing, traffic control systems, medical devices, aircraft, to name but a few applications and markets. Other kinds of chips store data, as memory, in computers, servers and data centres. Still other types of chips create and receive radiofrequencies (RF) as the backbone of all wireless communication systems.

> *The rapid pace of change and reliance on semiconductor chips is illustrated by their use in automobiles: chips did not first appear in commercial vehicles until 1968, but today there are over 50 chips in the average car.[1,2] Chips and the related electronics now account for about 40 percent of the total cost of an average car. Electric and autonomous vehicles will likely increase the proliferation and reliance on chips even further.*

Being vital to most defence, space and critical infrastructure systems and applications, capabilities related to chip design, fabrication and intellectual property protection are also of high strategic significance. As one of the most complex products to develop (over 400 separate process steps) semiconductors represent both a key industry and enabler for other industries. As a result, the sector assumes an even greater level of economic, social and strategic importance.[3]

Chips come in many types and are applied in diverse end-use markets, each market with its own set of performance and cost requirements, and market dynamics. The main distinct 'families' of semiconductors, each with their own

[1] Deloitte, 2019, Semiconductors - the next wave. Opportunities and winning strategies for semiconductor companies.
[2] KPMG, 2019, Automotive semiconductors: the new ICE AGE.
[3] For example, see the detailed semiconductor sector analysis, conducted from a US perspective by the Semiconductor Industry Association. Semiconductor Industry Association, 2016, Beyond Borders: The Global Semiconductor Value Chain. Semiconductor Industry Association, 2020, SIA Fact Book, 2020.

market dynamics, are memory, logic, microprocessors, analog, opto-electronic, sensing, and discretes. The functionality incorporated into chips, either in pre-fabrication design or post-fabrication programming, are diverse. Post-fabrication programming allows a chip to be used for many possible applications. These applications are as varied as landing a rocket on Mars, changing traffic lights, running a washing machine, tracking a heartbeat and Global Positioning System (GPS) position, running Machine Learning (ML) and Artificial Intelligence (AI) algorithms, or driving the sensors and connectivity in Internet of Things (IoT) devices and networks.

3.1 Semiconductors are Crucial to All Industries

Semiconductor chips are a critical intermediate good in a vast value chain, which then feeds into multiple industry value chains. The semiconductor sector includes an important set of markets such as: markets in materials (for example, high-grade silicon); capital equipment for manufacturing (where tens to hundreds of specialised pieces of equipment each costing up to US$150M are utilised within a single chip fabrication plant); chip design and architecture, including the use of Intellectual Property (IP) Blocks such as those offered by Arm (a British semiconductor company dominant in mobile phones and tablets); as well as fabrication, test and packaging. Most people conceive of the semiconductor sector as solely focused around 'branded chips' from companies such as Intel, AMD or NVIDIA. Gaining more attention lately due to supply-chain and geopolitical concerns are the 'pure-play' semiconductor fabrication companies, such as Taiwan Semiconductor Manufacturing Company (TSMC). However, the semiconductor value chain extends downstream with more economic profile than it does upstream. Industries affected by the dynamics of the semiconductor sector range from the consumer to industrial, from telecommunications to defence, from transport to medical. Not only is the semiconductor value chain vast in its breadth and multi-market complexity, but it is of large direct and indirect economic consequence.

The global semiconductor market for just the chips themselves is around US$425 billion per year today and by some estimates is forecast to hit US$1 trillion by 2030.[4] However, as an intermediate good, chips are used downstream in a huge variety of equipment and devices – for example, in smartphones, cars, and medical devices. The equipment market incorporating chips is, by some estimates, at least US$4 trillion per annum. [5]

Just as importantly, the chip itself is the result of an elaborate up-stream value chain starting from inputs such as minerals in the ground, through mining, refining and processing into silicon wafers (often 'doped' with rare and critical earth minerals), then fabricated into chips that have been designed with, and utilising, sophisticated tools and engineering expertise. The chip fabrication process is one of the most complex sets of processes for any manufactured good on the planet. Scale, hence large capital expenditures, and high levels of research and development to sustain competitive differentiation, are characteristic of many steps in the semiconductor value chain.

These economic and structural fundamentals have resulted in a fracturing of business models across the value chain over time. Previously the path to market was to design, manufacture and sell the chips all within the one company, the so-

[4] Oxford Economics, 2013, Enabling the Hyperconnected Age: The role of semiconductors, www.semismatter.com/enabling- the-hyperconnected-age-the-role-of-semi conductors. Semiconductor Industry Association, 2020, 2020 SIA Fact Book. Semicon West Conference (Virtual) 2020, presentation by Ajit Manocha, July 2020.

[5] British Broadcasting Corporation, 2020, The humble mineral that transformed the world, accessed November 2020, https://www.bbc.com/future/bespoke/made-on-earth/how-the-chip-changed-everything.

called Integrated Device Manufacturer (IDM) approach still largely exemplified by Intel. The currently ascendant business model duality is for pure-play manufacturers (for example, TSMC) to provide fabrication services to the many hundreds of 'fabless' chip companies (for example, AMD, NVIDIA and Qualcomm) who focus primarily on the design and marketing of chips. Further evolution of the value chain should be expected as competition drives both incremental as well as discontinuous R&D, new market opportunities open up (such as ML, AI and IoT), and new business models are ventured. While 'adopters' of technology resulting from this vast value chain, such as Pakistan, have benefited as much as any other country, it is places, such as Taiwan, that have seen their absolute and relative prosperity soar as they embraced opportunities across the semiconductor value chain. Figure 1 illustrates the semiconductor value chain.

3.2 The Current Semiconductor Landscape

The semiconductor landscape is wide and consists of literally hundreds of types of chips. In addition, there are a host of related products and services that are required in the overall industry, including manufacturing, packaging, testing, IP equipment, and manufacturing materials and business.

The diagram below tries to capture the complexity of the semiconductor industry. Wafer manufacturing is quite complex and capital intensive and, as a result, not recommended for developing nations. On the other hand, the design of chips, IP, package, and test, sometimes referred to as OSAT (outsourced assembly and test), is low CAPEX and suitable for developing nations. However, these steps do require skilled human resources.

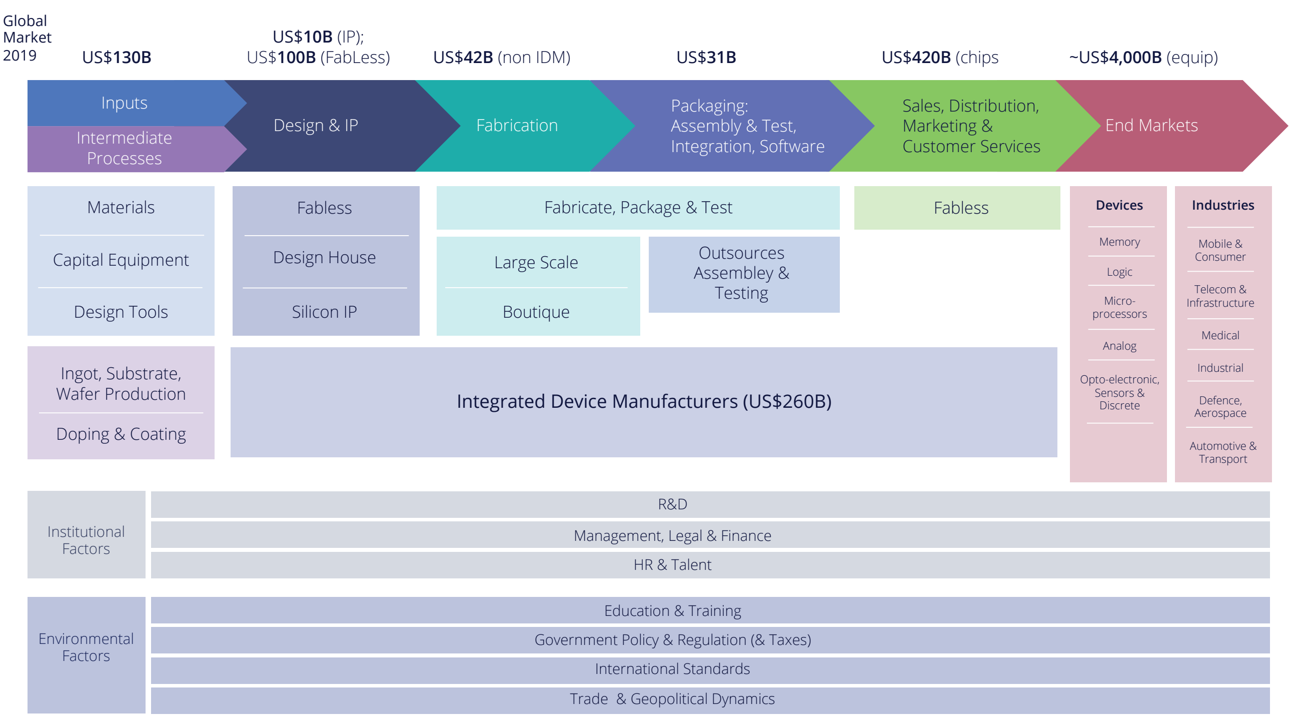


Figure 1: Semiconductor value chain
Note: Global market size estimates in US$ billion. Refer to Appendix 2 for references supporting estimates of market size in 2019.

3.3 Critical Semiconductor Chip Segments

Semiconductors are specialized materials which possess the properties of both insulator and conductor; whereas due to this characteristic the behavior of the device can be controlled i.e., allow the flow of current or not. Semiconductors can be divided in to three main categories i.e. Integrated Circuits (or Chips), Discrete semiconductor devices, and Optoelectronics and sensors. The details are as follows:

1. Integrated Circuits: An IC is an arrangement (or circuit) of components mostly made up of transistors. The ICs can be classified based on their fabrication technology node (i.e. that determines size of transistor) and for most modern ICs, it is specified in nano-meters e.g. 180nm, 90nm, …., 7nm etc. There are several types of ICs such as:

   a. Analog and Mixed Signal (AMS): The real-world is mostly analog, therefore, ICs are used to convert from digital to analog and vice-versa or those which directly deal with analog signals are classified at AMS. AMS ICs are an essential part of Radio-frequency (RF) receivers and transmitters.

   b. Digital Logic ICs: These ICs perform logical operations on input provided to them and produce an output. Some of the most important digital ICs include:

      i. Central Processing Units - CPUs. These chips perform the basic compute function and are central to cloud, servers, laptops, cell phones, etc. These chips fall in 3-4 major types based on architecture. X86 chips are made by Intel and AMD. ARM based chips are made various chip companies including Qualcomm, Apple, Broadcom, etc. A new category of open-Source RISC-V chips are emerging as well.

      ii. Graphics processing units -GPUs. These chips are key to gaming, cloud, AI driven workloads. These chips are made to Nvidia and AMD.

      iii. Field Programmable Gate Arrays – FPGAs. These chips are used for systems where applications may be changing in the field. These are very necessary in almost all systems that work in industrial, defence and other such areas. These chips are made by Altera (acquired by Intel), Xilinx (acquired by AMD), lattice, Microchip, Gowin, Rapid Silicon and others.

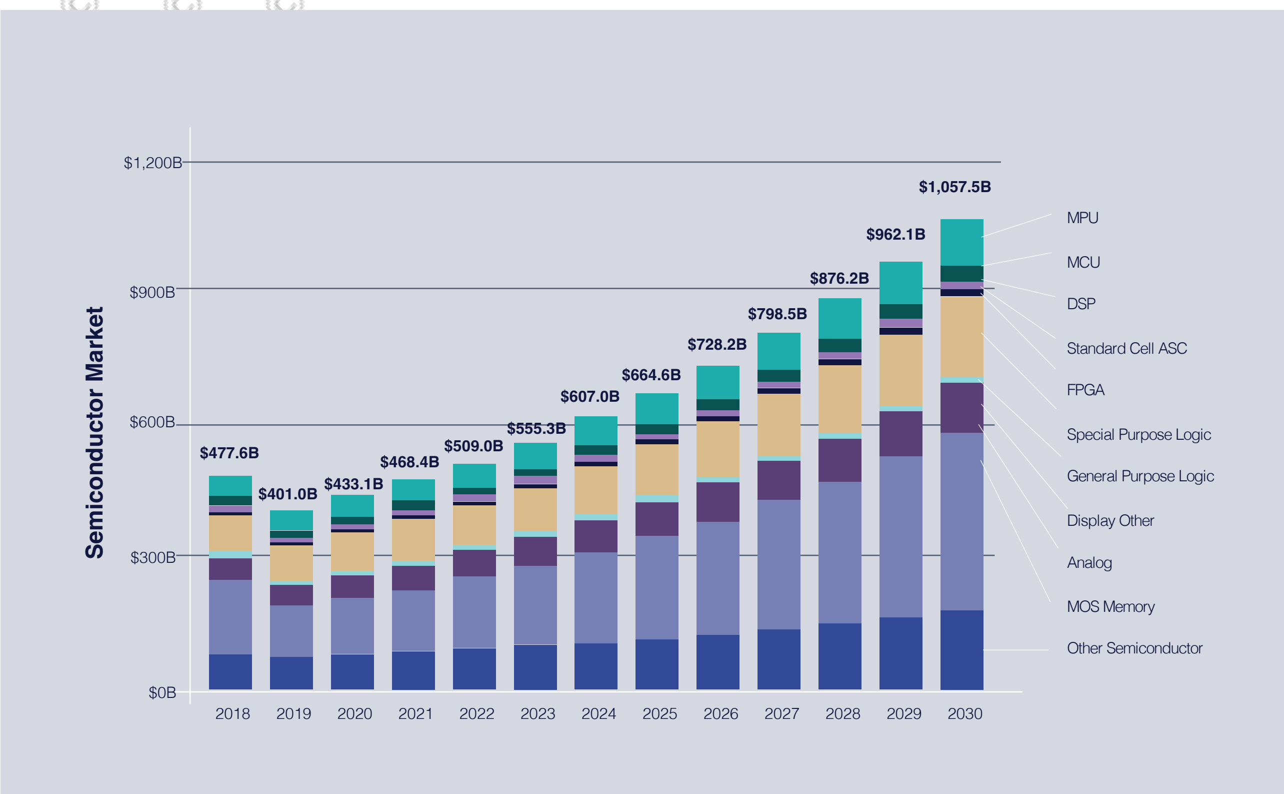
      iv. Micro controller units – MCUs. Such chips are used for low level Control functions in applications such as edge computing, industrial controls etc. such chips are made by NXP, Renesas, and others.

   c. Memory ICs: These ICs are used to store digital information. Some of the most common memory technologies are: Dynamic Random-Access Memories (DDR), NAND flash memories, etc.

2. Discrete Semiconductor Devices: These are devices or components that are available as a single unit in an individual package e.g. Diodes, Transistors, etc.

3. Optoelectronics and sensors: These components are used to detect or produce light. One of the most common components of this class is Light-emitting-Diode or LED.

It is pertinent to mention that, for most of the aforementioned semiconductors the design cycle and EDA tool suites vary from type to type. Dedicated streams of courses can be designed to target each area of semiconductor specialization. As it is cleared from figure below, almost all areas of semiconductors show a steady growth in terms of market size.



Source: SEMI 2020

According to SEMI 2020 report, the semiconductor market will be $1 Trillion in 2030. Pakistan cannot afford to not participate in a massively growing industry. Pakistan can look to countries like India for short-term growth in design centres and long-term growth in manufacturing.

4. Semiconductors & National Prosperity

The semiconductor sector continues to be a global engine for technology, economic, and social progress. Countries with long-term participation in the semiconductor sector, such as the US and Japan, have enjoyed corresponding levels of economic prosperity. Other countries like Taiwan, Singapore, and South Korea have implemented deliberate national industrial policy strategies and initiatives to participate in the semiconductor value chain and rise in prominence and significance. These comprehensive national-based policies have leveraged and accelerated the existing and emerging comparative and competitive advantages held by each country. The third groups of countries, including Malaysia, Vietnam, India, and the Philippines, have more recently created a presence in the semiconductor sector, utilizing different value chain insertion approaches.[6] The historically fragmented European Union (EU) market now appears to be gathering a more coordinated and unified set of initiatives.[7]

Pakistan is lagging in semiconductor value creation, delivery, and capture, and is lacking strategic supply chains and security profiles in one of the world's most technologically significant and challenging sectors.

The following case studies identify Taiwan's rise over the last 35 years that pursued deliberate, consistent, long range and successful, governmental policy, targeted assistance and capability-building to significantly advance their participation in the global semiconductor value chain, and India's rise to prominence in the semiconductor industry via human resources.

[6] A useful general introduction to global value chain analysis, insertion and upgrading options is presented in Gereffi and Fernandez-Stark, 2016, Global Value Chain Analysis: A Primer.
[7] Individual national efforts (and differences) within the EU have provided isolated successes, a number of which continue to reap benefits today for their individual countries and regions.

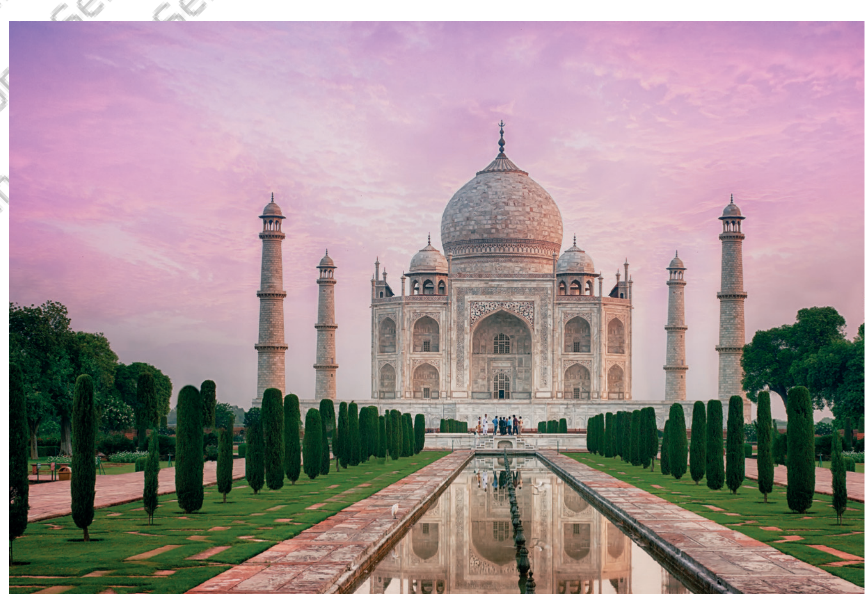
4.1 Taiwan Case Study

Taiwan's share of the semiconductor market has increased from almost zero in the early 1990s to seven percent in 2014 and to over 50% today

In 1987, the Taiwanese government led a strategic investment in TSMC, which contributed to momentous growth in the semiconductor industry across the country. The government further assisted the burgeoning venture by securing a license to important, matured manufacturing technology from the US. Via ITRI International, the government funded a team to go to the US for six months to undertake the know-how and technology transfer process. Although this manufacturing technology was two generations behind what was considered cutting-edge in the US and Japan, the TSMC team with the support of the Taiwanese government, carved out a new business model that steadily attracted a diverse group of chip designers to utilise TSMC's facilities. In November 2020, TSMC's market capitalisation exceeded US$400 billion, with an annual revenue of over US$35 billion and growing over 20 percent per year. Due to the investment of the government and the presence of TSMC, key industry players were attracted to the region, including ASE, which is the world's largest package and test vendor (OSAT). Taiwan's share of the semiconductor market has increased from almost zero in the early 1990s to seven percent in 2014 and over 50% today. The industry is also making a significant contribution to Taiwan's GDP.

In summary, investments by the government that were made 35 years ago made Taiwan one of the most critical and strategic regions in the world, sitting at the top of the entire semiconductor supply chain.

4.2 India Case Study



In the early 1990's, India did not have a presence in the semiconductor industry. However, the country had top-notch educational institutions such as IITs that offered microelectronics and chip design classes at both the undergraduate and graduate levels. By the late 1990's, India had acquired another asset - hundreds of citizens who were now working at leading semiconductor companies across the US and reaching executive-level positions. At the same time, the US semiconductor industry, startups in particular, exploded, which resulted in the dire need to increase headcount for chip design. The leading managers naturally looked to Bangalore, Delhi, Pune, Ahmedabad, and others. The number of design centres went from a few to hundreds in a matter of five to seven years. Today, all major semiconductor corporations such as Intel, AMD, NVIDIA, Qualcomm, Broadcom, Marvel, Juniper, Cisco, Samsung, and others have large design centres across India. In addition, consulting companies, like Wipro Data Consulting, built service employment systems that employed hundreds of thousands of people.

The number of design centres went from a few to hundreds in a matter of five to seven years.

In summary, India's investment in education and its critical link to the US provided the opportunity for India to thrive. This is a completely different approach to Taiwan, but the end result still created a windfall for India making it one of the most strategic global players in the semiconductor industry.

5. The Role of Government and Private Sector

Historically, economic arguments based on national economic benefit alone could have justified much deeper and substantial investments by Pakistan into the semiconductor sector. Today, strong new arguments can be made based on broader economic assessment frameworks (China & US Trade War), and increasingly on national security and strategic grounds to forge greater participation in global 'apex' value chains such as the semiconductor sector.

Pakistan is a developing nation that does not have deep pockets. It does not have an ecosystem that can invest in semiconductor manufacturing, hence the focus should be on design and light manufacturing, like OSAT. To enable design, we see a complementary effort between the government and the private sector.

The role of the government is to set policies, define and set national goals, streamline processes between ministries, and ensure maximum efficiency and ease of business operations. The government may provide lease land or facilities to minimize the set-up and operational cost of design centres. Since a large part of education is government-supported, the government also has an important role to play in investing in public universities and training institutions. Since customs and taxation are considerable concerns to businesses, the relevant government agencies should also focus on creating policies on minimum or zero taxes and zero-in, zero-out custom policies. However, we do not foresee the government directly investing in design centres or manufacturing.

The role of the private sector is to establish training centres, design centres, and light manufacturing. This includes planning, fundraising, development, and operations of such facilities. The private sector should seek international collaboration with design and OSAT companies and work closely with the training centres to ensure the availability of high-quality and properly trained human resources.

6. Opportunities, Challenges, and Policy Recommendations for Pakistan

In examining where Pakistan's semiconductor sector-related capability existed in 2021, this study focused on the commercial sector (as distinct from the public research sector). As a whole, Pakistan's existing participation in the global value chain is well under weighted for an economy of its size and maturity. During consultations, many challenges were highlighted to account for this low participation.

6.1 Challenges

In the semiconductor space, Pakistan is certainly a newcomer. It does not have a rich history of semiconductor companies and faces several challenges in the semiconductor space. The challenges Pakistan faces include:

1. Pakistan does not have a good reputation when it comes to the ease of setting up and operating a business. This can be overcome by highlighting the recent changes in ease of doing business in Pakistan.

2. Design centre owners have expressed concerns about finding high quality facilities and infrastructure with good power, AC, parking, security, etc. This can be addressed by the government pursuing policies that develop high quality facilities and make them available to foreign design centres at low to no cost.

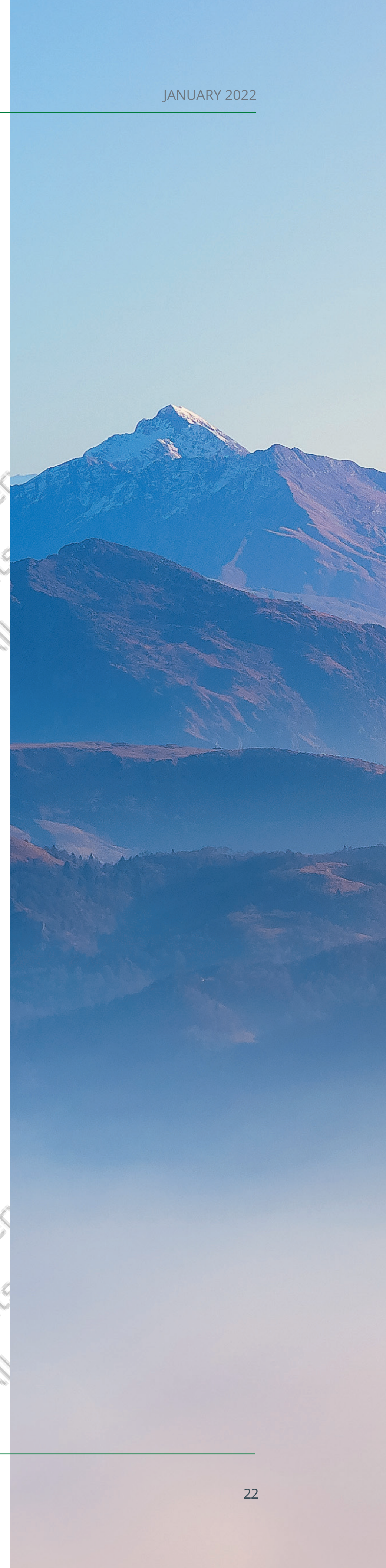
3. Pakistani universities are not producing graduates who are trained to work on chip design. This can be addressed by setting up advanced training centers that will help bridge the gap between academia and industry.

4. Pakistan does not currently offer incentive plans to encourage chip design companies to start design centres. This can be solved by offering world-class incentives that help bring US and Chinese design companies to Pakistan.

5. Pakistan is not competing on the world stage as a suitable destination for semiconductor design centres. This can be addressed by effective marketing campaigns that highlight Pakistan's abundant talent and low cost structure as an attractive location for design centres.

6. Pakistan does not have enough senior executives in the US and China to create pathways for destination design centres. This can be addressed through a collaborative effort between consulate in key cities (Silicon Valley, Beijing, Shenzhen, and Shanghai) and Pakistani semiconductor diaspora.

7. Pakistan has a complex custom regime that is difficult for companies to navigate through and can be quite expensive by international standards. This can be simply addressed by implementing a one-stop shop with a zero-in, zero-out policy.



6.2 Opportunities

Pakistan has a unique opportunity to become the next best destination for semiconductor design centres and manufacturing because of the large pool of low-cost human resources.

This unique opportunity has now become a historic moment in time due to the US China trade war. The issues related to chips and silicon technologies are at the heart of trade conflict between China and the US. This conflict is likely to expand in scope, forcing other nations to choose their alignment in this conflict.

China clearly has a weak hand in this conflict. While China has tried to compete, it is 10-15 years behind the US. The response by China to its trade war with the US is unprecedented. It started a national effort supported by $300 - $400B to establish thousands of companies in all conceivable aspects and sectors of semiconductors. The companies required a large amount of trained headcount, currently estimated at 500,000, over next 3-4 years. China does not have most of this headcount, and potentially cannot produce it fast enough. Hence, it must be found elsewhere in friendly countries, which rules out India.

Pakistan can be a source of a significant part of this headcount. We can focus on two specific directions:

1. Chinese companies (and US companies to some extent) should be encouraged, via tax incentives and other programs, to start their design centres in Pakistan. This will only happen if low cost and well-trained human resource is available.

2. We should also create favourable policies to export our headcount to work in Chinese companies.

The US has an almost identical but less severe problem with a headcount of 100,000 needed over the next 3-4 years. US companies have traditionally outsourced to India, Vietnam, and South-East nations but this has still failed to meet the growing demands of the US companies. This is simply due to the supply and demand effect in that the global demand is growing far ahead of supply within the existing markets. Therefore, US companies are looking for new design centre locations in new markets. Pakistan can be one such destination.

6.3 Summary of Opportunities and Policy Recommendations

The semiconductor sector has undergone constant change, but the sector's continuing importance and complex dynamics give rise to valuable opportunities in Pakistan. Pakistan must identify the challenges it is facing in the semiconductor sector and utilise its areas of strength to grow Pakistan's participation.

> *Semiconductors are an area of increasing strategic importance and of growing criticality for Pakistan's sovereignty.*

The centrality of semiconductors in the national agenda is key to the economy, trade, and security. As an emerging economy with 65% of the population below 30 years of age, Pakistan must maximally capture the opportunities in the global semiconductor market, which is expected to be $1 Trillion by 2030. Semiconductors are a key focal point in the US/China trade war. This trade war creates opportunities for both sides, and Pakistan is strategically positioned in this matter. We currently see a demand of 100,000 chip designers in the US and 500,000 chip designers in China. The hiring dynamics remain challenging due to rising wages, increased churn and attrition. The global semiconductor market is in urgent need of trained, economically efficient engineering capacity in strategically positioned markets.

We have already engaged with the leading 20 universities with EE programs across Pakistan to create and leverage a global talent pool that can serve the semiconductor market and wider STEM educational needs. This young expert population can be trained at low cost to offer differentiated expertise and engineering capability to the global market. A large number of educational institutions and a very large young population can be trained at a very low cost to participate in the many design aspect of semiconductors.

- Pakistan has a great relationship with both China and the US; hence, it can be a very attractive location for design centres given the difficulties of hiring people in existing locations
- Pakistan should follow the design centre approach for short-term growth due to low capex requirements but invest in semiconductor manufacturing in the long-term
- Even if Pakistan employs 100K design engineers, either in Pakistan or at offshore locations, this can create a potential $3B - $4B in revenue for the nation
- Pakistan does not face significant trade barriers

As a result, we make eight recommendations consisting of three broader policies and five specific short-term (2025 plan) recommendations, which propose investments of approximately $240M, and include private, public, and private public partnership (PPP) into the semiconductor sector.

The three broad recommendations include:

1. Establish the national semiconductor goal that Pakistan must ensure accessibility to all critical semiconductor technologies by 2050
2. Establish a cabinet-level task force, headed by a czar, to implement these goals with short (2025), medium (2030), and strategic long-term (2050) plans
3. Establish offices at key consulates headed by special officers with a specific mandate of growing semiconductor businesses in Pakistan

The five specific recommendations include:

4. Establish a private non-profit association, the Pakistan Semiconductor Association (PSA), to work with all stakeholders and promote Pakistan's semiconductor businesses both within and outside of the country with an investment of $5M over three years
5. Invest $75M in universities to upgrade semiconductor education and research with PNSP - focused programs in six hubs
6. Advanced Training Institutes (ATIs) to train the human resources so that it can productively work in international-level design centres
7. Invest $80M to incentivise Chinese and US companies to establish design centres in Pakistan
8. Invest $65M in a package and test business as the first step into semiconductor manufacturing

The amount of funding mentioned here are estimates made by the PNSP team. The actual amount of funding and disbursement mechanism is to be worked out by the proposed task force.

7. Details of Policy Recommendation

Pakistan needs a clear policy for both semiconductor chip development and the development of silicon technologies. Such a policy must identify the critical chips and related technologies and provide a clear plan that ensures complete access to all governmental and non-governmental Pakistani organisations, entrepreneurs, and developers of such technologies. The policy should be a public-private partnership and have a short-term, mid-term, and long-term impact horizon.

We have eight specific policy recommendations:

7.1 Establish National Semiconductor Goals

No progress can be made on any project without establishing clear and measurable goals with set deadlines. This is even more important for national projects. Establishing a national goal is necessary to align all governmental and private sector resources on the PNSP. We believe our national goal should state that:

> *"Pakistan must ensure secure accessibility to all critical semiconductor technologies either through domestic development/manufacturing or via strategic alignment with other countries with such capabilities no later than 2050."*

This does not mean that we should not have intermediate milestones. In fact, we believe that one short-term and one mid-term plan with specific goals are also needed. We refer to those goals as 2025 and 2030 goals and the corresponding plans as the 2025 Plan and 2030 Plan.

The national semiconductor goals need to be transparent and must be reviewed on a yearly basis to ensure on target execution and to make any adjustments if required.

7.2 Establish a Task Force Headed by a Semiconductor Czar

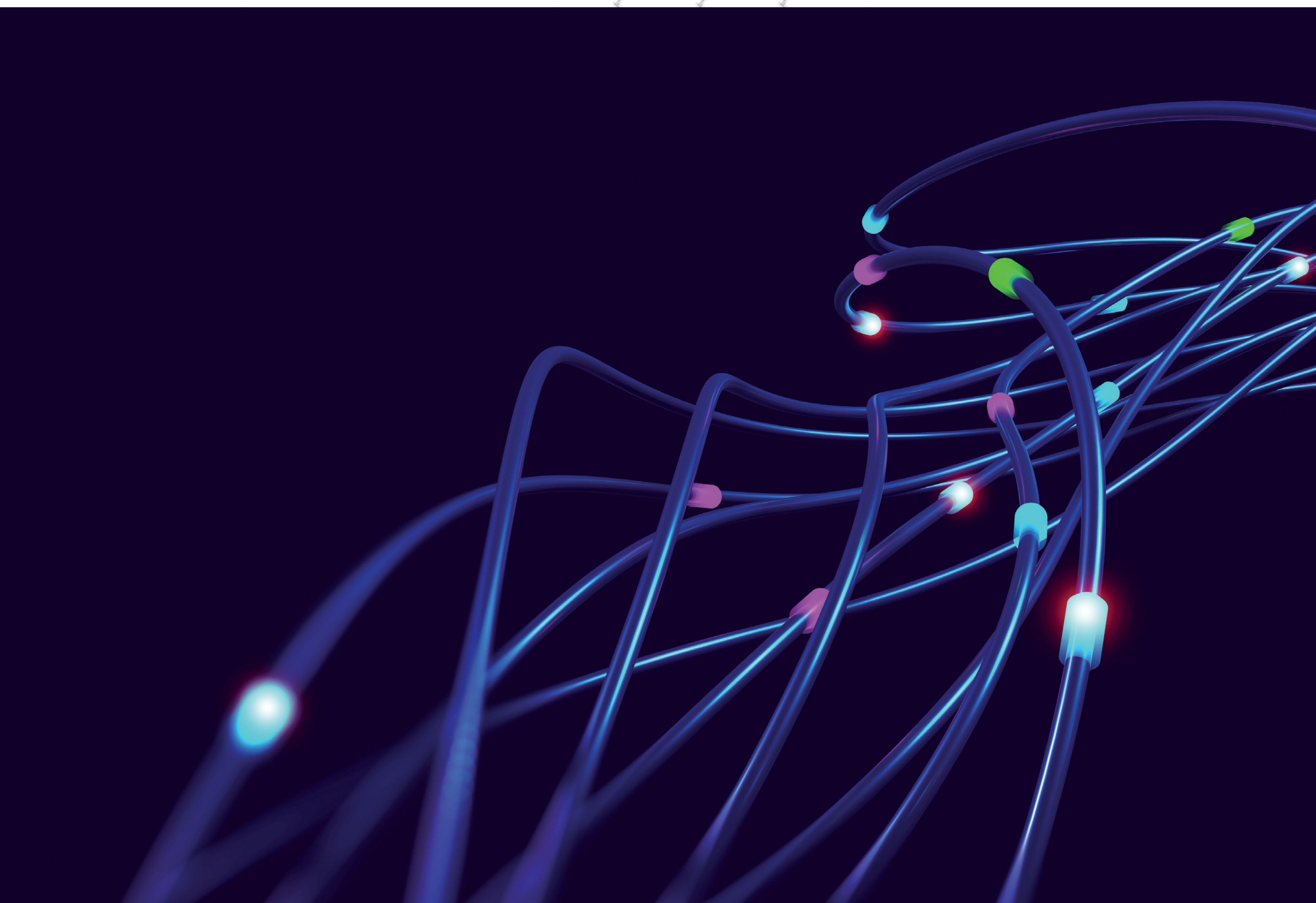
The semiconductor business is complicated and likely to need the support of various experts around the world and various departments, such as MoST, MoIT, MoE/HEC, MoFA, PEC, STZA, CPEC, PM Secretarial, NECOP, FBR, Customs, among others. Hence, coordination among these departments is key to the success of the PNSP. Secondly, this coordination must be done at a high level given the very strategic nature of the PNSP.

We recommend the formation of a cabinet-level task force for semiconductors, headed by a semiconductor czar, and consisting of foreign and domestic experts to ensure well-rounded representation. Such a task force should publish a detailed semiconductor policy and plan to ensure access of critical semiconductors to Pakistan. The semiconductor plan for Pakistan should set goals for chip design and include a short-term 2025 plan, a mid-term 2030 plan, and a long-term 2050 plan.

7.3 Establish Semiconductor Offices at Key Consulates

A key component in the PNSP is to attract Chinese and US design companies to open design centres in Pakistan or hire Pakistani engineers to work in their design centres elsewhere. These design companies need a lot of support and encouragement to make that happen. An international design company's first contact is likely to be Pakistani consulates, either for enquiring about setting up businesses, assessing the availability of trained human resources, learning about customs and trade regulations, or seeking visas.

This is likely to happen in cities with a concentration of semiconductor businesses. However, consulates, if available, are usually understaffed and commercial attaché, and not likely to have experts in semiconductors. In order to resolve this issue, we propose adding a very specific role to the embassies, which is to promote semiconductor businesses in Pakistan. We recommend the establishment of semiconductor coordination and facilitation officers in four consulates - Silicon Valley, Beijing, Shanghai, and Shenzhen. The goal of these officers is to work under the direction of the semiconductor czar and work with government bodies and the Pakistan Semiconductor Association (PSA) in both China and the USA.



7.4 Establish Pakistan Semiconductor Association

This organization will be required to orchestrate all semiconductor activities with various stakeholders and to market Pakistan's semiconductor industry to the world.

1. Establish the Pakistan Semiconductor Association (PSA) to represent all bodies involved in semiconductors (universities, research institutes, design companies and individuals) and all others interested in this field. This includes semiconductor diaspora from the UK, Europe, Korea and China.

2. The first role of the PSA is to market Pakistan as a favourable destination for the semiconductor industry. This will include an aggressive social media campaign, regularly-scheduled webinars and conferences, and coordination of visits by Chinese and American companies to Pakistan.

    a. The second role of the PSA is to drive coordination of semiconductor programs across the nation.

    b. The third role of the PSA is to facilitate bringing more design centres to Pakistan.

    c. The fourth role of the PSA is to recruit Pakistanis to come back to Pakistan and participate in the semiconductor industry.

    d. The final role of the PSA is to help with fundraising for Pakistani semiconductor startups working with OPEN Silicon Valley, PakLaunch, Ejad Labs and others. We can also seek affiliation with the GSA (Global Semiconductor Association) if we choose. We invited the GSA president, Ms. Jodi Shelton, to Pakistan a few months ago, and he left with a great opinion about Pakistan.
        a. Encourage various Chinese and US companies to set up design centres in Pakistan
        b. Identify job opportunities for Pakistani talent in Chinese and US companies
        c. Recruit Pakistani semiconductor experts to relocate to Pakistan

> *We recommend $5M over three years for the support of marketing and other efforts of the PSA, including conferences, webinars etc. We should plan one major news item and action per week for four years. This drumbeat can include announcements of experts visiting Pakistan, the starting of design centers, taping out of chips, seminars, conferences, interments into Pakistani semiconductor startups, and more. This should be primarily led by the PSA marketing office.*

7.5. Invest to Boost Academic and Research Capabilities in Semiconductors

At the foundation of any semiconductor industry is the educational research capabilities of universities. Universities must prepare students with the necessary microelectronics knowledge and skills, but they cannot be expected to prepare them for specific job descriptions at companies. Universities must hire research professors in various areas of semiconductors who are actively working on research projects, request grants, and engage with masters and PhD students. Universities must also establish labs to allow such research to be conducted.

We propose $75M to build a coordinated research plan by supporting 20 national-level (public and private) universities to:

a. $40M for PNSP specific teaching and training by building semiconductor research labs coordinated into six hubs and train professors in specific areas of semiconductor research coordinated with the hubs

b. $4M towards student scholarships that will encourage high-achieving students

c. $6M towards PNSP driven R&D to support for university professors

d. $5M for inviting international semiconductor experts to visit Pakistan and deliver lectures in various institutions and ATIs. The PSA and consulate semiconductor facilitation officers can help orchestrate this influx of experts

e. $20M for research professors to enhance research programs in our universities. Such professors will not only improve the quality of our research, increase collaboration with international researchers, but also increase the probability of more research grants

We understand that each university has a different need due to the nature of its programs. The university programs will identify the specific needs of each university and allocate specific resources. The emphasis will be on using low-cost tools and taping out as many chips as possible.

The details of this program are included in the chart in section 8.

7.6 Invest in Advanced Training Institutes

Universities provide the necessary general education, which needs to be enhanced with specific training that is required to fulfill a job in a design centre. It is not feasible to modify university programs for specific job training for two reasons:

1. The process to modify or introduce new programs has to go through a rigorous HEC review, which can take one to two years

2. Job descriptions change due to the changing needs of the design centres

It is our goal to make the general education as robust as possible to minimize the training needed.
In order to provide training, we propose to set up four Advanced Training Institutes (ATI) in Lahore, Islamabad, Karachi and Peshawar. The ATIs will take output from our universities and provide 6-9 months of real industrial training so that graduates can be productive on the first day. The training will be tailored towards the incoming design centres. It is important to note that ATI is not a degree or certificate granting institute, instead it trains a candidate for a specific job. ATI's can also be used for general skill development or improvement for existing or new employees.

We propose an investment of $20M to develop and operate four ATIs. The money ($3-7M depending on the size of the ATI) will be used over 3-4 years to pay for facilities, trainer salaries, student stipends, tapeout costs, and design tools.

7.7 Incentivise US and Chinese Design Centres

The US and China can open design centres in any part of the world. In order to encourage them to open design centres in Pakistan, there needs to be incentives to help attract large companies to make Pakistan a destination.

We propose an investment of $80M to support 40 design centres. This consists of the following elements:

a) Provide trained human resources as per requirements of the design centre (see 7.6)

b) Invest $20M towards foreign design centres, which will not only reduce cost but simplify the process of establishing high quality facilities. We believe the government should provide assistance with rent, utilities, upgrades, and maintenance.

c) The single largest expense in a design centre is typically the cost of Electronic Design Automation (EDA) tools, which are crucial to the operation of a design centre, generally costing millions. In countries like India and China, it was possible to negotiate a deal with tool vendors that allowed all design centres to access the EDA tools.

In a similar model, we are proposing a $40M investment towards EDA tools. This should be run by a private non-profit entity. This entity should negotiate nation-wide, potentially cloud-based solutions, with EDA companies such as Cadence, Synopsys, and Siemens/Mentor. Some funds should be allocated for buying essential IP and making it available to design centres at low or no cost. Eventually, Pakistan should establish its own IP companies. If implemented correctly, this could be the single largest incentive for Pakistan's semiconductor industry.

d) Provide business setup and facilities to initiate and accelerate the establishment of design centres in Pakistan. A one-stop shop is crucial to incentivise design centre management, which is used for processes in the US and other advanced countries. We must offer a similar or better solution to address this.

e) Establish a zero-in/zero-out policy for all machinery and materials related to design centres to allow for full access. This is one of the biggest concerns of potential design centre management since equipment required for labs and hardware required for the data centres can take months to clear customs and can be very costly given the complex tax and custom regime in Pakistan.

f) The government of Pakistan can offer tax incentives for ten years to US and China design centres to encourage them to establish design centres in the country. This package should be comparable or better than the packages provided by competing nations such as India, Bangladesh, and Vietnam.

g) Invest $20M towards the subsidy of international talent that can help lure semiconductor industry veterans to work and live in Pakistan. This can be addressed by supporting the design centres with salaries of employees. The target is to facilitate 200 foreign experts (potentially of Pakistani descent) to work in design centres in Pakistan.

7.8 Establish OSAT IC Manufacturing Facilities

We propose an investment of $65M in semiconductor chips packaging and test. The goal is to build a 50,000 sq. ft facility with a clean room for standard wire-bond, advanced flip-chip, & hybrid packaging. This should start by meeting all Pakistan local needs plus to support international multinational customers to generate revenue for Pakistan. We should require that all future chips used in manufacturing in Pakistan should be packaged in Pakistan, if possible. Such a facility can generate revenue of $100M at full loading. It can also return the initial investment in 3-4 years after full loading.

All (or majority) of chips used in Pakistan should be required to be packaged and tested in Pakistan. This will promote OSAT in Pakistan, which will be initially for chips used in Pakistan but will eventually be for export markets as well.

8. Summary of Policy Recommendations

		Activity	Responsibility	Budget	Timeline	Status
1		Establish the national semiconductor goal	MoIT, MoST, PM Secretarial		Immediate	
2		Establish a cabinet-level task force	MoIT, MoST, PM Secretarial, MoFA		Immediate	
3		Establish offices at key consulates	MoIT, MoST, PM Secretarial, MoFA		Immediate	
4		Establish PSA	Private Sector (PakLaunch, OPEN, OSFPGA, GSA)	$5M	3 years	In discussion
5		Invest $75M to boost academic and research capabilities in semiconductors				
	a	PNSP specific teaching and training	MoE/HEC, PEC, MoST	$40M	3 years	
	b	Student scholarships	MoE/HEC, PEC, MoST	$4M	3 years	
	c	PNSP driven R&D	MoE/HEC, PEC, MoST	$6M	3 years	
	d	Invite semiconductor speakers	MoE/HEC, PEC, MoST	$5M	3 years	
	e	Attract semiconductor research professors	MoE/HEC, PEC, MoST	$20M	3 years	

		Activity	Responsibility	Budget	Timeline	Status
6		Invest $20M in ATI to train HR			3 years	
	a	ATI Lahore	Private Sector in partnership with MoIT, MoST, KJ	$6M	Immediate	MOU Signed by Lahore Technopolis
	b	ATI Karachi	Private Sector in partnership with MoIT, MoST, KJ	$6M	1 year	MOU in discussion with NED
	c	ATI Islamabad	Private Sector in partnership with MoIT, MoST, KJ	$5M	1 year	To be discussed
	d	ATI Peshawar	Private Sector in partnership with MoIT, MoST, KJ	$3M	1.5 years	To be discussed
7		Invest $80M to incentivise US & China design centres				
	a	Training through ATIs			1-3 years	See item 6
	b	Facilities (rent, utilities, upgrades, maintenance)	MoST	$20M	Immediate	
	c	Design tools	MoIT, MoST	$40M	Immediate	
	d	Business setup and facilitation				
	e	Establish zero-in/zero-out policy for all machinery and materials related to design centres	SPB, Customs, FBR	Policy issue	Immediate	Policy required to initiate OSAT investment
	f	Tax incentives for 10 years	FBR, MoIT, MoST,		Immediate	
	g	Subsidize international talent	MoIT, MoST	$20M	1-3 years	

		Activity	Responsibility	Budget	Timeline	Status
8		Invest $65M in package & test				
	a	Establish IC packaging plant	Private Sector with government support	$50M	1.5 years	MOU Signed by Lahore Technopolis
	b	Establish PCB manufacturing plant	Private Sector with government support	$15M	1.5 years	Under discussion – Target Islamabad Technopolis
	c	Establish zero-in/zero-out policy for all machinery and materials related to OSAT	SPB, Customs, FBR,	Policy issue	Immediate	Policy required to initiate OSAT investment
	d	Tax incentives for 10 years	FBR, STZA	Policy issue	Immediate	
	e	All chips used in Pakistan require packaging and test in Pakistan (if possible	Customs	Policy issue	2 years (progressively applied)	

9. Additional Data and Tables

The Basics of Academic Research to Academic Research Detailed breakdown

Having six government-backed hubs across Pakistan will provide centralized access to EDA tools and chip tape-out opportunities. One of the hubs will serve as a central hub that is aligned with OSAT and manufacturing. These Hubs will act as open-access national facilities in terms of resources/tools and knowledge sharing and utilization. Besides other budgetary heads, these hubs will have funds for centralized tools, tape-outs, chip testing facilities and prototype development. In parallel, universities will be responsible for teaching programs through undergraduate and postgraduate degrees, short training and certifications and research in the focus areas in strong and integral collaboration with local and international industry. These hubs will establish a viable liaison with nearby universities to accelerate the outcomes from the academic sector.

	Head	Major Items and Broader Rationale for Funding	Tune of Funding /Projected Cost (US$)	Timeline (Phase 1: Year 1-5; or Phase 2: Year 6-10 or Both)	Responsibility/Model
1	Support to BS programs Tapeout Pakistan Program (undergraduate)	10 microelectronics research labs housed in 10 different universities, training for 20-40 students per university per year with hands-on tapeout experience Cost includes infrastructure support, stipend to faculty and students Target is to create HR of 200 undergraduate students with tapeout/digital design-verification and chip bring up experience	2,500,000	Phase 1: Year 1-5	Government of Pakistan through the concerned Ministries (Ministry of Science and Technology, Ministry of Education/ Higher Education Commission)
2	Support for MS programs for all hubs	**Target: 2160 MS graduates** Students/year: 72 for the participating universities No. of universities participating in Phase1: 10 Fee /student: Rs 350,000 # of intakes: 3 (year 1, 2 & 3)	4,200,000	Phase 1: Year 1-5	
3	Support for PhD programs for all the hubs (PhD student stipend and single tapeout cost or equipment cost)	Target: 40 PhD students (Phase I) Cost = 800000 USD 40 PhD students (Phase II) Cost = 800000 USD	1,600,000	Phase 1: Year 1-5 Phase 2: Year 6-10	
4	HPC for cloud setup of EDA Tools	Dedicated setup for all design hubs	1,675,000	Will cover both Phases	
5	EDA and allied Tools	Cloud based Cadence IC design suite at all design hubs	3,100,000	Will cover both Phases	
6	Laboratories / Facilities	Extended chip testing facilities at all the 6 hubs	12,000,000	Will cover both Phases	
		Semiconductor packaging, MEMS-IC tools and testing laboratory with allied facilities (at OSAT & manafacturing hub)	3,000,000	Will cover both Phases	
7	Tape-out & prototype development support	Tape-outs (2 sq. mm two times a year per hub for 10 years)	1,200,000	Will cover both Phases	

	Head	Major Items and Broader Rationale for Funding	Tune of Funding /Projected Cost (US$)	Timeline (Phase 1: Year 1-5; or Phase 2: Year 6-10 or Both)	Responsibility/Model
8	Establishment cost (inclusive of any desirable HR requirements on full-time and partial support model)	Special package to attract foreign faculty members, technical staff for all 6 hubs, lab engineers etc. ($200,000 for 10 universities for 5 years)	3,000,000	Phase 1: Year 1-5	Government of Pakistan through the concerned Ministries (Ministry of Science and Technology, Ministry of Education/ Higher Education Commission)
9	Seminars, conferences, travel support	Promote exchange between universities and presentation at conferences, holding local conferences and seminars etc.	1,000,000	Phase 1: Year 1-5	
10	Incubation cost of commercial research idea from academia	20 incubation in I Phase 30 incubation in II Phase (individual incubation cost is approx. $10,000 USD)	4,790,000	Phase 1: Year 1-5 Phase 2: Year 6 - 10	
11	Misc. activities and contingencies	$100,000 for all the hubs for 5 years	2,000,000	Phase 1: Year 1-5	
		Total Cost (US$)	**40,065,000**		

List of Abbreviations

ADC	Analog to Digital Converter
ASICs	Application Specific Integrated Circuit
ATI	Advanced Training Institute
CMOS	Complementary Metal-oxide semiconductor
CoTs	Customer owned Tooling
IC	Integrated Circuit
IoT	Internet of Things
ISSCC	International Solid-State Circuits Conference
LNA	Low Noise Amplifier
MEM	Micro Electromechanical Systems
OSAT	Outsourced Assembly and Test
PLL	Phase Locked Loop
RF	Radio Frequency
R&D	Research and Design
SoCs	System on Chips