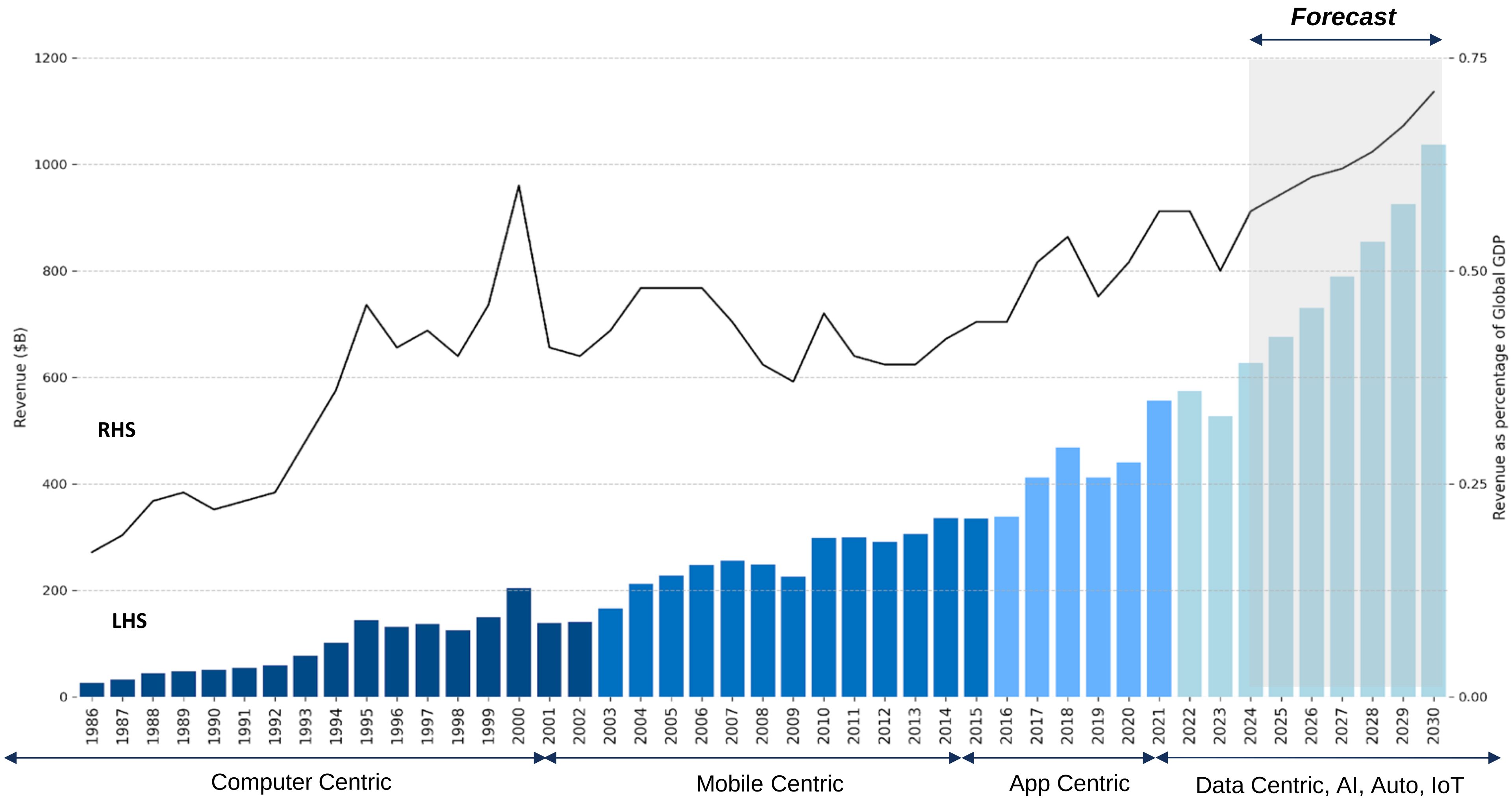
The Silicon Playbook

OCTOBER 2024

BLUME

The Semiconductor Arms Race: From Computers to AI and Beyond

These little silicon squares have quietly grown to almost 1% of global GDP—turns out they're pretty important for, well, everything



Over the past four decades, the semiconductor industry has experienced rapid growth to meet technological demands from changing consumer preferences and transformative technology inventions. The importance of this sector as measure in revenue as a percentage of Global GDP has nearly quadrupled in this period.

Source: Statista, World Bank, Blume Analysis

A day in life with Semiconductors

From smartphones to cars, you unknowingly rely on several thousands of semiconductor chips every single day

Imagine a world without smartphones, computers, or electric vehicles. That's a world without semiconductors. These tiny electronic components are the **physical connection to the digital world**

5:00 AM
Alarm clock

5:15 AM
Electric Toothbrush

5:30 AM
Toaster Oven

6:00 AM
Adjust temperature

6:15 AM
Drive to work in an EV

7:00 AM
Elevator up the office

7:15 AM
Hit the coffee machine

7:20 AM
Work PC

8:30 AM
Video Camera for a meeting

10:00 AM
ATM for cash

12:00 PM
Lunch from refrigerator

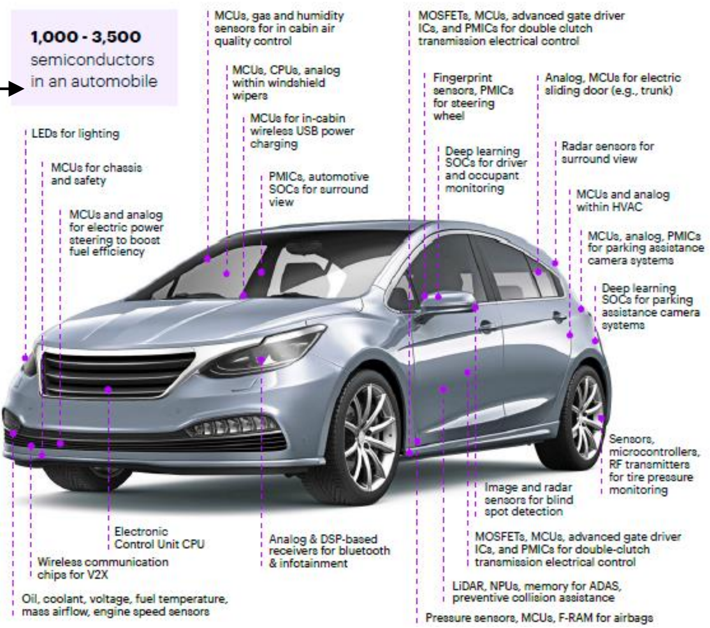
5:00 PM
Visit Doc to follow up with MRI

6:00 PM
Treadmill workout

7:00 PM
Check email on smartphone

8:30 PM
Washer and Dryer

10:00 PM
Nightly news on TV



1,000 - 3,500 semiconductors in an automobile

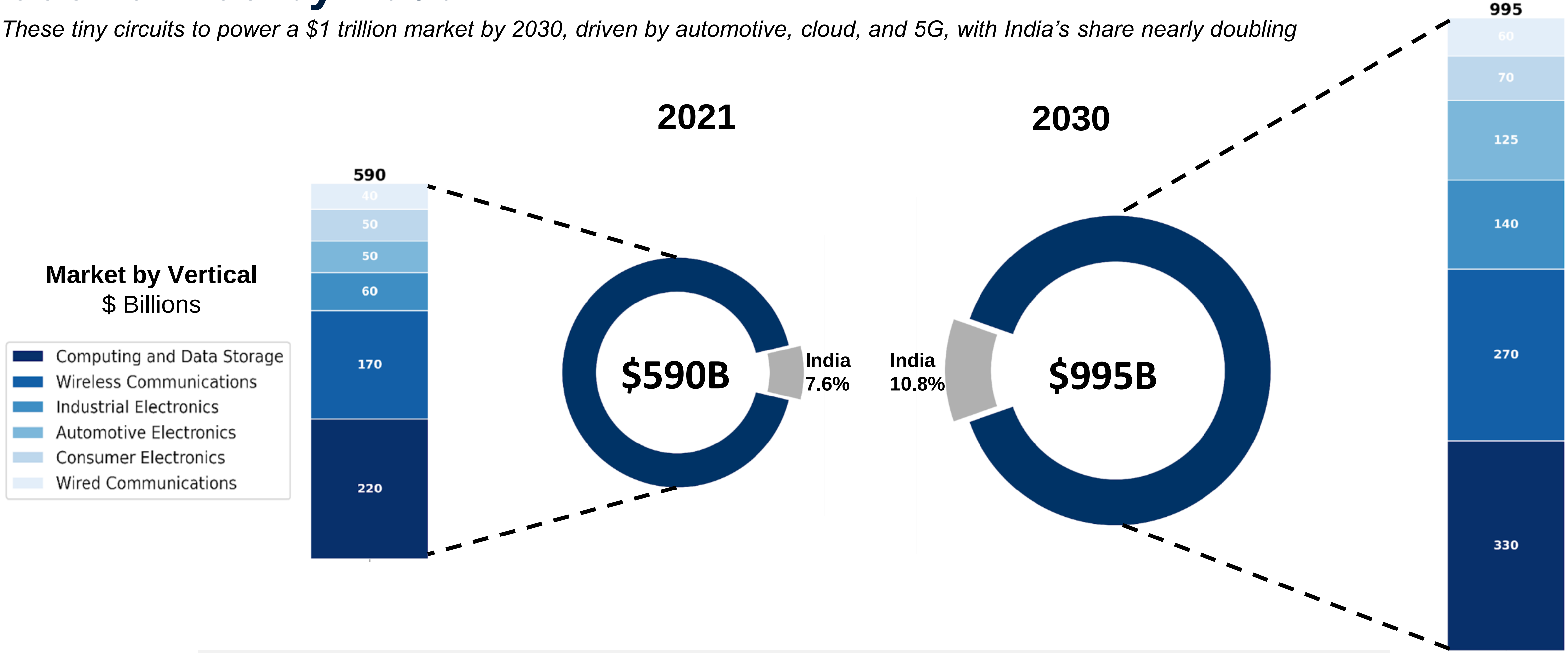
~169 semiconductors in a smartphone

10+ semiconductors in a coffee machine

Source: Accenture

Semiconductors are set to be worth more than most countries' economies by 2030!

These tiny circuits to power a $1 trillion market by 2030, driven by automotive, cloud, and 5G, with India's share nearly doubling



About **70% of future growth** will be driven by just 3 industries:
Automotive: Fueled by autonomous driving and rise in mobility solutions
Computation and Data Storage: Fueled by demands for servers to support AI and cloud-based solutions
Wireless: Supported by shift from lower-tier to mid-tier smartphones in EM and growth in 5G

Source: McKinsey

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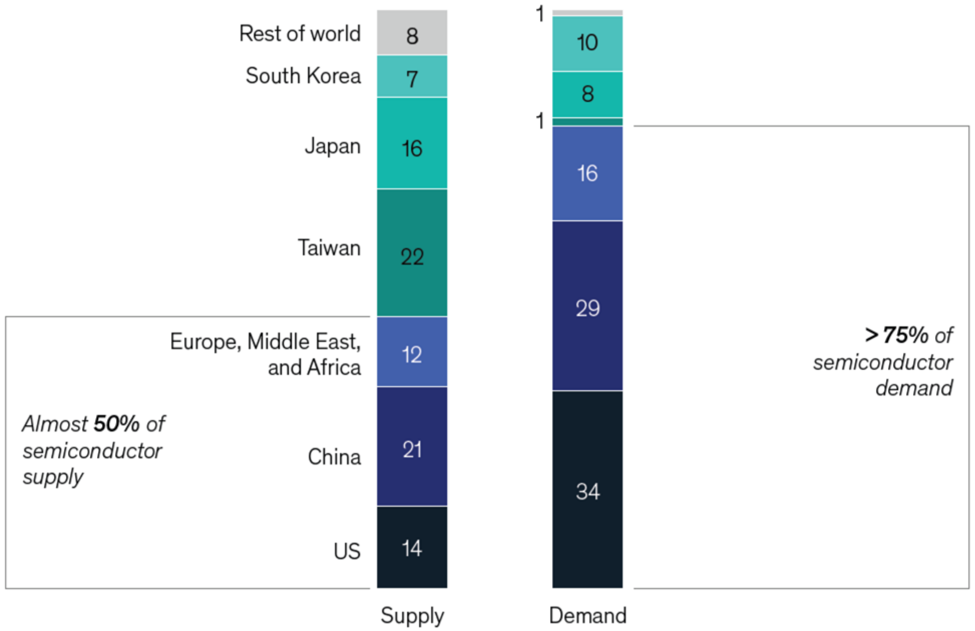
Global Chip Supply: A Geographical Mismatch

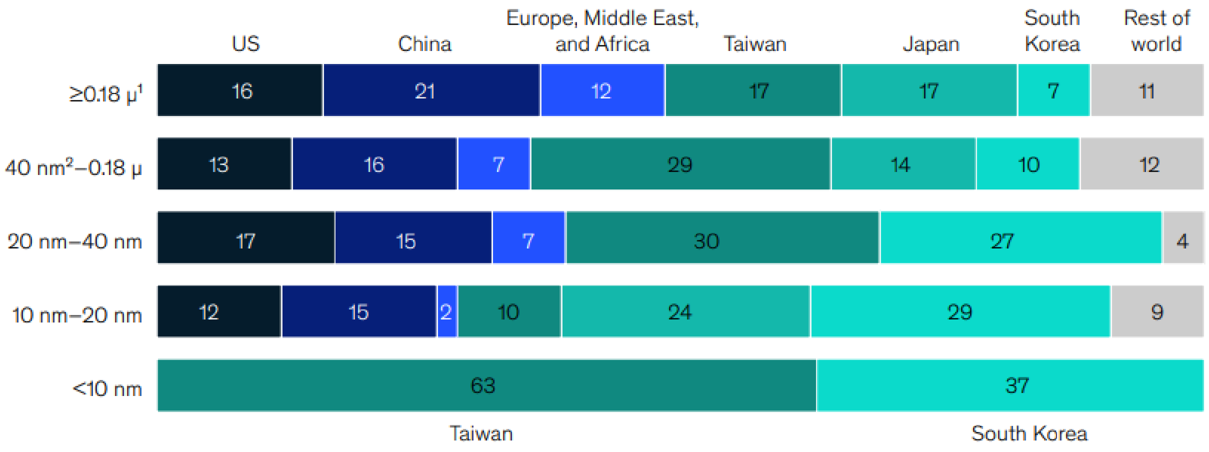
Half of the chips are produced far from their demand hubs, prompting new interest in diversifying fab locations.



*Almost **50%** of semiconductor supply*

***> 75%** of semiconductor demand*

Semiconductor supply and demand is not regionally balanced



Regional semiconductor chip production varies by node size

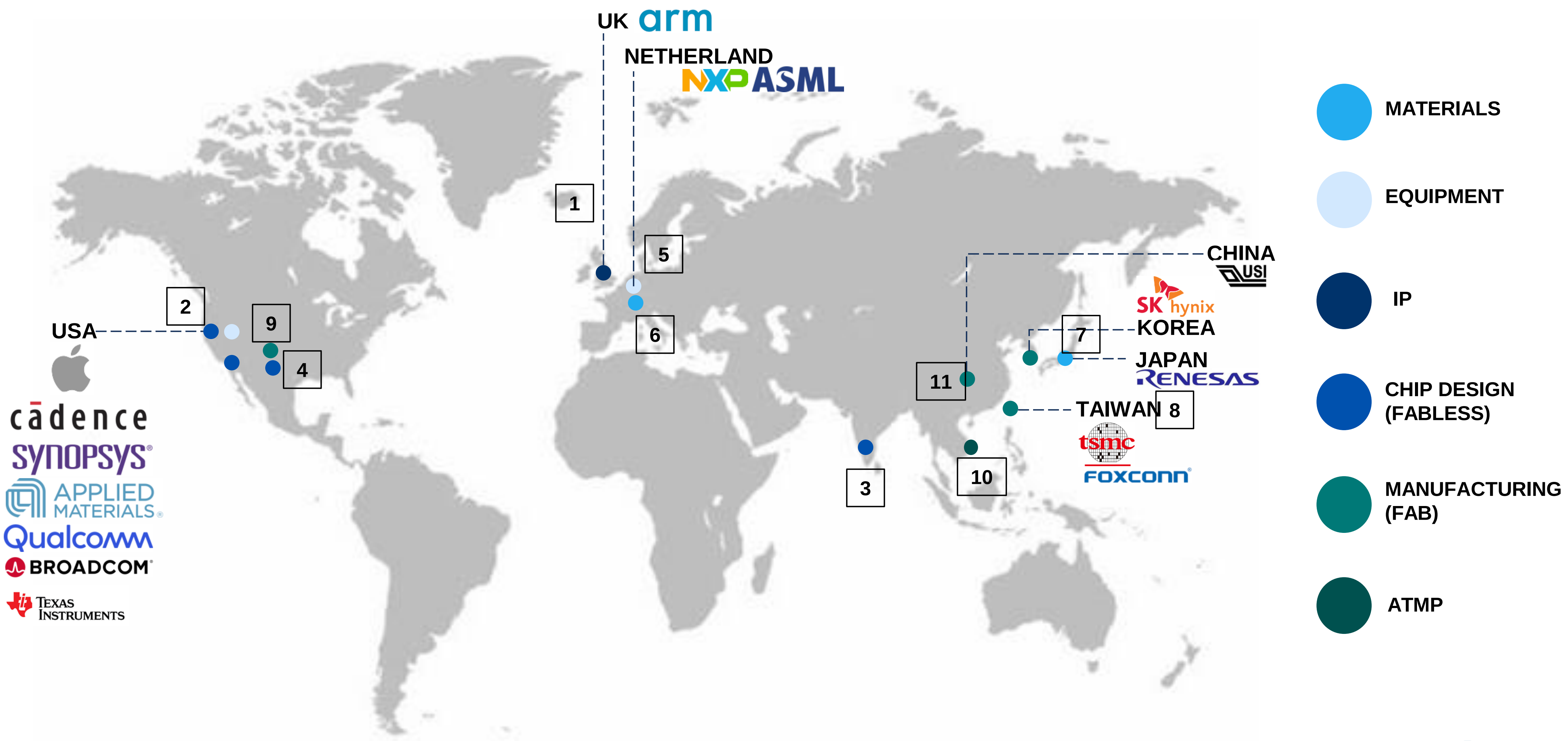
For many years, chip manufacturing has been consolidated in Southeast Asia and China, with leading-edge chips, those with node sizes under 10 nm largely produced in East Asia.

However, the COVID-19-related supply chain disruptions, the 2021 Taiwanese drought and recent geopolitical tensions have prompted companies to take a new interest in diversifying their fab locations. The availability of subsidies is one of the major considerations when evaluating potential new sites.

Source: McKinsey

Case in Point: Apple iPhone 15 Pro Chip's Global Supply Chain

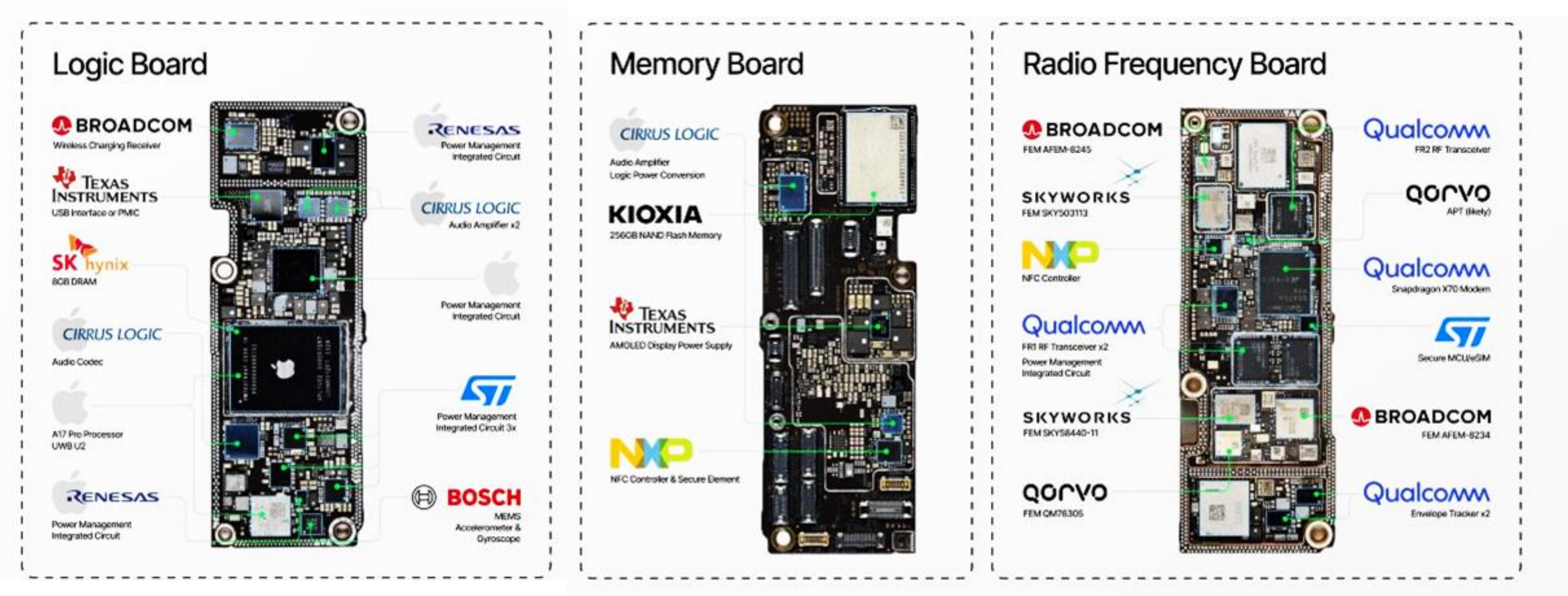
Need for deep technical know how and massive scale have created a highly specialized global supply chain



Source: Blume Analysis; Most widely adopted flow shown

Apple iPhone 15 Pro Board Teardown

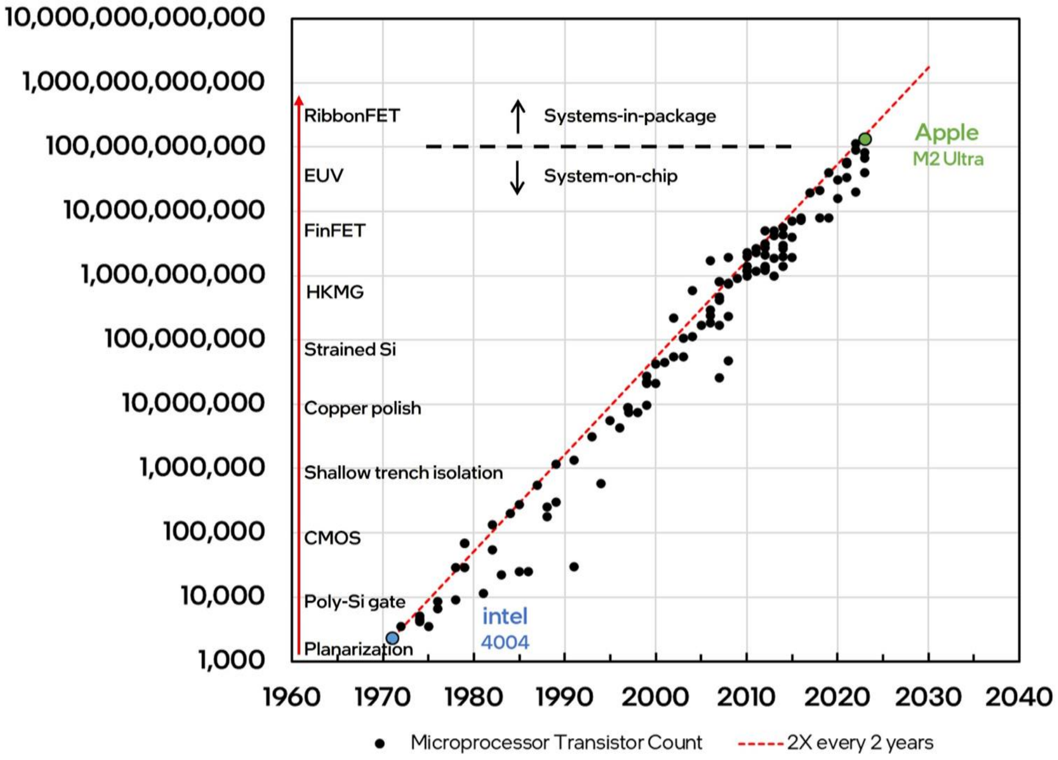
A Semiconductor Symphony- From logic to memory to radio frequency, each chip plays a crucial role in powering Apple's flagship device

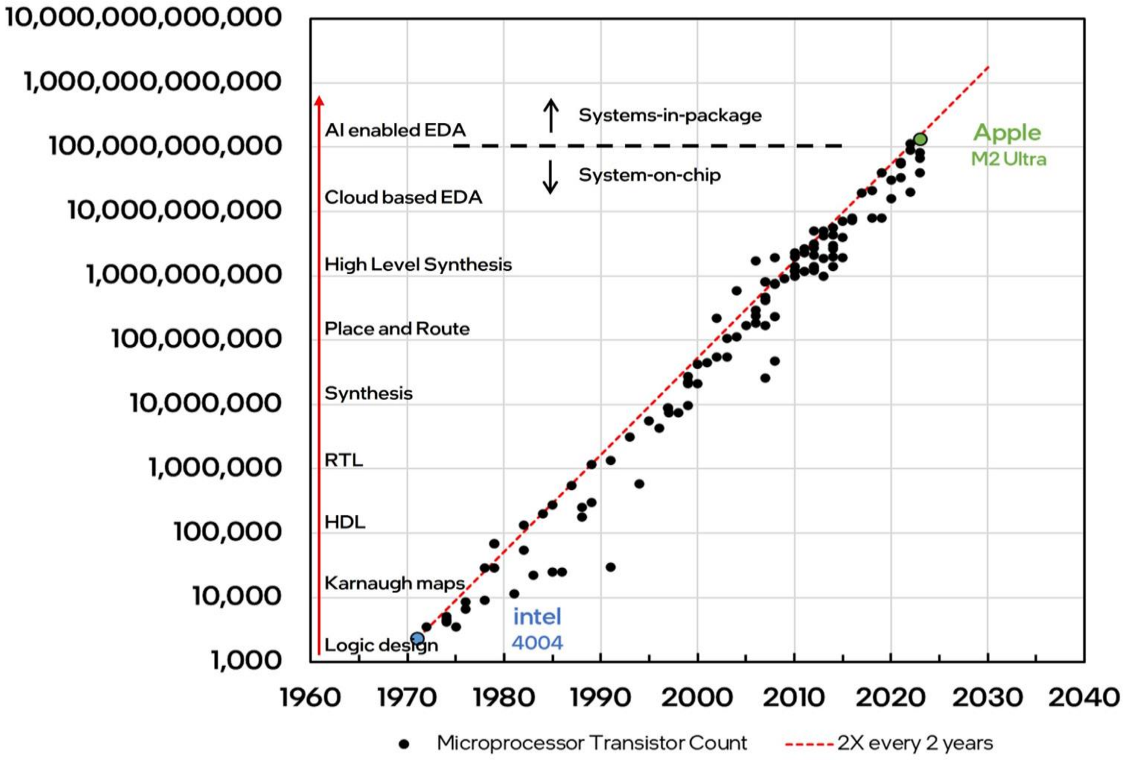


Source: Accenture

Chasing Moore’s Law: The Exponential Race in Semiconductor Innovation

As transistor counts soar and tech complexity rises, the challenge is no longer just technological—it's also economic





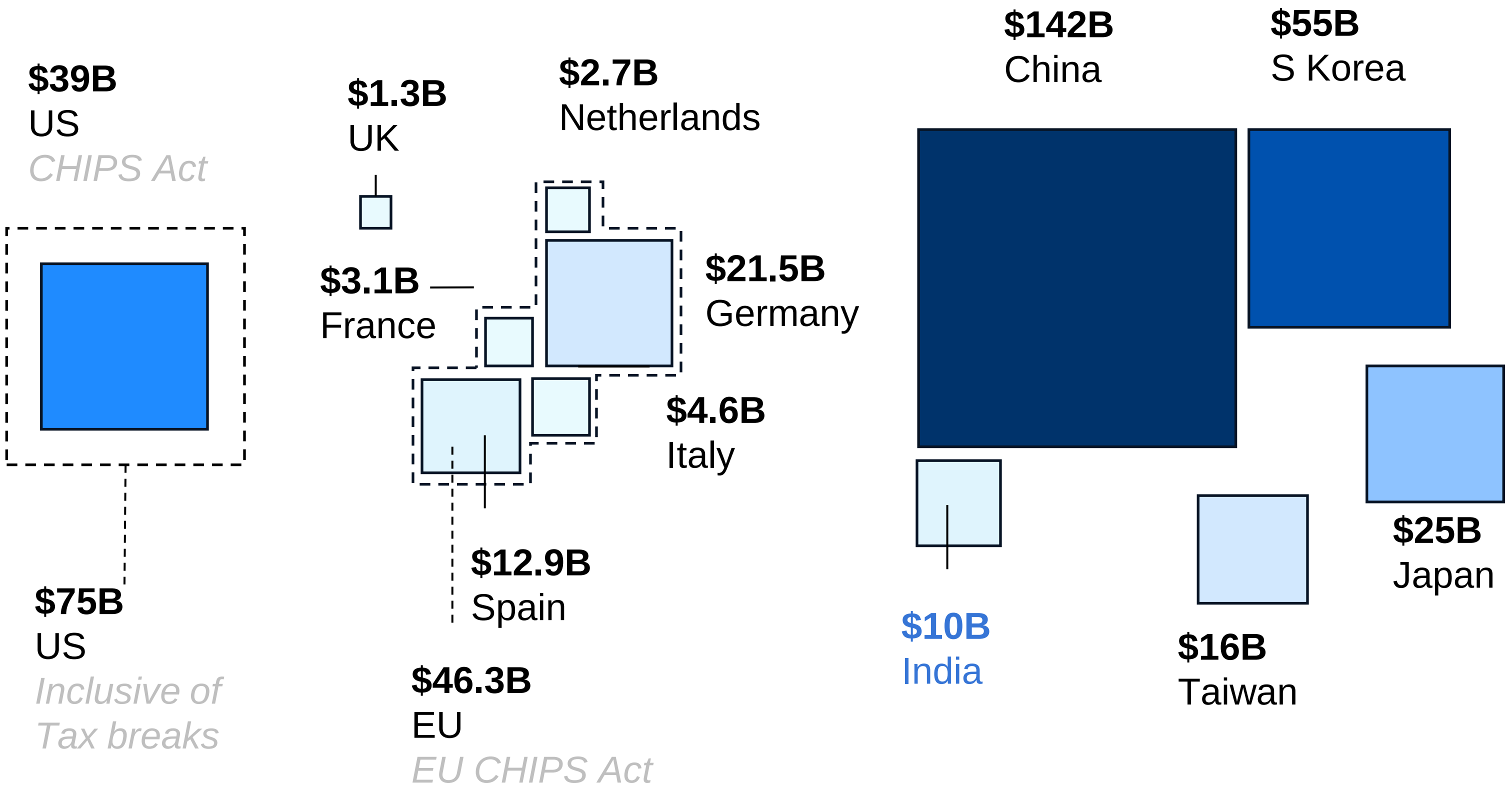
Every **10x increase** in transistor count was enabled by a **fundamental process technology** and a **major EDA innovation**

Moore’s vision for **exponential semiconductor growth** has become the self-fulfilling prophecy driving technological improvement. However, **keeping pace with Moore’s Law is becoming economically unviable** for many players as fab costs increase, transistors shrink to atomic proportions, and semiconductor process technology becomes more complex.

Source: Bits and Bytes Substack

The $380B Race to Dominate the Semiconductor Future

With China leading and the U.S. following closely, global powers are pouring billions into semiconductor production to secure technological supremacy in the Chip War

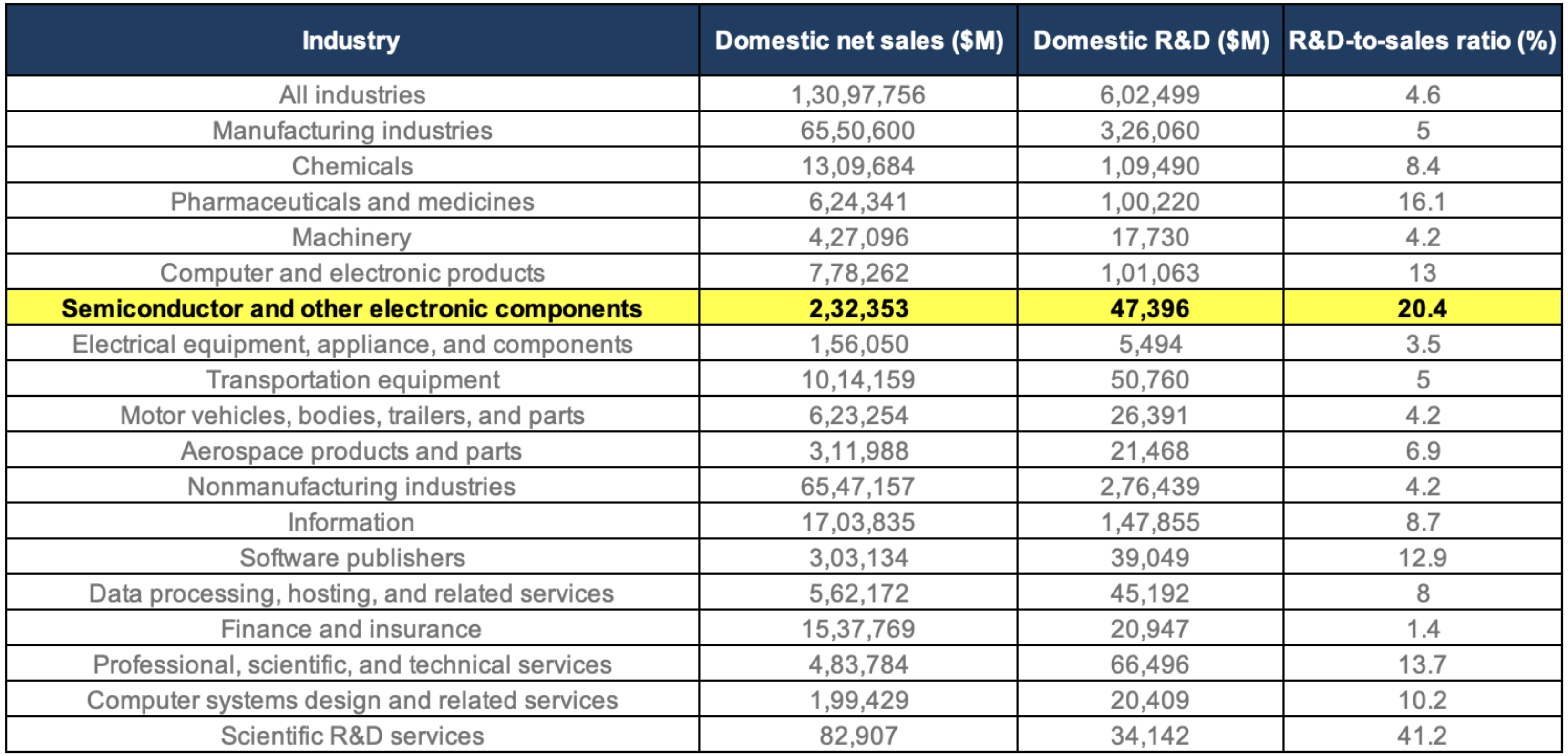


The 'Chip War' began as concern over China's rapid advancement in key electronics developed into a full-scale panic during the pandemic-era chip shortages. At stake now is everything from economic security to shoring up domestic manufacturing to the balance of peace in the Taiwan Strait. In the first wave of investments, close to $380B spending is planned by governments worldwide to boost production of ever more powerful chips.

Source: Bloomberg

Semiconductors: Among the most R&D-Intensive sectors, command the highest support from Govt

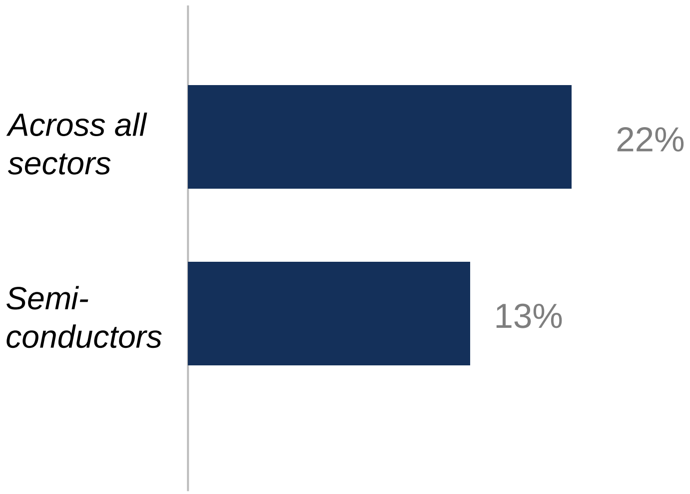
With a high R&D-to-sales ratio of 20.4%, emerging hubs like India will need significant R&D funding and govt support to stay competitive



Industry	Domestic net sales ($M)	Domestic R&D ($M)	R&D-to-sales ratio (%)
All industries	1,30,97,756	6,02,499	4.6
Manufacturing industries	65,50,600	3,26,060	5
Chemicals	13,09,684	1,09,490	8.4
Pharmaceuticals and medicines	6,24,341	1,00,220	16.1
Machinery	4,27,096	17,730	4.2
Computer and electronic products	7,78,262	1,01,063	13
Semiconductor and other electronic components	**2,32,353**	**47,396**	**20.4**
Electrical equipment, appliance, and components	1,56,050	5,494	3.5
Transportation equipment	10,14,159	50,760	5
Motor vehicles, bodies, trailers, and parts	6,23,254	26,391	4.2
Aerospace products and parts	3,11,988	21,468	6.9
Nonmanufacturing industries	65,47,157	2,76,439	4.2
Information	17,03,835	1,47,855	8.7
Software publishers	3,03,134	39,049	12.9
Data processing, hosting, and related services	5,62,172	45,192	8
Finance and insurance	15,37,769	20,947	1.4
Professional, scientific, and technical services	4,83,784	66,496	13.7
Computer systems design and related services	1,99,429	20,409	10.2
Scientific R&D services	82,907	34,142	41.2

Domestic net sales, R&D, and R&D-to-sales ratio (US, 2022)

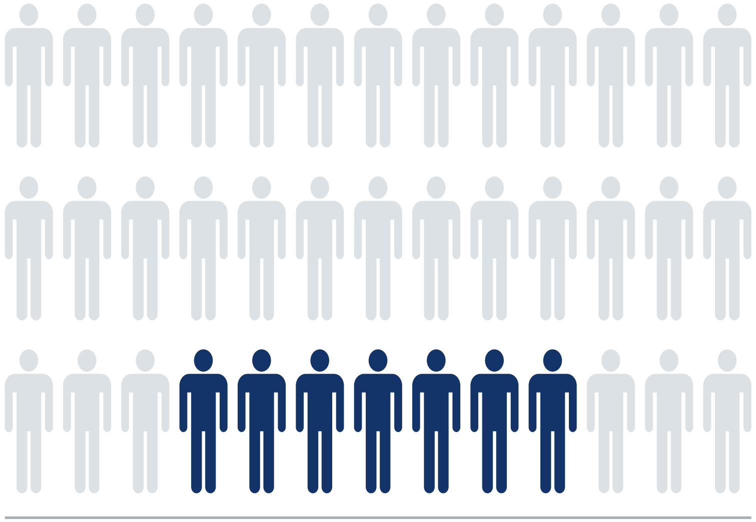
Comparison of US Govt share in total R&D investment in 2022



Source: National Science Board, CHIPS, Science Act

The Magic of Semiconductors: One Job Creates an Army!

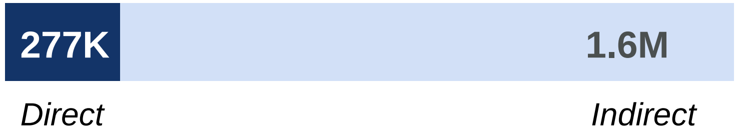
Economy's Hidden Cheat Code: Every $ spent in the US semiconductor industry creates $1.32 elsewhere. The multiplier effect will be much higher for a growing economy like India



US SEMICONDUCTOR INDUSTRY JOBS MULTIPLIER- 6.7X

For each U.S. worker directly employed by the semiconductor industry, an additional 5.7 jobs are supported across the wider U.S. economy

US JOBS SUPPORTED INDIRECTLY



EMPLOYMENT MULTIPLIER FOR INDIA

US ELECTRONIC MANUFACTURING ECONOMIC BOOST

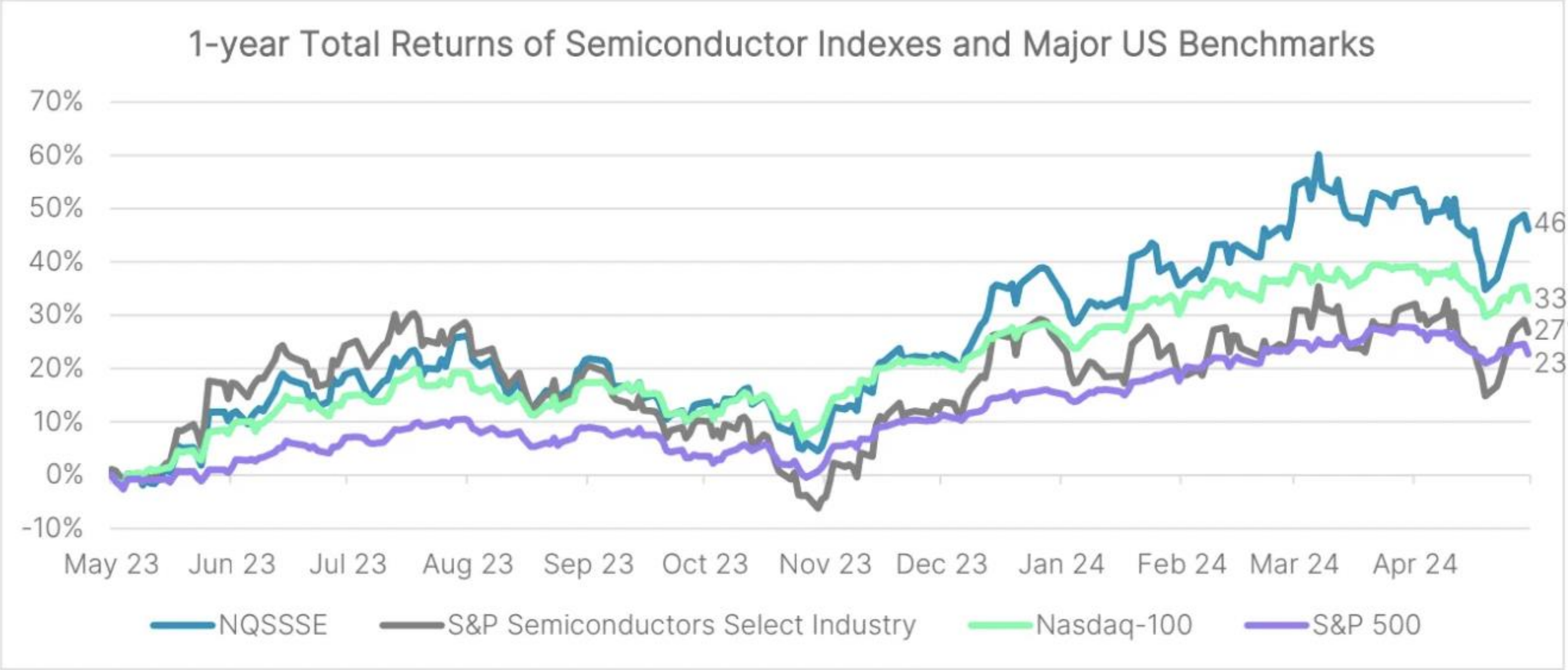
Every dollar added to U.S. GDP by the electronics manufacturing sector creates $1.32 elsewhere in the economy

Source: ITIF, The Financial Express

Proof of the Pudding: Semiconductors are the economic backbone that a country like India needs now

With a stellar 46% return in just 12 months, NQSSSE is outperforming key benchmarks and positioning itself as the ultimate indicator of semiconductor market strength

NQSSE- The leading multifactor index for the semiconductor industry



The Nasdaq US Smart Semiconductor Index (NQSSSE) achieved a 46% return over the past year, outperforming both the Nasdaq-100 and S&P Semiconductor indexes with its factor-weighted selection based on profit, return on assets, momentum, and cash flow

Source: Bloomberg, NASDAQ Global Indexes

Decoding the Semiconductor Spectrum

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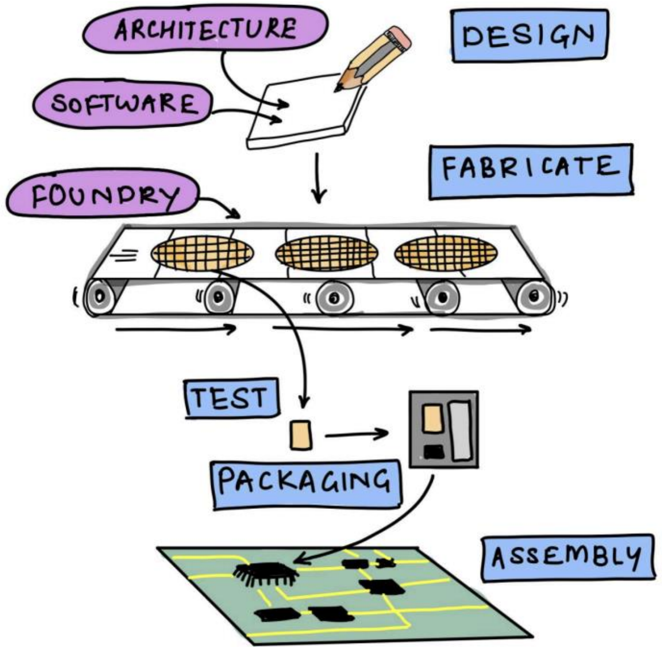
1. Sand to Silicon: The Semiconductor Value Chain



Business Models Across the Semiconductor Value Chain

Each segment plays a critical role, with revenue and margins varying by capital intensity and specialization.

	IP	EDA*	Fabless	Fab	Materials	Equipment	OSATs*	IDM*
Revenue	$5B	$5B	$128B	$71B	$85B	$71B	$35B	$260B
GM	85%	85%	60%	50%	35%	45%	15%	50%
	Monopoly like margins	***Design Innovation***	***Asset –light model***	***High Capex & R&D, Precision Manufacturing***	***Specialized supply chain***	***High R&D High barrier to entry***	***Labor Intensive, Low Margins***	***Vertically integrated End-to-End control***
	*Firms that specialize in developing and **licensing IP cores**, which are predesigned circuits used as building blocks in chip design*	*Companies that provide **software and tools** used by engineers to **design and simulate** semiconductor chips*	*Fabless firms choose to **focus on design** and outsource fabrication as well as assembly, packaging, and testing*	*Foundries address the fabrication needs of the fabless & IDMs alike, as most IDMs don't have sufficient installed manufacturing capacity in-house*	*Providing raw materials used in semiconductor manufacturing, ranging from **silicon wafers** to various **chemicals** and **gases***	*Supply the machinery and equipment used in **front-end** and **back-end in** semiconductor manufacturing*	*OSATs provide **assembly, packaging and test** services under contract to both IDMs and fabless companies.*	*IDMs are vertically **integrated** across multiple parts of the value chain, performing design; fabrication; & assembly, packaging & test activities inhouse*

Source: Blume Analysis; *Revenue is based on FY22, EDA= Electronic Design Automation, OSAT= Outsourced Semiconductor Assembly and Test, IDM= Integrated Device Manufacturers

The Power Players Behind Every Chip We Use

These top players in the global semiconductor value chain drive most of the innovation and value addition

Design

Fabrication

Assembly

IDMs

IP	EDA	Fabless	Fab	Materials	Equipment	OSATs	IDM
arm	cadence	NVIDIA	tsmc	ShinEtsu	ASML	Amkor Technology	intel
Imagination	SYNOPSYS	AMD	GlobalFoundries	siltronic perfect silicon solutions	APPLIED MATERIALS	TERADYNE	SAMSUNG
		Qualcomm	UMC	GW	Lam RESEARCH	ADVANTEST	Texas Instruments
		BROADCOM		SUMCO	HITACHI		Micron
					KLA		RENESAS
					TEL		SK hynix
					Nikon ZEISS		

Source: Blume Analysis; *Bucketing is done basis the largest share in revenue, multiple overlaps are possible

Spotlight 101: Semiconductor Design

Design dictates the holy grail of a chip's power efficiency and processing speed, the combination that governs which chips power particular end applications

What do design companies do in a nutshell?

- Software helps in Designing the chip
- Analyse & Verify if chip performance is optimal
- Simulate the behaviour & performance of the chip
- Prepare a photomask to send for fabrication

1

License IP cores from Semiconductor IP Houses

IP cores are reusable design components that save costs by using pre-designed blocks instead of building circuits from scratch, due to the amount of technical know-how and design verification and validation time needed

2

Integration of external and in-house IP Cores

If IC= a modern home then IP blocks= prefabricated sections (eg modular kitchens, appliances) that streamline construction. External vendors expedite time-to-market offerings & reduce hardware-software integration risk

3

EDA for logical & physical design & floor planning

EDA help simulating functionality, integrating IP & optimizing floorplan. These software also help foundries reduce the prototyping cycles (design-technology co-optimization)

4

Verification of design

The final design data is stored on a magnetic tape- tapeout. Verification teams are then leveraged to ensure design is functional and manufacturable at designated fab. EDA also helps in this part of the process

5

Fab manufactures test wafer

For final design validation, a test wafer is manufactured by a fab with the help of a chip tapeout. EDA also helps share coded versions of their manufacturing processes to design houses to ensure manufacturable chip layouts

53%

of industry R&D and **13%** of industry capex

Design is the most R&D-intensive stage of the value chain—and the fundamental enabler of silicon technology. Design projects typically last for 4-5 years

50%

Is the value added by Design alone in the entire Value chain

The costs associated with designing for advanced 3nm nodes range from $500M to over $1.5B

Source: Accenture, BCG, Blume Analysis

We Can't Choose Where the Oil is, But We Can Choose Where the Fabs Go!

With 77% of industry capex locked into manufacturing, every step from front-end to back-end is a high-stakes, high-tech dance to ensure your chips work

Front-end Manufacturing

Front-end manufacturing (Fab, bump, wafer sort) is a complex & unforgiving process that requires a 99.99% yield at minimum for each precise step to produce a viable semiconductor end-product.

Wafer fabrication can be a 350-step, 45-60-day process in a mature node or 700+ step, 60+ day process in an advanced node

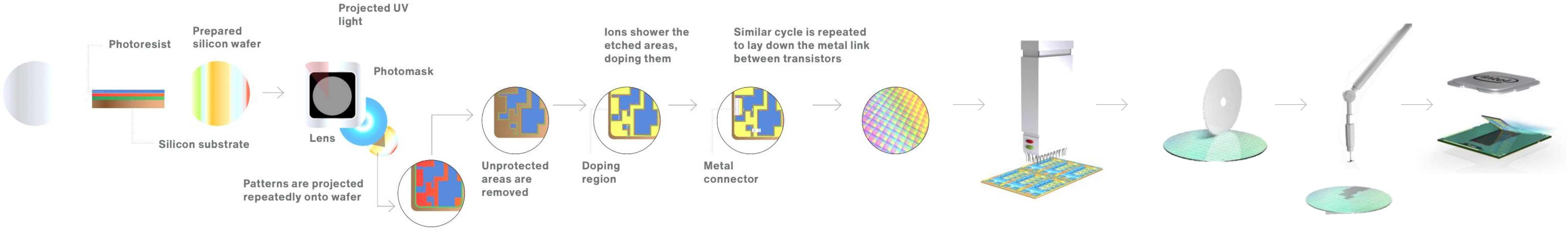
77%

of Industry Capex belongs to just the manufacturing step of the supply chain

Back-end Manufacturing

Each individual chip is probed before slicing the wafer into the die & packaging it between substrates & heat spreaders. Packaged chips are then sent to assemblers, who assemble chips into circuit boards with passive components and protective encasing

Recent advancements here include Advanced Packaging- 2.5D/3D, chiplets, fan-out expands, and system-in-package (SiP)



Silicon Wafer

Oxidation & coating

Lithography

Etching

Doping

Metal deposition & etching

Completed Wafer

Wafer Sort

Wafer Slicing

Selecting Die for Packaging

Packaging

Front-end Manufacturing
24% of the value added

Back-end Manufacturing
6% of the value added

Source: Intel, Blume Analysis

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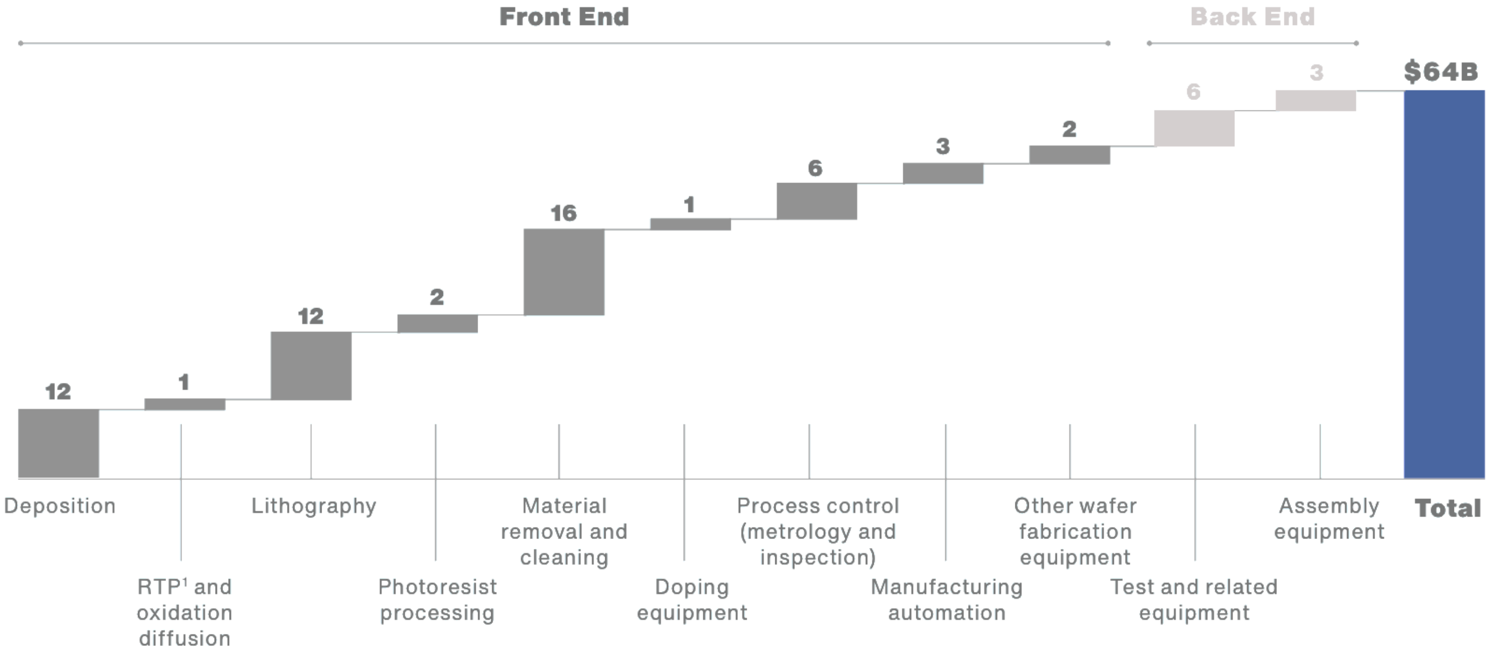
Semiconductor Equipment: The Pricey Backbone of Chip Manufacturing

Each piece of equipment costs on average $2M – $6M, Despite the price tag, a typical semiconductor manufacturing equipment depreciates after 5 – 8 years in operation

Breakdown of market size of semiconductor manufacturing equipment (front-end and back-end), 2020 ($B)



# Equipment types											
12	**4**	**6**	**1**	**12**	**4**	**16**	**2**	**2+**	**3**	**5**	**50+**

Key Players and their respective revenues in FY2023

Equipment Vendor	FY 23 Revenue	Focus Areas
Applied Materials	$26.52B	Plasma etching equipment; deposition, etch, ion implantation, rapid thermal processing, CMP
LAM Research	$17.4B	Plasma etching equipment; systems integral in film deposition, plasma etch, photoresist strip, wafer cleaning
KLA	$9.7B	Metrology equipment for quality control; process control systems
ASML	$30.04B	Photolithography equipment, including EUV (extreme ultraviolet lithography) equipment to produce chips smaller than 7nm (leading node)
Tokyo Electron	$11.16B	Thermal processing, photoresist coating/developing, wet surface preparation, CVD, wafer probing

Source: Gartner; 1- Rapid Thermal Processing

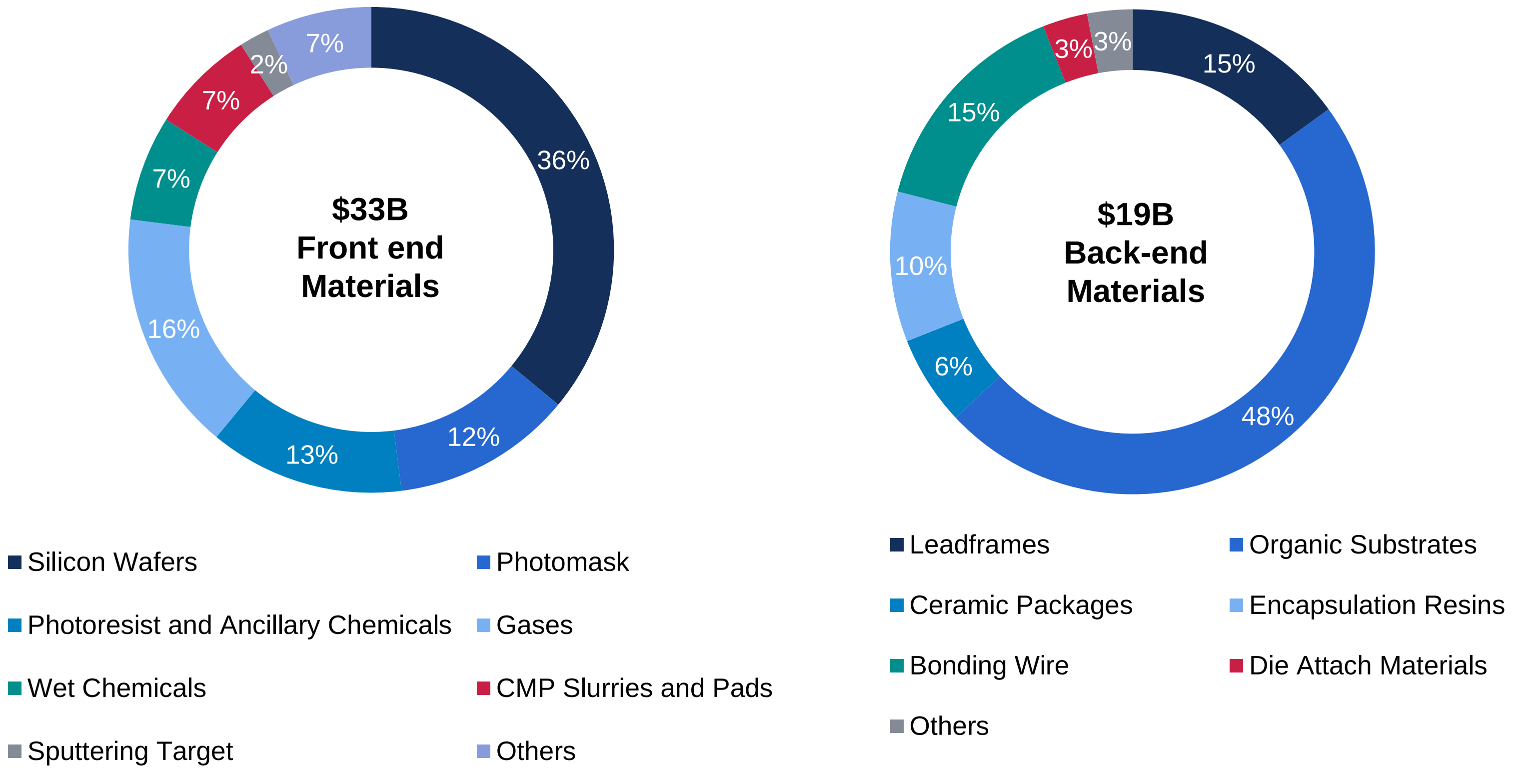
Semiconductor Materials: The Building Blocks of Advanced Chipmaking

Wafer fabrication requires nearly 500 specialized process chemicals, with the number and amount of chemicals continuing to rise as semiconductors become more complex

Chemicals, gases, minerals, and high-purity materials are integral to semiconductor fabrication (e.g., patterning, deposition, etching, polishing), equipment operations, facility cleaning, and packaging.

New materials are needed to perform extreme ultraviolet lithography (EUV), high-resolution etch and deposition, and various other steps at nanometer scale dimensions. Hafnium, cobalt, ruthenium, molybdenum, gallium nitride, and graphene are among the new materials that have been incorporated into leading-edge manufacturing

Breakdown of Market size of semiconductor manufacturing materials, 2019 (% of $B)

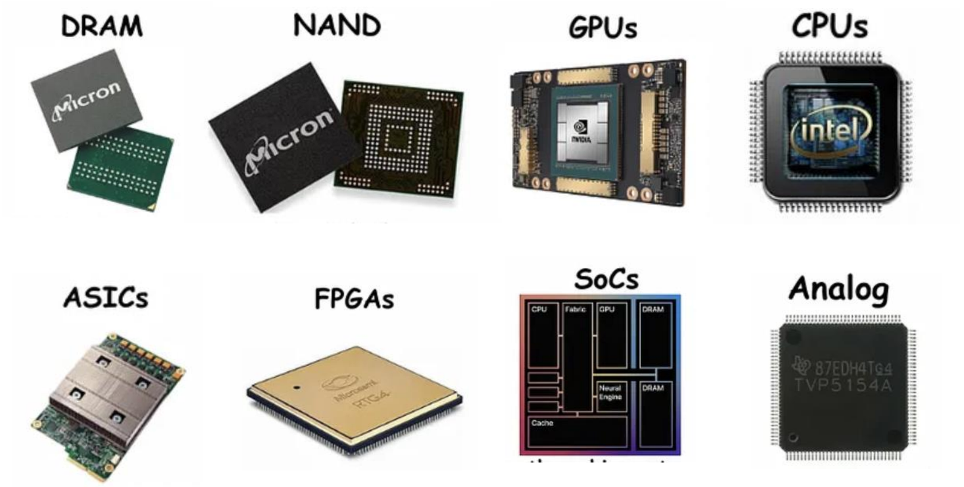


- India’s chemical and gas producers already produce many of the chemicals that are required for semiconductor manufacturing, but India will need to build refinement capabilities in order to improve the purity of India-produced chemicals to support semiconductor-grade need

- An investment of ~$300M to $500M will be needed to upgrade Indian chemicals and gas manufacturers’ quality and purity to meet semiconductor-grade needs

Source: BCG, Blume Analysis

2. Semiconductor Product Segments



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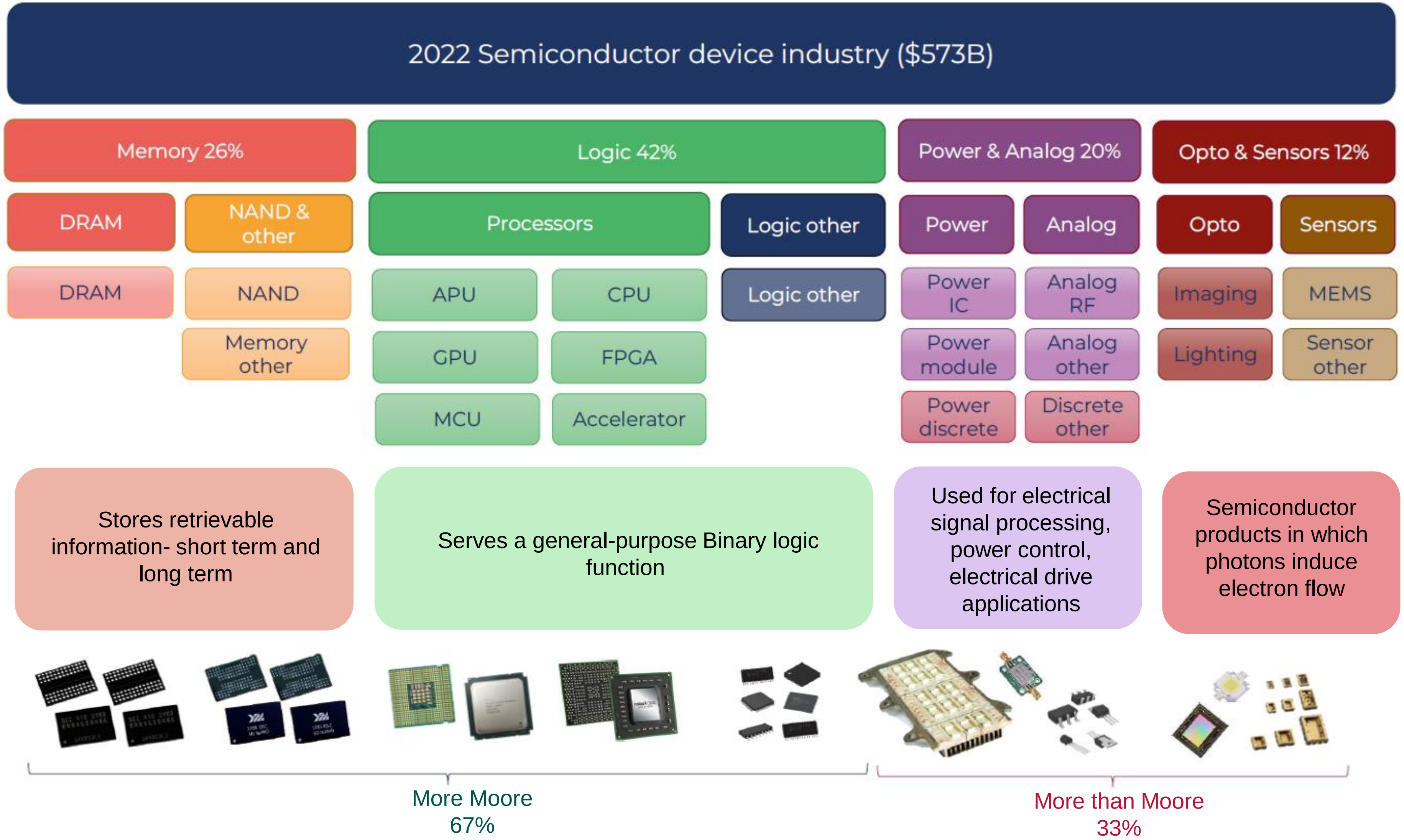
Semiconductor Product Market Segmentation: The Shift from Traditional Scaling to Diversified Applications

Exploring Market Segments and the "More Moore" vs. "More than Moore" Paradigms in a $573 Billion Industry



2022 Semiconductor device industry ($573B)

- Memory 26%
  - DRAM
    - DRAM
  - NAND & other
    - NAND
    - Memory other
- Logic 42%
  - Processors
    - APU
    - CPU
    - GPU
    - FPGA
    - MCU
    - Accelerator
  - Logic other
    - Logic other
- Power & Analog 20%
  - Power
    - Power IC
    - Power module
    - Power discrete
  - Analog
    - Analog RF
    - Analog other
    - Discrete other
- Opto & Sensors 12%
  - Opto
    - Imaging
    - Lighting
  - Sensors
    - MEMS
    - Sensor other

Stores retrievable information- short term and long term

Serves a general-purpose Binary logic function

Used for electrical signal processing, power control, electrical drive applications

Semiconductor products in which photons induce electron flow

More Moore
67%

More than Moore
33%

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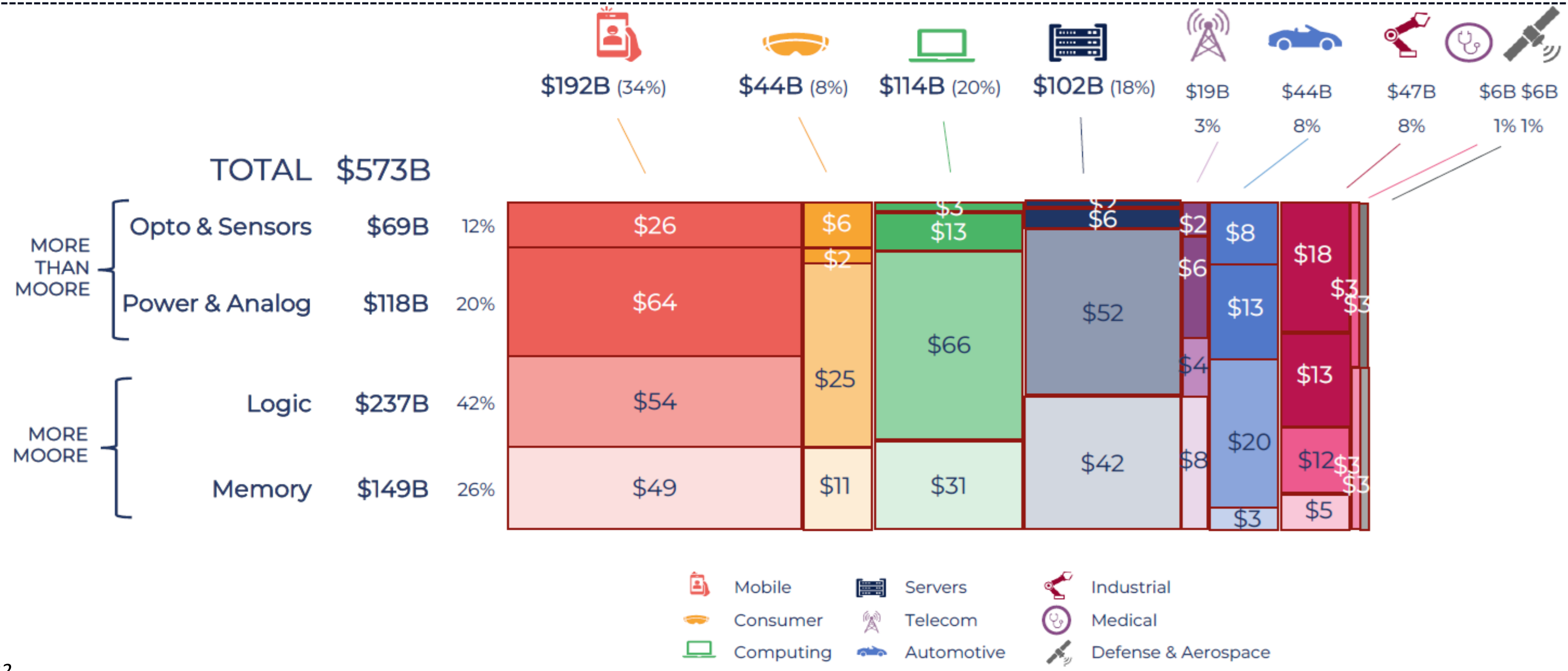
A $573B Industry at the Intersection of Innovation and Application

From logic chips driving AI to memory fuelling data storage, ICs power the digital economy, making up 42% of industry revenues with logic chips alone

While industry taxonomies typically describe 30+ types of product categories, semiconductors can be classified into 3 broad categories:-

- **Logic (42% of industry revenues)-** 1) Microprocessors- CPU, GPU, APs 2) General purpose logic- Field Programmable Gate Arrays (FPGAs) 3) MCUs 4) Connectivity products, such as cellular modems, Wi-Fi or Bluetooth chips or Ethernet controllers
- **Memory (26% of industry revenues)-** 1) DRAM 2) NAND
- **Discrete, Analog, and Other (DAO) (32% of the industry revenues)-** These Semiconductors transmit, receive, and transform information dealing with continuous parameters such as temperature and voltage. 1) Discreet 2) Analog 3) Others

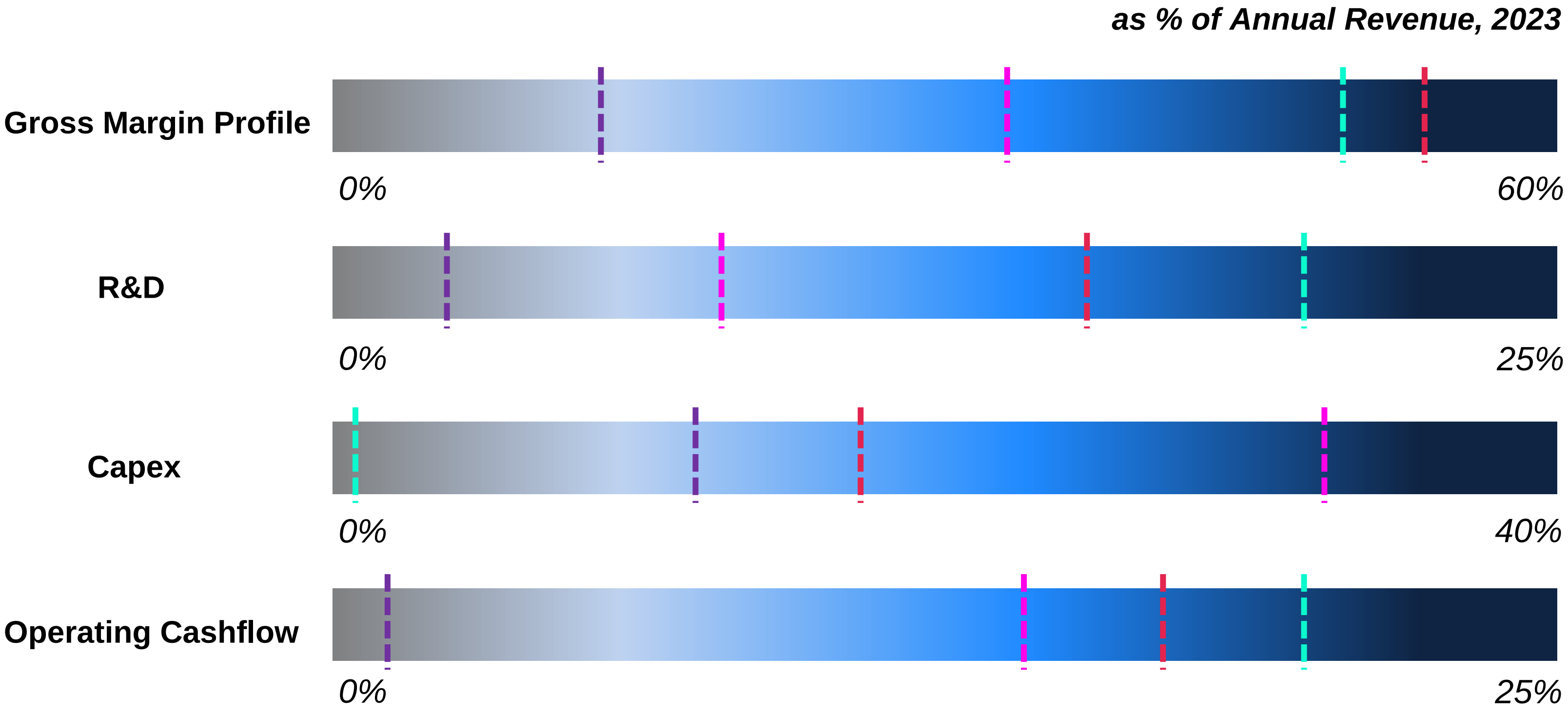


*For Year 2022

3. Semiconductor Business Models

Decoding Semiconductor Financials: A Business Model Breakdown

A Benchmark Analysis of Financial Metrics: How IDMs, Fabless, Foundries, and OSATs Allocate Resources and Generate Margins



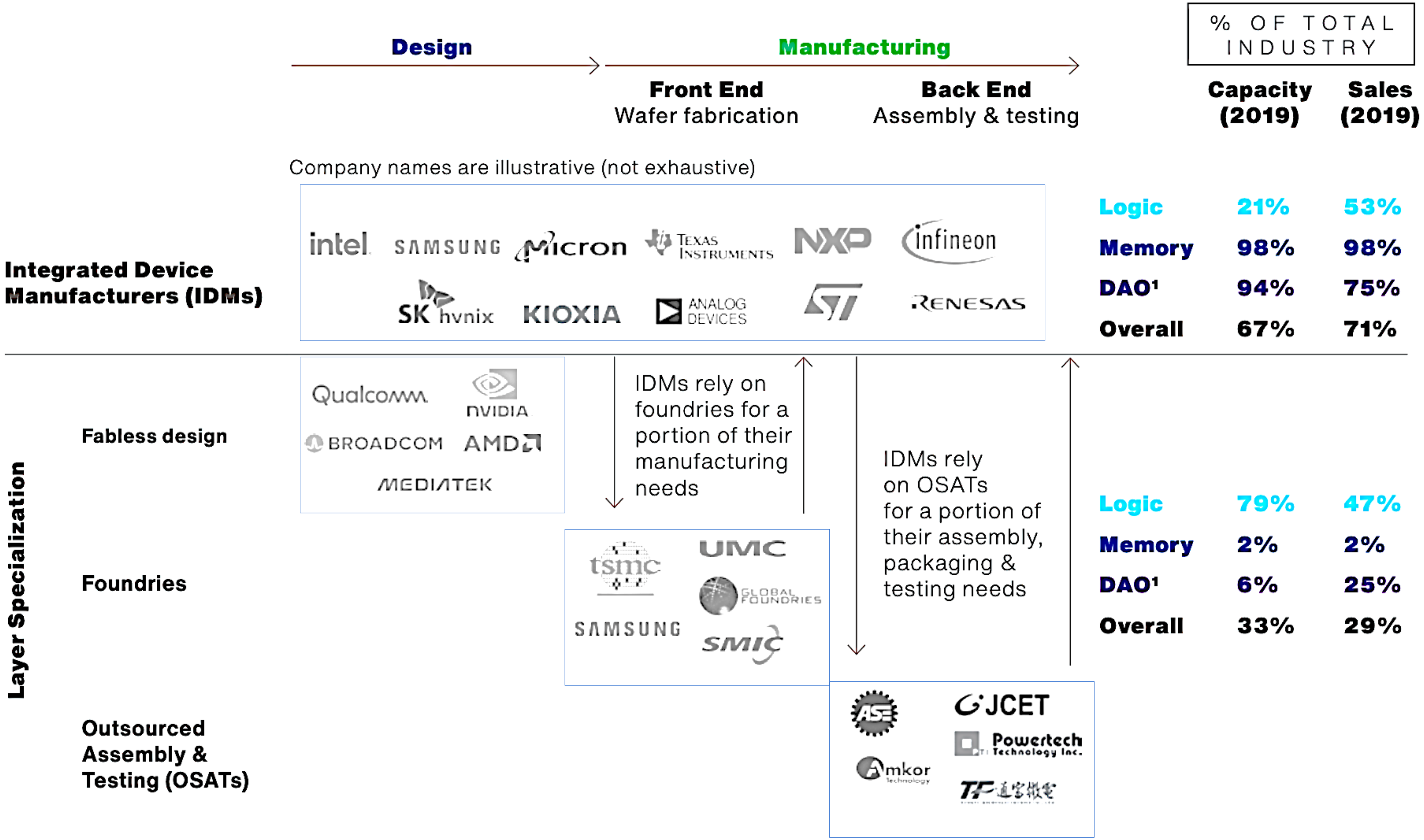
Integrated Device Manufacturers (IDMs) and **Foundries** tend to have the highest **Capex** as a percentage of annual revenue, while **Fabless design companies** enjoy a significantly **higher gross margin profile** and **lower Capex.** **Operating cash flow** is more evenly distributed, but IDMs and Fabless companies tend to be more profitable relative to OSATs. Consequently, Fabless and OSATs should be the most ripe business models for the Indian ecosystem to explore

- - - - - IDMs
- - - - - Fabless Design (including services)
- - - - - Foundries (front end and backend)
- - - - - OSATs

Source: Blume Analysis, BCG, Tracxn

The interdependencies in manufacturing and specialisation across business models

While IDMs like Intel, Samsung, TI etc. constitute more than 70% of the overall sales revenue of the semiconductor industry, verticalization and technology complexity have made every layer (like fabless, OSATs etc.) a multi-billion-dollar outcome



Design → **Manufacturing** →

Front End
Wafer fabrication

Back End
Assembly & testing

Company names are illustrative (not exhaustive)

Integrated Device Manufacturers (IDMs)

intel
SAMSUNG
Micron
Texas Instruments
NXP
infineon
SK hynix
KIOXIA
ANALOG DEVICES
ST
RENESAS

	% OF TOTAL INDUSTRY	
	Capacity (2019)	**Sales (2019)**
Logic	**21%**	**53%**
Memory	**98%**	**98%**
DAO[1]	**94%**	**75%**
Overall	**67%**	**71%**

Layer Specialization

Fabless design

Qualcomm
NVIDIA
BROADCOM
AMD
MEDIATEK

IDMs rely on foundries for a portion of their manufacturing needs

Foundries

tsmc
UMC
GLOBALFOUNDRIES
SAMSUNG
SMIC

IDMs rely on OSATs for a portion of their assembly, packaging & testing needs

Outsourced Assembly & Testing (OSATs)

ASE
JCET
Powertech Technology Inc.
Amkor Technology
TF 通富微電

	Capacity (2019)	**Sales (2019)**
Logic	**79%**	**47%**
Memory	**2%**	**2%**
DAO[1]	**6%**	**25%**
Overall	**33%**	**29%**

Source: Gartner, BCG

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India’s Chip Journey: From Design to Dominance

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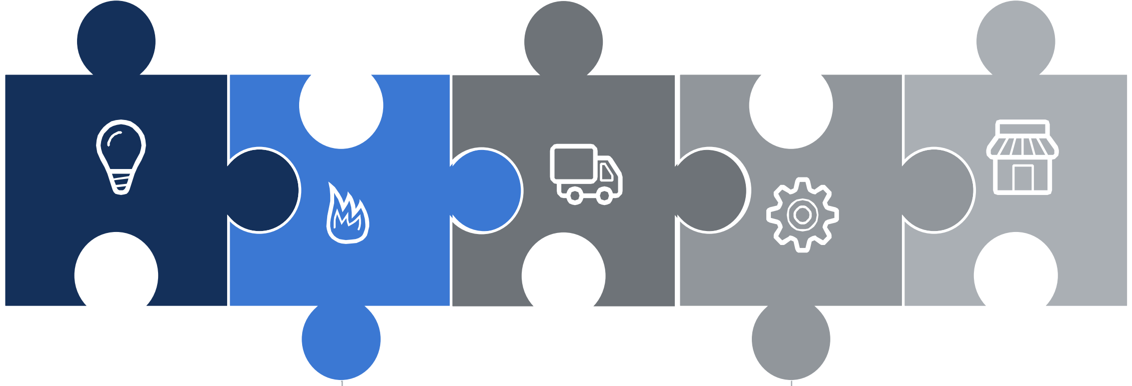
India’s Semiconductor Potential: Cracking the Code

From design dynamos to supply chain snags, India's semiconductor journey is a work in progress



WORLD'S BIGGEST DESIGN ECOSYSTEM

***20%** of Global Semiconductor Design workforce*

POOR DOMESTIC SUPPLY

*Only **9%** of India’s semiconductor components are locally sourced. India intends to increase its local sourcing to 17% by 2026*

UPCOMING FAB FACILITIES

Upcoming fabs to produce legacy semiconductors at 28 nm or above with state’s help

A LARGE DOMESTIC MARKET

*Annual consumption of semiconductors worth **$50B** (2021)*

GROWING ELEMENTS

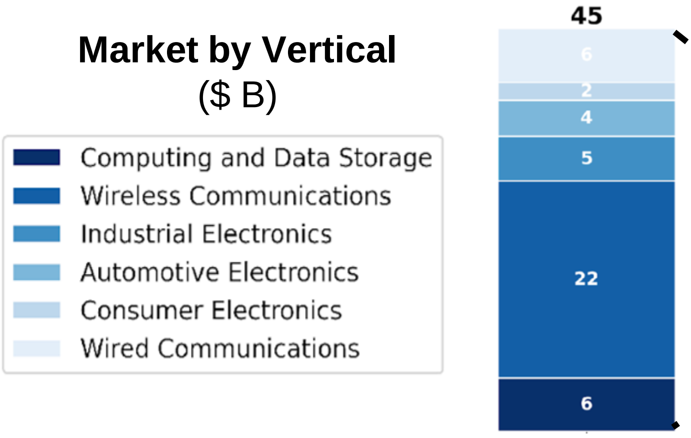
Ecosystems for design, Assembly, Testing and Packaging (ATP) and manufacturing materials growing rapidly

Source: Invest India, Deloitte, Blume Analysis

India’s Semiconductor Surge: Powering a $110B Opportunity

By 2030, India’s semiconductor market will more than double to 11% of the global share, de-risking supply chains and cementing its role as a crucial player in the trillion-dollar semiconductor revolution

Market by Vertical
($ B)

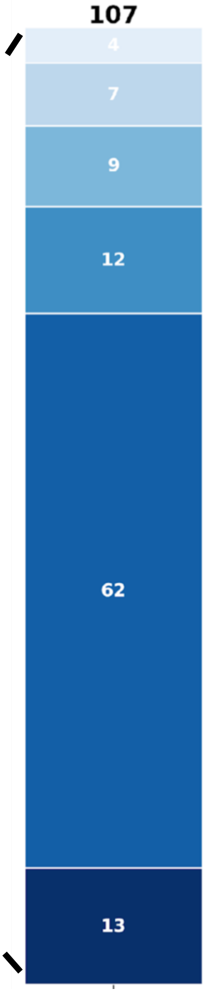


2021

$45B
7.6% of the Global Market

2030

$110B
10.8% of the Global Market



By 2030, Global semiconductor industry is expected to grow to $ 1 trillion and Indian semiconductor demand is expected to grow at as faster rate and cross **$110B (~11%).** India’s entry in the semiconductor manufacturing will significantly **de-risk global supply chains** and will make India a very important player in the global semiconductor industry

Source: Invest India, ISEA, McKinsey

Fabless: India’s Semiconductor Superpower in the Making

India’s domestic fabless design ecosystem has considerable room to grow, if it can overcome certain barriers like domestic manufacturing capabilities and liquid capital

India is home to **20% of the world’s semiconductor design engineers**, with over 125,000 experts designing 3,000+ ICs annually

A thriving fabless ecosystem is key to realizing India’s semiconductor manufacturing aspirations

40+ Indian startups are focusing on chip design, given fabless accounts for around 50% of value addition. Startups are venturing into high-volume, low-margin industries such as IoT, energy meters, toy controllers and embedded systems

Fabless design startups requires **more liquid risk capital** given **longer gestation periods**

Due to **limited manufacturing capabilities**, Indian chip designers send their design abroad for prototype development and testing.

India's nascent fabless ecosystem, with **less than $50M annual revenue**, has significant growth potential, aided by government incentives to offset high IP and EDA costs

Source: Invest India

From Labor to Silicon: Can India's ATP ambitions bridge the global semiconductor gap?

With 75% of ATP tied to China and Taiwan, India's push into assembly, test, and packaging could reshape the global chip landscape

ATP (*assembly, test, and packaging)* is a **labor intensive, high volume & low margin business**. India has sufficient labor availability that can be employed as shop floor technicians or entry-level engineering staff

Major Asian players (Korea, Taiwan and Singapore) entered the chip industry through ATP before moving to fabrication, given the adjacency to device, PC and smartphone assembly, India has a lot of scope in this model

In the next 5 years, India has the potential to expand its presence in the ATP segment to as many as **5 facilities** and to attract fabs producing legacy chips at **28 nm or above**

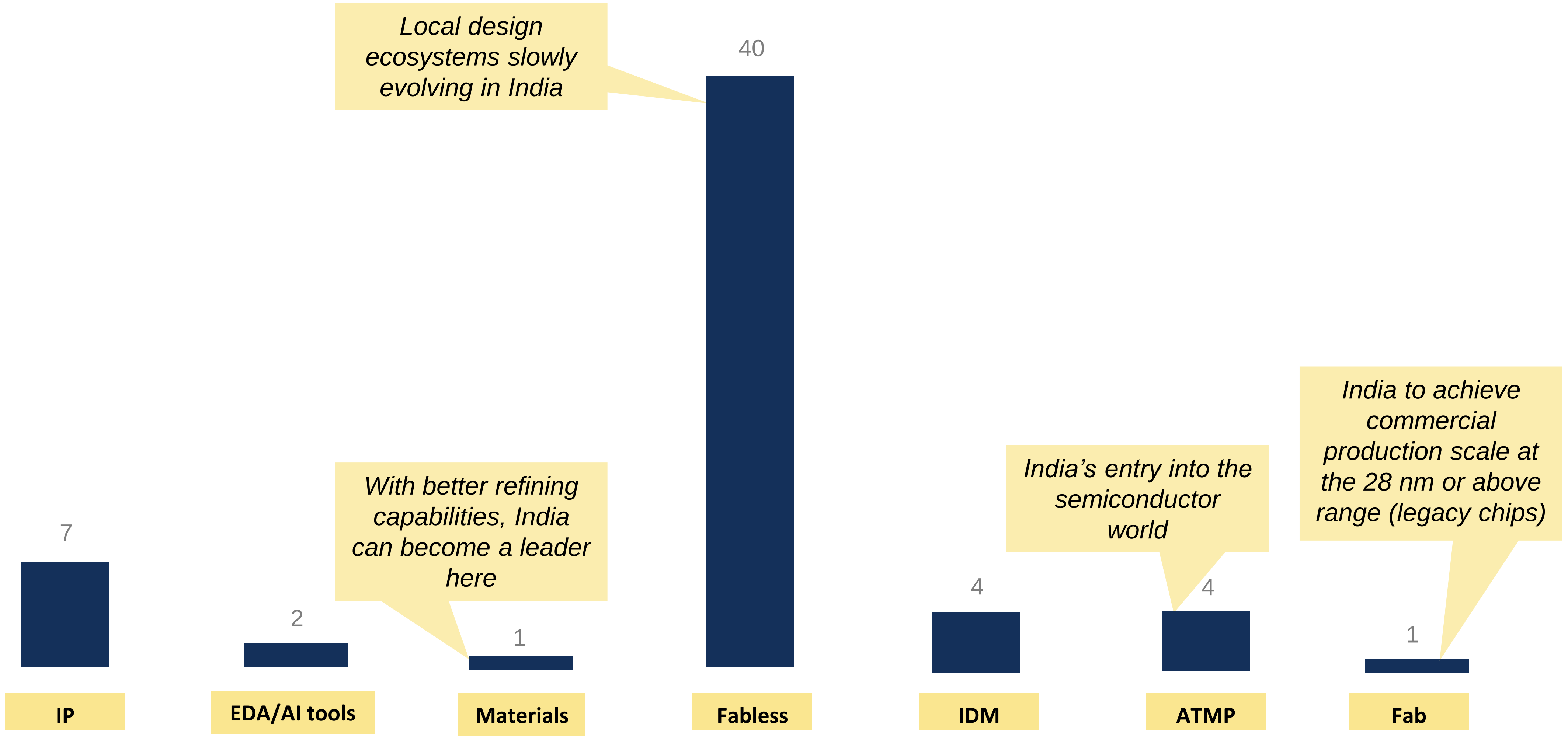
Most ATP units are coupled with **strong fab linkages**. Except for trailing edge nodes & specialty fabs (Gallium Nitride etc.) that may be established in India, there needs to be incentives for a fab outside create a finished wafer, transport to India for ATP and then re-export finished product abroad

With shifting focus to advanced packaging which involves high R&D spend, **R&D spends will gradually take over cheap labor availability as the comparative advantage**. India may have a small window to capitalize on its labor strength

Source: Invest India, Blume Analysis

India's Semiconductor Startups: Leading in Fabless, Aspiring for More

While most Indian startups thrive in the Fabless space, opportunities abound for growth in IDM, ATMP, and Fab segments as the ecosystem evolves



Source: Tracxn; ATMP = Assembly, Testing, Marking, and Packaging

India's Rising Stars in the Semiconductor Value Chain

From IP to IDMs, India's growing semiconductor startup ecosystem is lighting up every step of the value chain—highlighting the country's ambitions to become a global semiconductor powerhouse

Design

Fabrication

IDMs

Assembly

IP | EDA | Fabless | Fab | Materials | Equipment | OSATs | IDM

MORPHING MACHINES
SILICONCH SYSTEMS
InCore
Green IP Core Design with Innovation
Silizium Circuits
terminus circuits innovative solutions
SEMI DESIGN
SIGNITUDE®

CIRCUIT SUTRA TECHNOLOGIES
Ilmda

MINDGROVE
NETRASEMI
LEVI SEMICONDUCTORS
LIGHTSPEED PHOTONICS
FERMIONIC
Singularity
KALATRONICS Semiconductors Private Limited
ambit™ innovation and beyond
arch LABS
Saankhya Labs
LAKSH semiconductors excellence through innovation
Polymatech
SIGNALCHIP
VLSI MONKS
insemi TECHNOLOGY
ALBUM Semiconductors
DRUTAYA
TESSOLVE
METTLESEMI
optoML

SimYog®
Sahasra
infinipack

Oakter
AGNIT
QπSEMI
VISICON POWER

*A sample set of the complete startup universe

Emerging Trends You Can’t Ignore

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The Grand Challenges for the next decade(s)!

To meet the demands of true cognitive computing, the industry must address radical challenges across analog, memory, and computing — redefining performance, efficiency, and scalability for the future

We are **entering a new era where computing systems achieve true cognition**—gaining understanding through experience, reasoning, and perception. However, this new regime is unattainable with current semiconductor technologies and traditional advancements, as the reduction in feature size for performance improvements and cost reduction is reaching its physical limits. Therefore, **the existing paradigm must evolve to address a value proposition centered around information and intelligence**, driven by semiconductor technologies.

The most influential technologies will emerge by addressing the following “**Grand Challenges**”:

Analog:

The analog interface bridges the physical and digital worlds. With the exponentially increasing data from analog sensing, there is need for **emerging technologies to increase actionable information** with less energy, enabling efficient and low latency **sensing-to-analog-to-information with a reduction ratio of 10^5:1**

Memory and Storage:

The growth of memory demands will outstrip global silicon supply, providing opportunities for radically new solutions.

Memory: Develop memories and memory fabric with **>10-100X density** and energy-efficiency improvement.

Storage: Develop storage technologies with **>100X storage density**

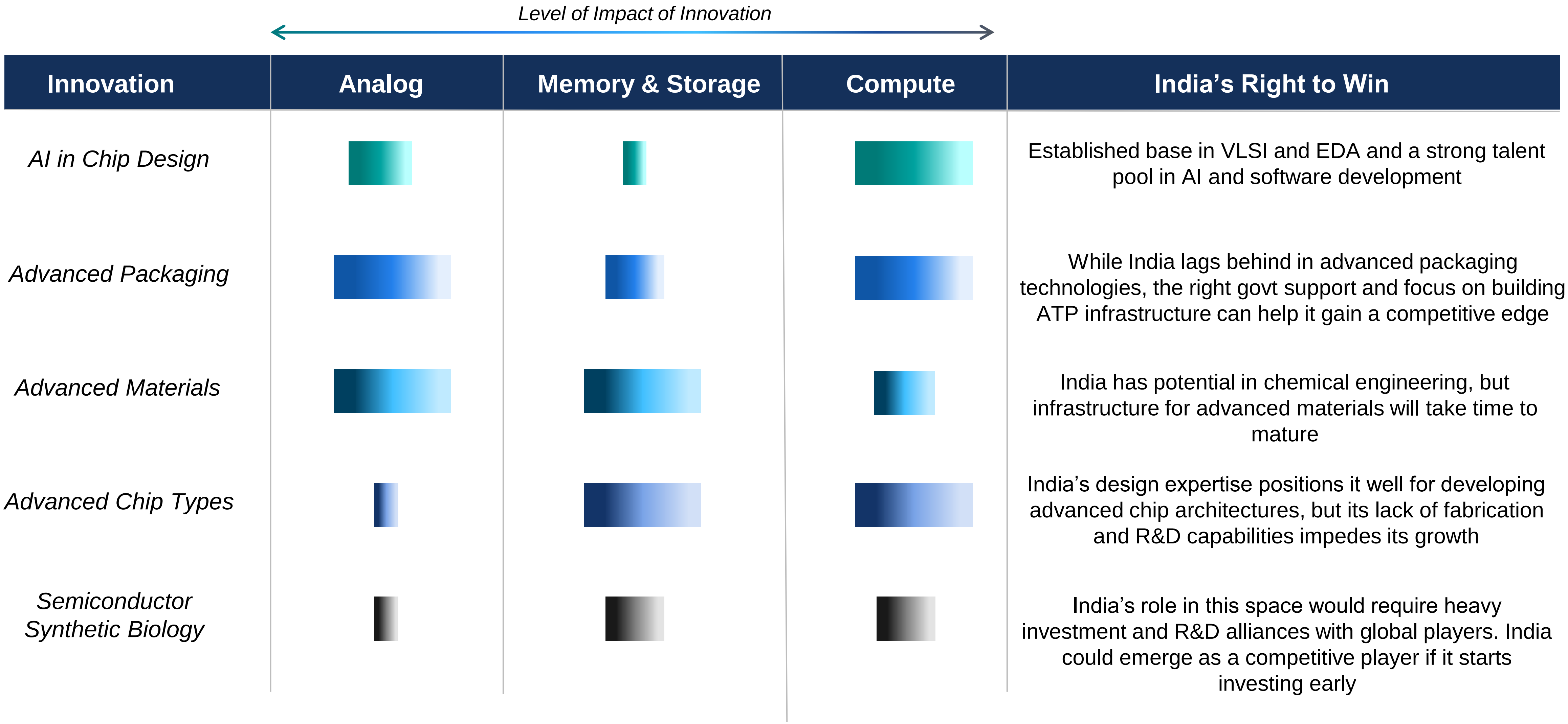
Computing:

Ever-rising energy demands for computing versus global energy production are creating new risk, **new computing paradigms/architectures with demonstrating >1,000,000x improvement in energy efficiency** will be a much more cost-effective way of addressing this challenge compared to dramatically increasing the world’s energy supply

Source: Semiconductor Research Council

The Grand Opportunities for the next decade(s)!

From AI chip design to cutting-edge materials, India has the talent and potential to lead — but strategic investments and breakthroughs are the key to unlocking its true semiconductor power



Level of Impact of Innovation

Innovation	Analog	Memory & Storage	Compute	India's Right to Win
AI in Chip Design				Established base in VLSI and EDA and a strong talent pool in AI and software development
Advanced Packaging				While India lags behind in advanced packaging technologies, the right govt support and focus on building ATP infrastructure can help it gain a competitive edge
Advanced Materials				India has potential in chemical engineering, but infrastructure for advanced materials will take time to mature
Advanced Chip Types				India's design expertise positions it well for developing advanced chip architectures, but its lack of fabrication and R&D capabilities impedes its growth
Semiconductor Synthetic Biology				India's role in this space would require heavy investment and R&D alliances with global players. India could emerge as a competitive player if it starts investing early

Source: Blume Analysis

AI in Chip Design

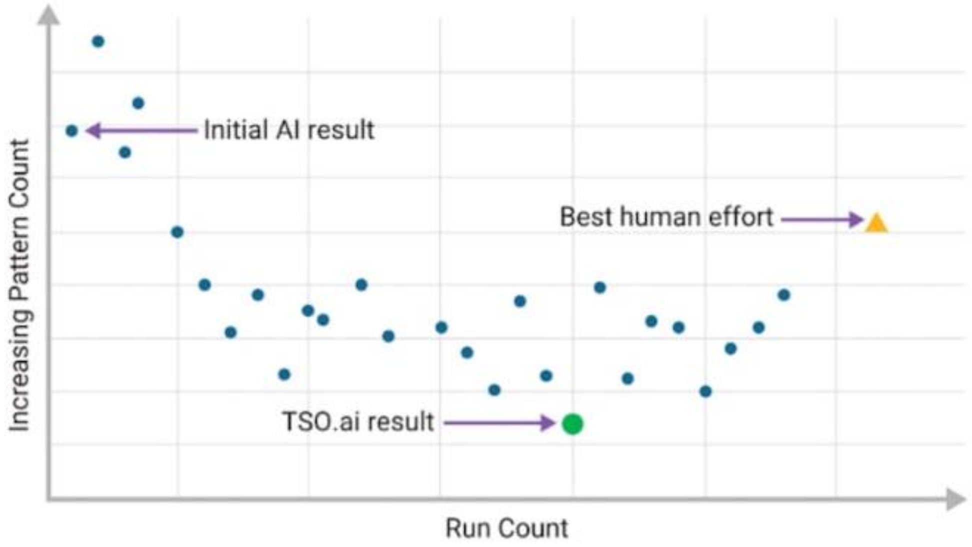
The answer to arrange 100 billion transistors on one square inch!

Growth in advanced AI tools for chip design is expected to be more than double that of EDA tools and more than triple the growth rate of chip sales

Five-year CAGR for chips, EDA tools, and advanced AI design tools (2023–2028)

- Advanced AI tools can test human designs by finding placement errors that increase power consumption, impede performance, or use space inefficiently; suggesting improvements; and then simulating and testing those
- These tools learn from prior iterations to improve PPA until it reaches its limit, and can do this autonomously, generating better PPAs than human designers using traditional EDA tools
- Such tools handle design complexity, take over repetitive tasks like design space exploration, verification coverage and regression analytics, and test program generation, and even help in improving fab yield
- These advanced AI capabilities fall almost entirely into 2 categories: graph neural networks (GNNs) and reinforcement learning (RL)

RTL-to-GDSII full flow optimization unlocks PPA potential across both logical and physical domains with reported productivity enhancements of more than 3x, power reductions of up to 15%, and substantial die size reductions



Synopsys' Test Space Optimization (TSO.ai) solution

While the AI boom is a recent phenomenon, it was expected that newer players would dominate this space. However, established EDA giants like Synopsys and Cadence have swiftly adapted to AI trends and are already leading the market with their innovations

cadence SYNOPSYS FARADAY TECHNOLOGY Ansys XILINX

Source: Global Market Insights, Deloitte, Synopsys

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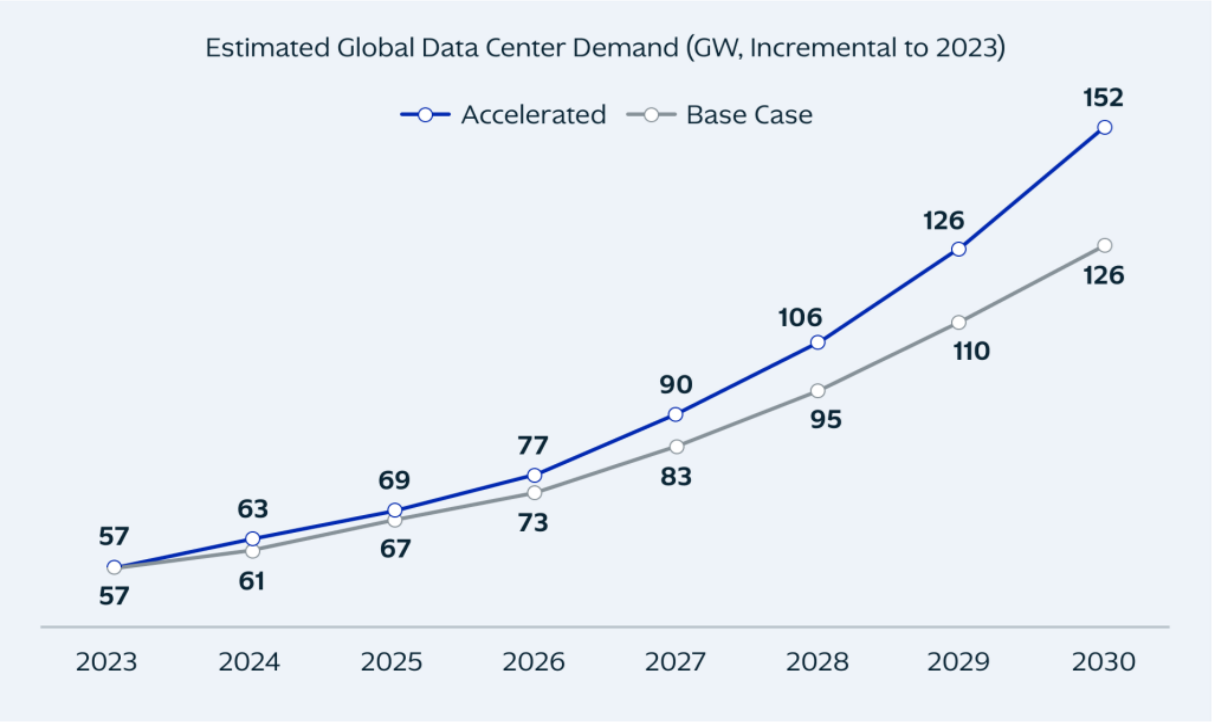
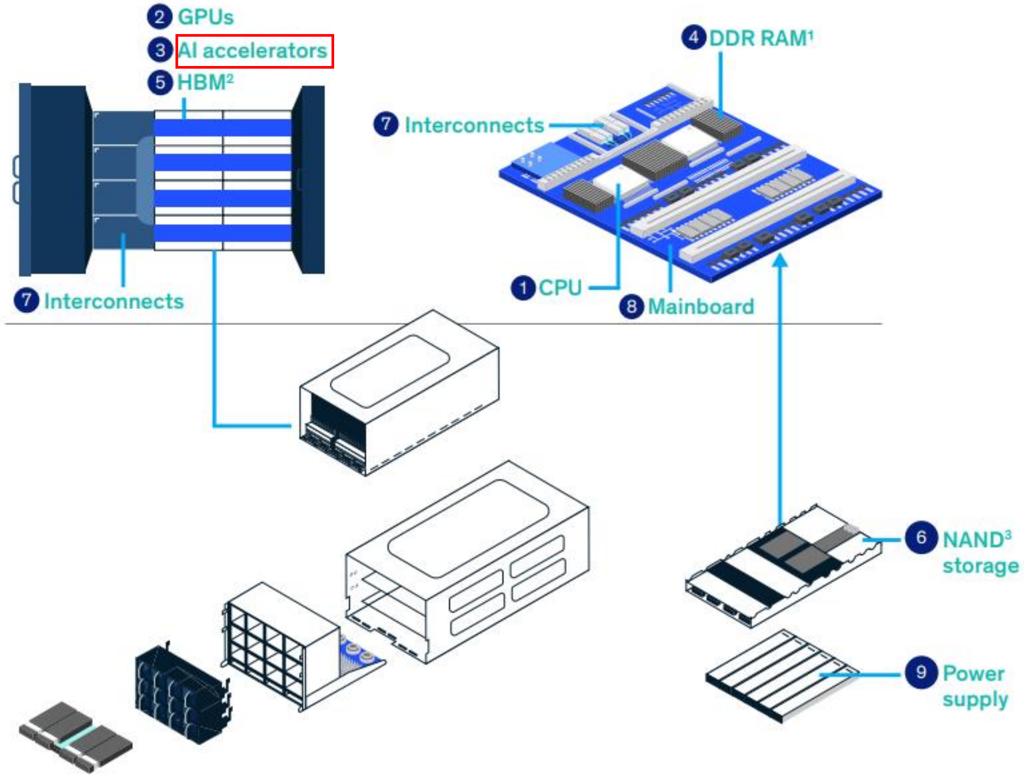
Artificial Intelligence: The next S-Curve ?

India's AI chip design could revolutionize tech by harnessing talent and forging powerful global partnerships





AI Server Breakdown

The surge of interest in and use of generative AI comes with a proportional increase in compute demand as seen by the rising demand of dedicated data infrastructure which runs AI application. This secular demand pushes the semiconductor industry to innovate faster and produce more capable, efficient and specialized chips like '**AI Accelerators**' to accelerate AI workloads by performing high-speed computations and optimize cost and energy.

Source: McKinsey

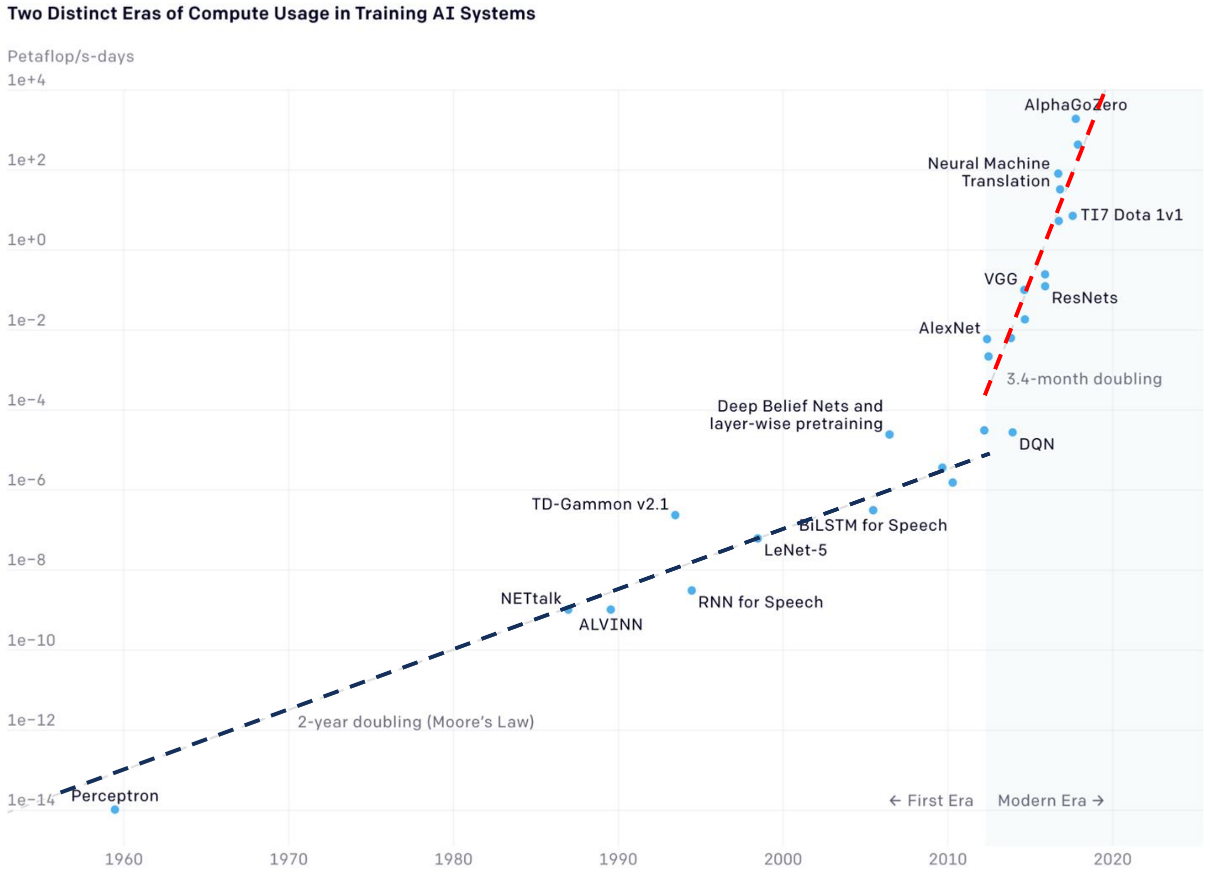
AI Accelerators: Turbocharging the Future of Machine Learning

From AlexNet to AlphaGo Zero, AI compute power has exploded 300,000x, reshaping the capabilities of machine learning with specialized parallel processing

An **artificial intelligence (AI) accelerator**, also known as an AI chip, deep learning processor or Neural Processing Unit (NPU), is a hardware accelerator that is built to speed AI neural networks, deep learning and machine learning.

For decades, computer systems depended on accelerators for a variety of specialized tasks. Typical examples of coprocessors include **graphics processing units (GPUs),** sound cards and video cards. But with the growth of AI applications over the last decade, traditional CPUs and even some GPUs couldn't process the large amounts of data needed to run AI applications. Enter AI accelerators, with specialized **parallel-processing** capabilities, **reduced precision arithmetic** and **memory hierarchy** that allow them to perform billions of calculations at once.

AlexNet to AlphaGo Zero: 300,000x increase in compute



Since 2012, the amount of **compute** used in the largest AI training runs has been **increasing exponentially with a 3.4-month doubling time!**

Source: IBM, OpenAI

AI Accelerators: Powering the Future Across Industries

From self-driving cars to robots, AI accelerators bring unprecedented speed, efficiency, and intelligence to the forefront of innovation

Autonomous Vehicle

AI accelerators can capture and **process data in near real time**, making them critical to the development of self-driving cars, drones and other autonomous vehicles. Their **parallel processing** capabilities are unmatched, allowing them to process and interpret data from cameras and sensors and process it so vehicles can react to their surroundings

Edge Computing and Edge AI

Edge computing is a process that **brings applications and compute power closer to data sources like IoT devices**, allowing data to be processed with or without an internet connection. Edge AI allows for AI capabilities and AI accelerators of ML tasks to perform at the edge, rather than moving the data to a data center to be processed, **improving energy efficiency and reducing latency**

Large Language Models

Large language models (LLMs) depend on AI accelerators to help them develop their unique ability to understand and generate natural language. AI accelerators' parallel processing helps **speed processes in neural networks**, optimizing the performance of cutting-edge AI applications like generative AI and chatbots

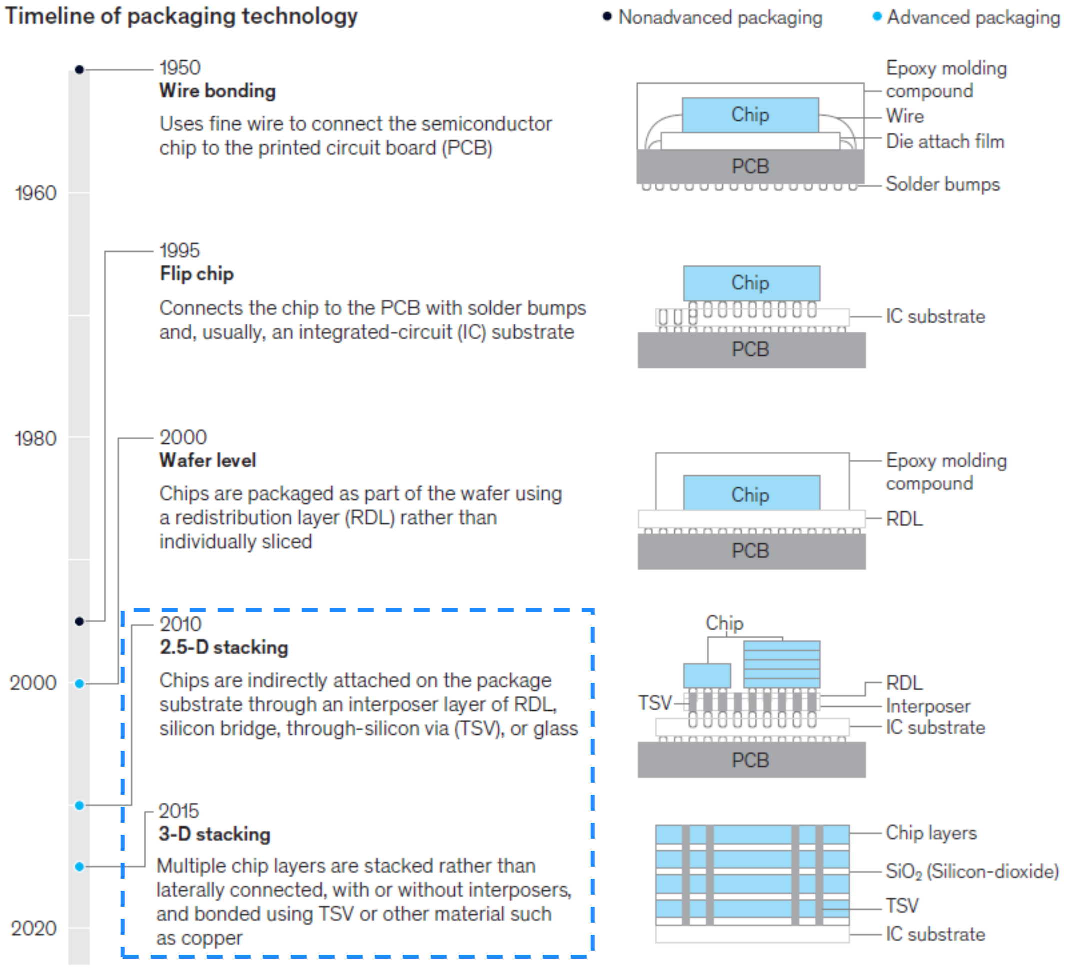
Robotics

AI accelerators are critical to the development of the robotics industry due to their **ML and computer vision capabilities**. As AI enhanced robotics are developed for various tasks—ranging from **personal companions to surgical tools**—AI accelerators play a crucial role in developing their abilities to detect and react to environments with the same speed and accuracy as a human

Source: IBM

Advanced Packaging: The Hidden Hero of Chip Performance

From flip chips to 3D stacking, advanced packaging is transforming semiconductor efficiency, enabling smaller, faster, and more powerful devices



1950
Wire bonding
Uses fine wire to connect the semiconductor chip to the printed circuit board (PCB)

1995
Flip chip
Connects the chip to the PCB with solder bumps and, usually, an integrated-circuit (IC) substrate

2000
Wafer level
Chips are packaged as part of the wafer using a redistribution layer (RDL) rather than individually sliced

2010
2.5-D stacking
Chips are indirectly attached on the package substrate through an interposer layer of RDL, silicon bridge, through-silicon via (TSV), or glass

2015
3-D stacking
Multiple chip layers are stacked rather than laterally connected, with or without interposers, and bonded using TSV or other material such as copper

Advanced Packaging

The wafers' **packaging**—whether metal, plastic, ceramic, or glass—connects them to their environment and protects them from chemical contamination and damage from light, heat, and impacts.

Compared with the front-end process of designing and fabricating wafers, **the back-end process of packaging has been undervalued** as packaging is mostly done by outsourced semiconductor assembly and test companies (OSATs) that compete largely based on low labor costs and old equipment, rather than other sources of differentiation.

This model will change with the introduction of **advanced packaging**, which uses sophisticated technology and aggregates components from various wafers, creating a single electronic device with **superior performance** unlocking **greater functionality** with a **reduced form factor**.

Market Size

2030(E)- $80B

2022
$44B

Key Players

tsmc
intel
SAMSUNG
Amkor Technology®
Advanced Semiconductor Engineering, Inc.

Source: McKinsey, Blume Analysis

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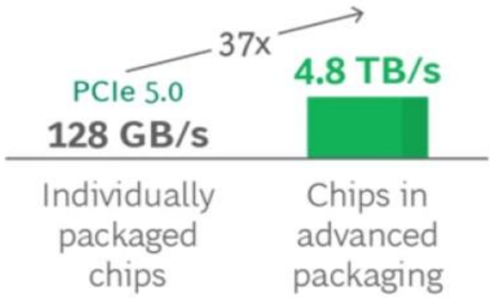
Advanced Packaging: End Use Cases

From AI to PCs, advanced packaging revolutionizes performance, cuts costs, and accelerates time to market

AI/HPC
NVIDIA H200

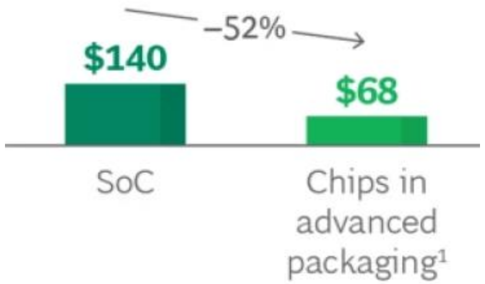


35x faster

- High-Bandwidth Memory Integration
- Superior interconnect speeds, 35x more than traditional chips
- Enhanced Power Efficiency
- Improved economics of data center

TAM (2030E): $330B

PC
AMD Ryzen 16-core

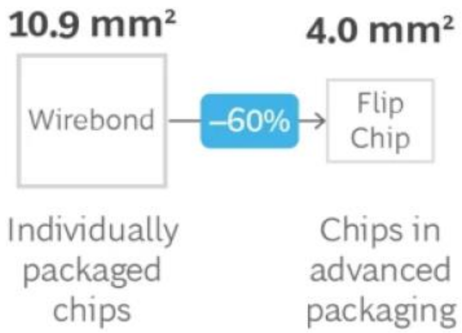


50% lower cost

- **Heterogenous Integration:** Allowed selection from a range of node sizes for each integrated die
- **Functional Optimization**
- **Cost Reduction**

TAM (2030E): $330B

ADAS
Infineon Optireg

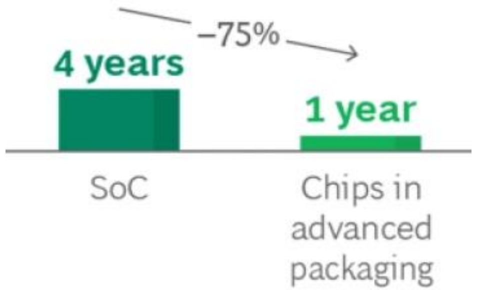


60% reduced area

Advanced Integration for Compact Devices: Reduction in footprint by 60% by integrating individual chips used in linear voltage controllers into an advanced package

TAM (2030E): $125B

PC
Intel HPC



75% faster time to market

Switching from a single large SoC to multiple dies in its Data Center GPU Max Series can minimize die complexity and allow existing die designs to be reused in multiple packages and **reduce time to market by up to 75%.**

TAM (2030E): $330B

Source: BCG, Blume Analysis

Advanced Materials: More than Moore

Chips made of newer materials surge ahead, handling the volts that would fry silicon chips!

Beyond reducing structure size, some semiconductor companies are pursuing “**more than Moore**” differentiated approach for product innovations. Some, for instance, are developing semiconductors based on materials other than silicon. **Compound semiconductor** materials, such as **silicon carbide (SiC) and gallium nitride (GaN**), are particularly well suited for applications requiring both **high power and frequency**, since they **limit energy loss** and allow for the creation of **smaller form factors**

66%
of the GaN chip market will constitute consumer electronics chargers by 2026

~60%
of the SiC chip market will come from automotive applications, mainly BEVs by 2026

However, a few things need to happen before GaN, SiC, and other power semiconductors truly boom.

- First, new facilities (fabs) for making these chips would have to be built
- However, both the fabs and the materials needed for them raise thorny supply chain and national security issues
- Silicon, carbon, and nitrogen are all abundant and available, but currently almost all gallium comes from France, Kazakhstan, and Russia
- As with other elements and gases used in semi manufacturing with a small number of possible sources, manufacturing risk is therefore higher

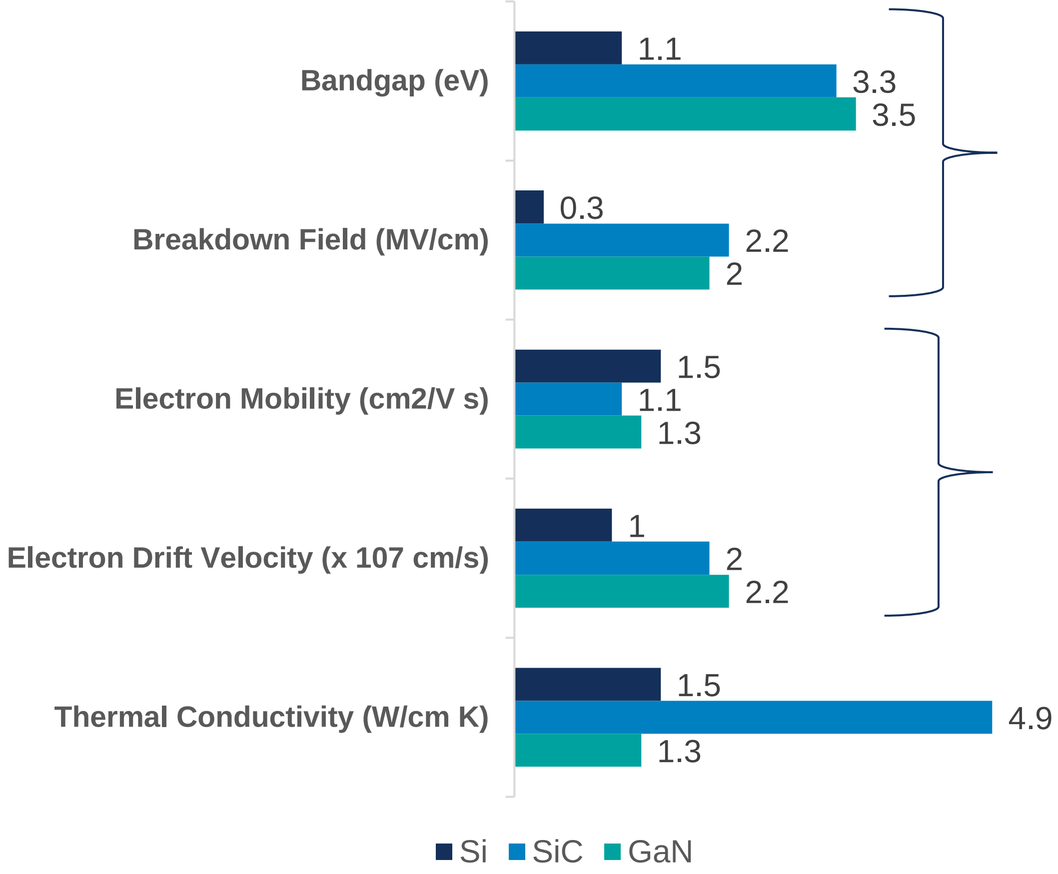
Annual Combined Sales of GaN and SiC in $B

Source: Deloitte Insights

Advanced Materials: GaN & SiC: Powering the Future

Unlocking higher voltages, faster speeds, and greater efficiency—these advanced materials are shrinking devices while boosting their power

Physical Properties



Effect on Device

Higher voltage
Lower resistance

Lower switching losses

Effect on System

High switching frequency and smaller passive components

High Power Density

Effect on End-Application

Higher efficiency
Smaller
Lighter
Cheaper

Silicon Carbide (SiC) and Gallium Nitride (GaN) can sustain higher voltages, higher frequencies, and more complex electronics compared to silicon alone. These factors will lead to more widespread adoption of SiC and GaN across the power electronics market.

Source: Blume Analysis

GaN vs SiC: The Power Duo

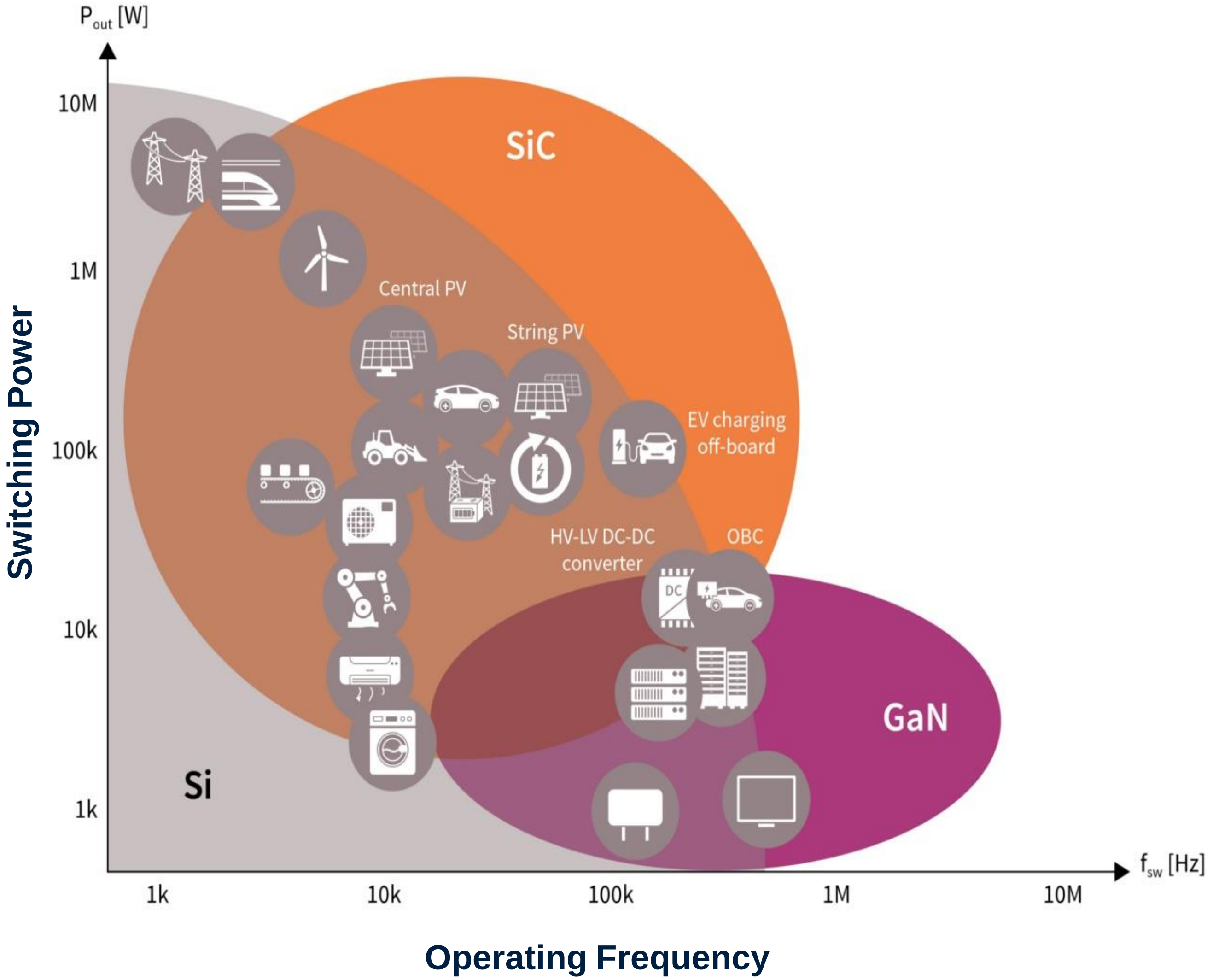
From EV chargers to solar inverters, GaN and SiC are driving the next generation of high-efficiency, high-power electronics

Gallium Nitride (GaN)- with its superior switching FOM, inherent manufacturing and cost advantages and ability to switch at much higher frequencies, GaN has become the device of choice for many designers in <10-kW applications. Designers finally have tools that enables them to make the best choice when designing greener, lighter and more cost-effective products

- Wireless device charging
- EV Charger
- Solar Inverter
- Server Power supply
- Handheld Power Tools

Silicon Carbide (SiC)- SiC devices offer voltage levels as high as 1,200 V with high current-carrying capabilities. This makes them a good fit for applications like automotive & locomotive traction inverters, high-power solar farms etc

- Solar Inverter
- EV Battery
- Industrial Robotics
- Electrical Grid
- Rail



Source: Infineon, Blume Analysis

Quantum Qubits: Where Classical Computing Meets the Future

From superconducting to photonic, qubits are reshaping how we process information, offering exponentially more possibilities than classical bits

A traditional digital computer process binary information with bits that can be in one of two states: 0 and 1; thus, a 4-bit computer register can hold any one of 2^4, or 16, possible numbers. **Quantum computers process quantum bits, or qubits**, that exist in a ***superposition*** of 0 and 1 values; thus, for example, a 4-qubit computer register can handle 16 different numbers simultaneously.

There are several types of qubits that have been proposed or implemented in quantum computing platforms, some of them are:

Superconducting Qubits: The most common type, are based on the Josephson junction, which is a device that allows the flow of supercurrent without resistance.

Trapped Ion Qubits: Utilize electronic and nuclear spin states of ions like that are trapped and manipulated using electromagnetic fields

Quantum Dot Qubits: Rely on the electronic spin states of electrons confined In semiconductor quantum dots, manipulated using electrical gates and magnetic fields.

Photonic Qubits: Based on the quantum properties of light, such as polarization and phase. They are manipulated using optical components such as beam splitters, phase shifters, and detectors.

Diamond nitrogen-vacancy (NV) center Qubits: Based on the electronic spin states of nitrogen-vacancy centers in diamond, manipulated using microwave and optical fields

Nuclear Magnetic Resonance (NMR) Qubits: Based on the nuclear spins of atoms or molecules that are manipulated using radiofrequency pulses in a magnetic field.

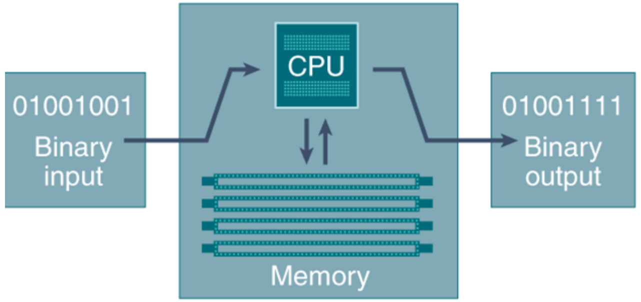
Source: Nature, Blume Analysis

Neuromorphic Semiconductors: Mimicking the Brain, Redefining AI

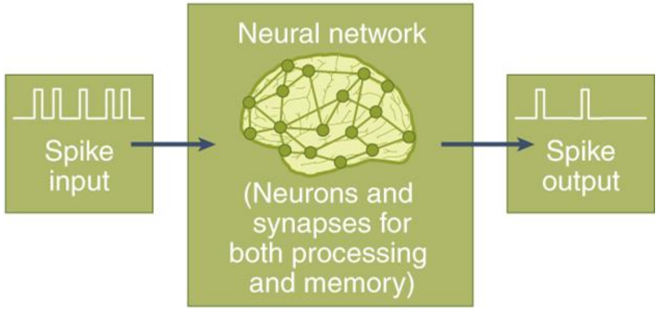
Where silicon neurons meet synapses—neuromorphic chips bring the power of parallel processing and brain-like efficiency

A **neuromorphic chip** is a specialized microprocessor designed to **mimic the structure and function of the human brain**, enabling efficient processing of neural networks. It employs **parallel processing and low-power consumption**, enhancing the speed and energy efficiency of artificial intelligence tasks. Neuromorphic chips hold promise for advancements in cognitive computing, machine learning, and the development of brain-inspired computing systems.

Traditional von Neumann Architecture



Neuromorphic Architecture



Operation	*Sequential Processing*	*Massively parallel processing*
Organization	*Separated computation and memory*	*Collocated processing and memory*
Programming	*Code as binary instruction*	*Spiking Neural Network*
Communication	*Binary Data*	*Spikes*
Timing	*Synchronous (clock driven)*	*Asynchronous (event-driven)*

Key Players

intel

SAMSUNG ELECTRONICS

GML GrAI Matter Labs

SK hynix

IBM

Source: Nature

SemiSynBio: Merging Biology with Semiconductors for a New Era of Computing

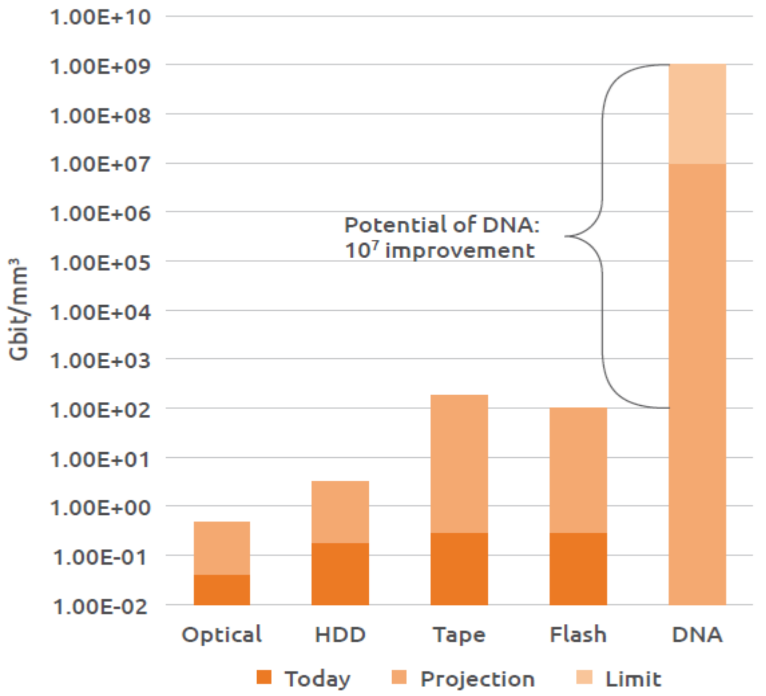
Harnessing biological systems to transform semiconductor efficiency, storage, and processing capabilities for a new technological era

SemiSynBio aims to take advantage of the significant **energy efficiency and information processing advantage**s that biological systems have over the best foreseeable equivalent silicon-based systems. SemiSynBio may fundamentally redefine semiconductor design and manufacture, unleashing forces of creative destruction and giving rise to industries that bear little resemblance to that which we know today.

These advances build upon breakthroughs in DNA synthesis and characterization, electronic design automation, nanoscale manufacturing, and understanding of biological processes for energy efficient information processing.

Key emerging technologies:

1. **DNA-based Massive Information Storage**
2. Energy Efficient, Small-Scale Cell-Based & Cell-inspired Information Systems
3. Intelligent Sensor Systems and Cell/Semiconductor Interfaces
4. Electronic-Biological System Design Automation
5. Biological pathways for semiconductor fabrication and integration



Volumetric Data Storage Comparison

Source: Semiconductor Research Council

Key Investment Directions

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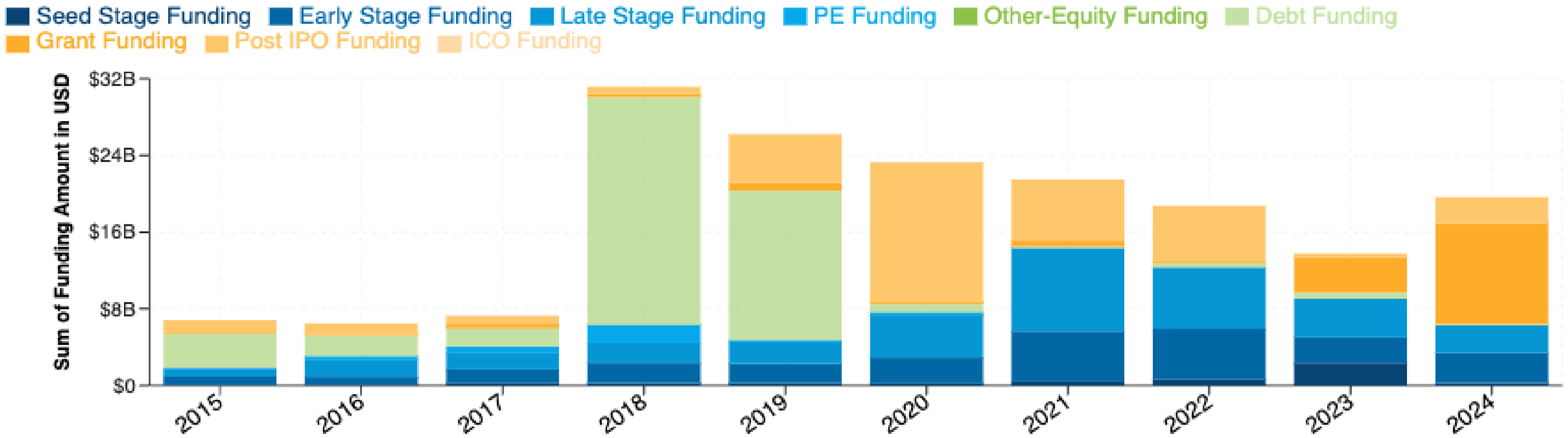
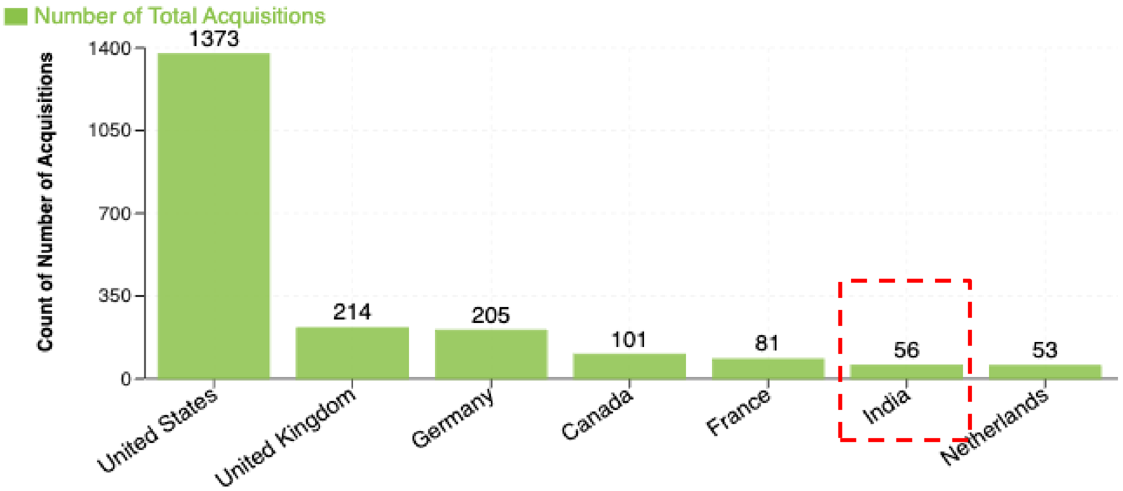
Navigating Funding and Exit Strategies for Semiconductor Startups

Government Grants and Early-Stage VC Fuel Growth, but Exit Multiples via Acquisitions Remain Low in India Compared to Global Markets



Global Funding ($B)

Can semiconductor businesses be built with VC money? With increasing Govt grants across the world, the good news for seed/early investors is that a billion $ outcome is possible with just Early-stage funding + Govt Grants



Acquisition might be a viable exit strategy but not necessarily a well-paying one- Though India has seen 56 acquisitions till date (6th highest across the world), the Average Acquisition Price is just **$43.7M** vs US ($1.08B), Taiwan ($1.29B), UK ($1.89B) and Israel ($721M).

Source: Blume Analysis, Tracxn

Scaling valuations across funding stages: India's semiconductor startups on the rise

Manufacturing services represent most of the funding & exits while the long tail entails emerging feeds like Photonics, EDA tools, Embedded Systems etc.

India	Median Revenue Multiple	Median Post-money Valuation
Seed + Angel	16.65x	$4.1M
Series A	12.1x	$5.48M
Series B	4x	$100.3M
Late Stage Series C + D	5.1x	$399.8M

Top Investment Feeds in India (Total Funding till date)

Electronic Manufacturing Services	Semiconductor Design & Manufacturing Services	Analog & Mixed Signal ICs	Sensors
$401M	**$153M**	**$133M**	**$37.8M**

Source: Pitchbook, Tracxn

Lessons from the Frontline: Case Studies

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cerebras

Pioneering world's largest AI chips and fastest supercomputers to revolutionize AI compute

Funding and Financials

Founded: 2015
Location: San Francisco, USA
Funding: $750M
Stage: Series F
Investors: Alpha Wave, Benchmark Capital, VY Capital

Technology and Innovation

World's fastest AI Accelerator: The CS-2 system is based on the largest processor ever built, the Cerebras Wafer-Scale Engine (WSE) vis-à-vis NVIDIA's H100:

- 57x larger
- 52x AI optimized compute cores
- 880x chip memory
- 7000x memory bandwidth

Product Market

Large Language Models: Train the largest models, with long context, across various languages and domains. Helping customers build models that set new performance records in Arabic text, medical data and mobile devices.

High Performance Computing: HPC applications traditionally use very large CPU and GPU, Cerebras architecture uses wafer-scale approach making possible orders of magnitude improvement in performance.

Challenges and Opportunity

Differentiated Product: With a unique wafer-scale integrated chip, Cerebras offers a step change in distributed computing and an alternative to GPUs which currently crowds the $71B AI Chip Market (2024)

Cost and Market Adoption: With a reported cost for the latest CS-3 chip in the range of $2-3M and the technical challenges with the fabrication of die-sized chip, might limit potential customer base.

Source: Cerebras Website, Statista

black semiconductor

Developing graphene based powerful microchips with integrated electronic-photonic circuits

Funding and Financials

Founded: 2019
Location: Aachen, Germany
Funding: $276M
Stage: Series A
Investors: Public Funding (*German State of North Rhine-Westphalia*)

Technology and Innovation

Developing a new way to build networks of chips leveraging a novel material: graphene. These new chip networks will speed up data communication between chips for unparalleled performance, improved energy-efficiency, and a significant reduction in manufacturing costs through 60% fewer production steps required.

Product Market

Large Language Models: Through more efficient and faster data communication at the chip level, it is possible to design efficient chip networks in data centers such that it does not strain the global energy resources.

Embedded AI Applications: Accelerated communication between sensors and the central control unit in autonomous driving will be the building block for next level of autonomous driving.

Challenges and Opportunity

EU Semicon Ecosystem: Black Semiconductor is well positioned to play a crucial role in developing the semiconductor value chain in Europe, enhancing the continent's technological sovereignty.

Tech Commercialization: Black plans to establish pilot manufacturing line by 2026 compliant with existing standards, transitioning from R&D to manufacture a commercially viable chip.

Source: Company Website, Techcrunch

Saankhya Labs

India's first fabless design startup founded in 2007, created a software-defined radio platform, offering chip solutions across sectors

Funding and Financials

Founded: 2007
Location: Bangalore, India
Funding: $18.6M
Stage: Acquired by Tejas Network at $50M+ (July 2022)
Investors: Various Angel and Institutional investors

Technology and Innovation

Saankhya's Open, Cognitive and Scalable **5G RAN** solution portfolio provides a differentiated solution to the operator to optimize spectrum use and reduce the Total Cost of Ownership

Product Market

Satellite Communications: Sankhya's ground based SDR chipset is used to operate variety of Satcom and Satellite IoT applications by Indian Railways for real-time tracking of electro-locomotives and for other strategic and defense purposes.

5G Communication

Challenges and Opportunity

Recent trends in 5G Deployment and the ORAN alliance enabled Saankhya to pivot into the telecom space, making the stage for it to be acquired by Tejas Networks to leverage its radio expertise, enabling a wider development and validating Saankhya's technology.

Source: Tracxn, Company Website

Indian Semiconductor Mission

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The "Maruti 800" Moment of the Indian Semiconductor Industry

India's semiconductor investment package, offering a 50% match by the central government and 20 to 25% by the relevant state government, is currently the world's most generous

$10B

Semiconductor Ecosystem

- Semiconductor and Display Fabs
- Compound Semiconductor
- ATMP
- Design Linked Incentive (DLI)
- Modernization of Semiconductor Laboratory (SCL, Mohali)

$7B

Electronics Manufacturing

- Production Linked Incentives (PLI) for Mobile Phones, Components, IT Hardware
- Capex Linked Incentive for components, sub-assemblies
- Development of Electronics Manufacturing Cluster

$13B

Support for Allied Sectors

Production Linked Incentives for

- Advanced Chemistry Cell
- Automobiles & Auto Components
- Telecom & Networking
- Solar PV Modules
- White Goods

Semiconductor Design

Product Design Linked Incentive: 50% of Eligible expenditure
Deployment Linked Incentive: 6% - 4% on Net Sales

Semiconductor Fabs

Fiscal Support: 50% of project cost on pari-passu basis
Technologies covered: All node sizes for Silicon CMOS based fabs

Display Fabs

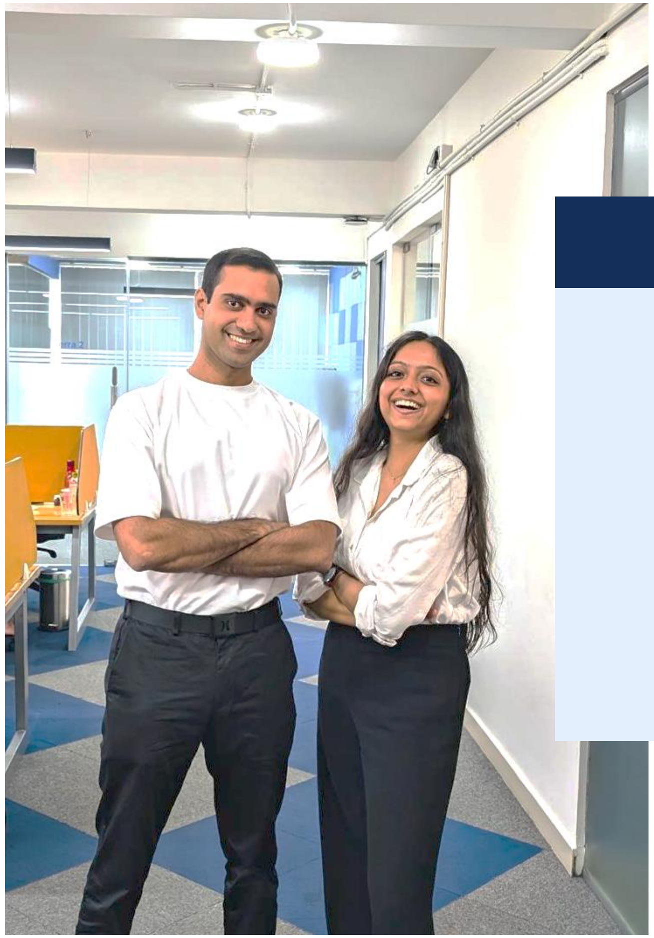
Fiscal Support: 50% of project cost on pari-passu basis
Technologies covered: New gen TFT LCD & AMOLED displays

Compound Semiconductor & Packaging

Fiscal Support: 50% of Capex pari-passu basis
Technologies covered: OSAT/ATMP, Compound Semiconductor, Silicon Photonics, Sensors (including MEMS)

Source: ISM, Ashish Kale, Invest India, Blume Analysis; * 70% Project Cost as incentives for Manufacturing

Meet our Authors



And by the end, we were dreaming BIG…in nanometres!

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Thank you!

While we are thesis driven, we are also open to questioning and changing our views as we learn from founders and the market. If you have any feedback on this thesis, or would like to push back on any view, please reach out!

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