Capital Markets Strategy

Essential inCights for the C-Suite

MUFG

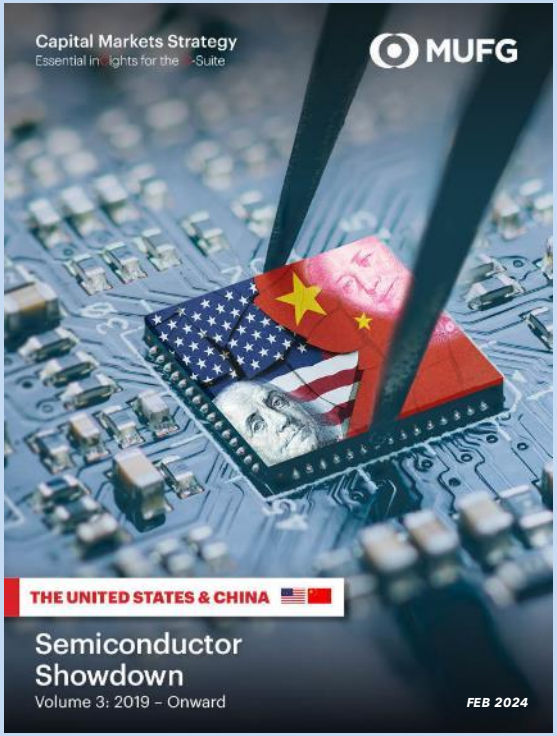
THE UNITED STATES & CHINA

Semiconductor Showdown

Volume 3: 2019 – Onward

FEB 2024

The United States & China



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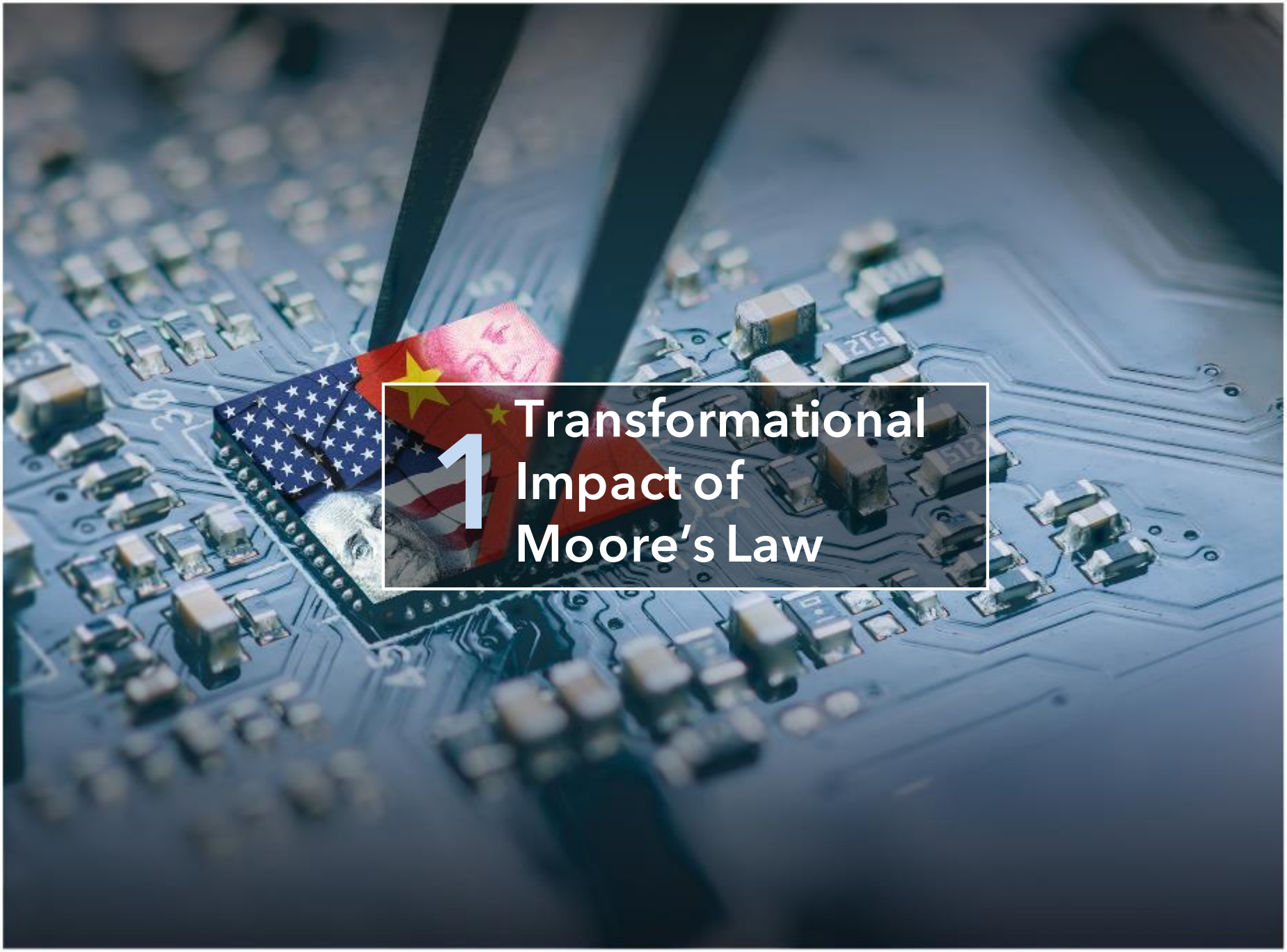
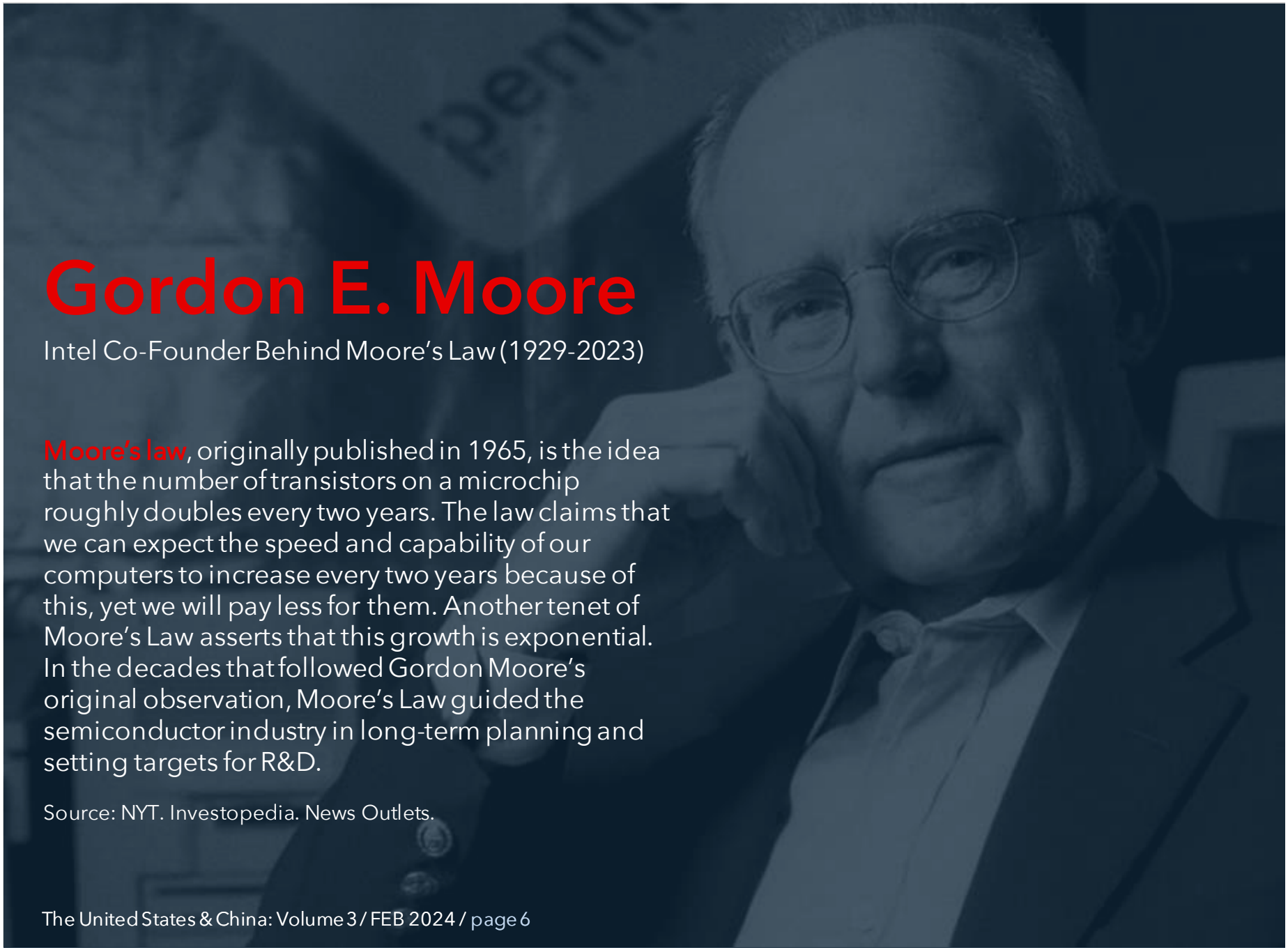
Contents



1 Transformational Impact of Moore's Law



Gordon E. Moore

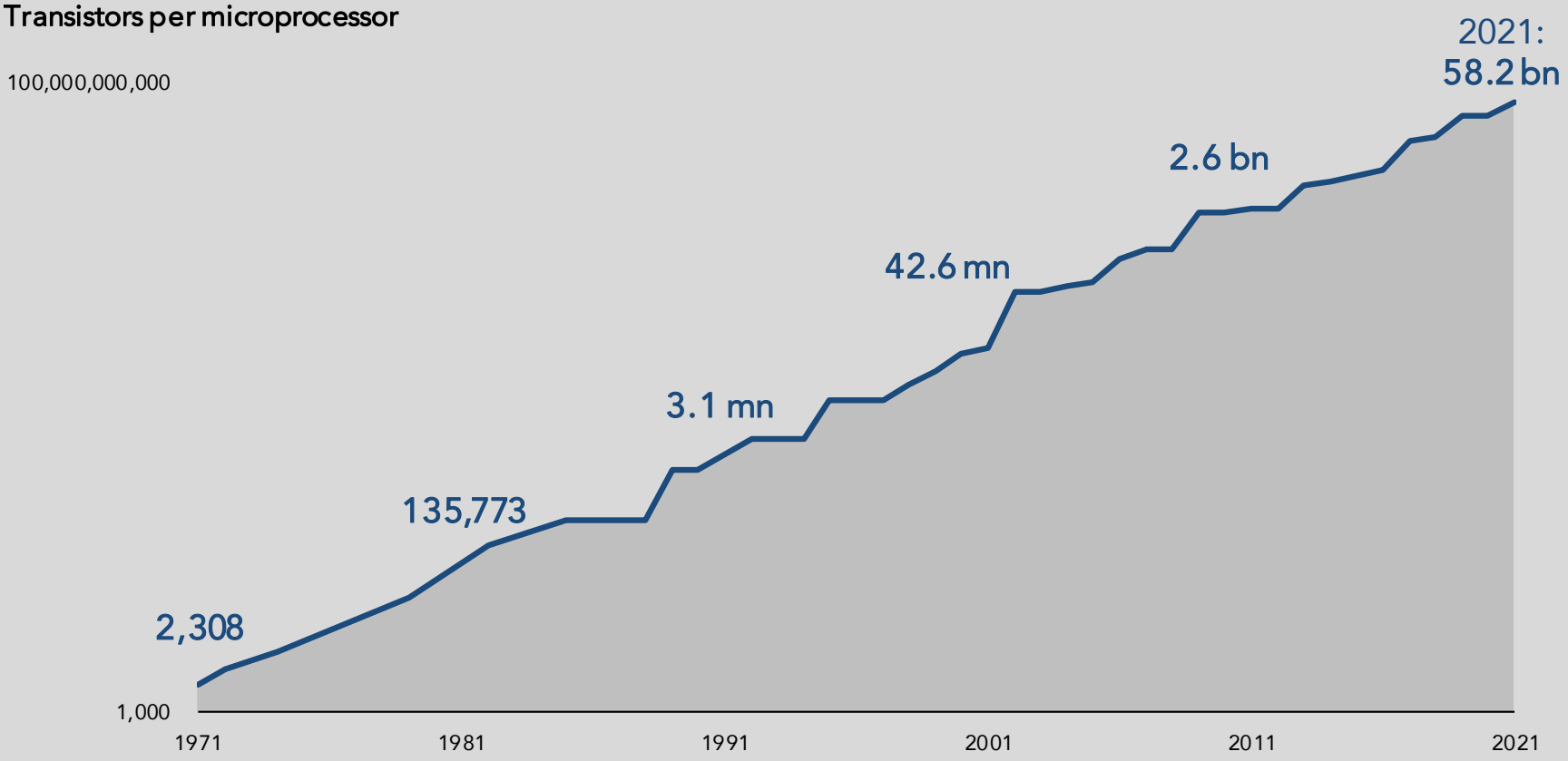
Intel Co-Founder Behind Moore's Law (1929-2023)

Moore's law, originally published in 1965, is the idea that the number of transistors on a microchip roughly doubles every two years. The law claims that we can expect the speed and capability of our computers to increase every two years because of this, yet we will pay less for them. Another tenet of Moore's Law asserts that this growth is exponential. In the decades that followed Gordon Moore's original observation, Moore's Law guided the semiconductor industry in long-term planning and setting targets for R&D.

Source: NYT. Investopedia. News Outlets.

Transformational Impact of Moore's Law

Nearly half a century after its original publication, Gordon Moore's 1965 pronouncement that the number of transistors on a microchip doubles about every two years still holds true today. In 2021, the number of transistors per chip stood at an astounding 58.2bn. The transformational impact in this multi-decade advancement in processing power lends itself to the extraordinary complexity of a globally extended and regionally concentrated semiconductor supply chain.



Source: (1) Karl Rupp. Microprocessor Trend Data (2022). Our World in Data. Axis is logarithmic scale.

Pervasive Impact of Semiconductors

From smartphones to airplanes, heart monitors and guided missiles, semiconductors are critical to nearly every component of modern life. As chip design advances, higher power, smaller and more cost effective semiconductors are being developed each year.

Memory chips

Circuitry: Digital

Function: Information storage

Types: Dynamic Random Access Memory (DRAM), NAND

Uses: running programs, storing files or photos

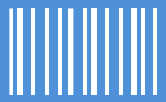
Logic chips

Circuitry: Digital

Function: "Brains" of electronic devices; process information to complete tasks or run programs

Types: central processing units (CPUs), graphical processing units (GPUs), neural processing units (NPUs)

Uses: basic computing, visual displays, machine learning applications



Application Specific Integrated Chips (ASICs)

Circuitry: Hybrid analog and digital

Function: performing repetitive processing

Uses: scanning barcodes

System-on-a-chip device (SOCs)

Circuitry: Hybrid analog and digital

Function: combine many chip functions and circuits on a single chip

Uses: Integrate processes for graphics, audio, camera, video and Wi-Fi

World's Most Competitive Economies

The 2023 IMD World Competitiveness Ranking

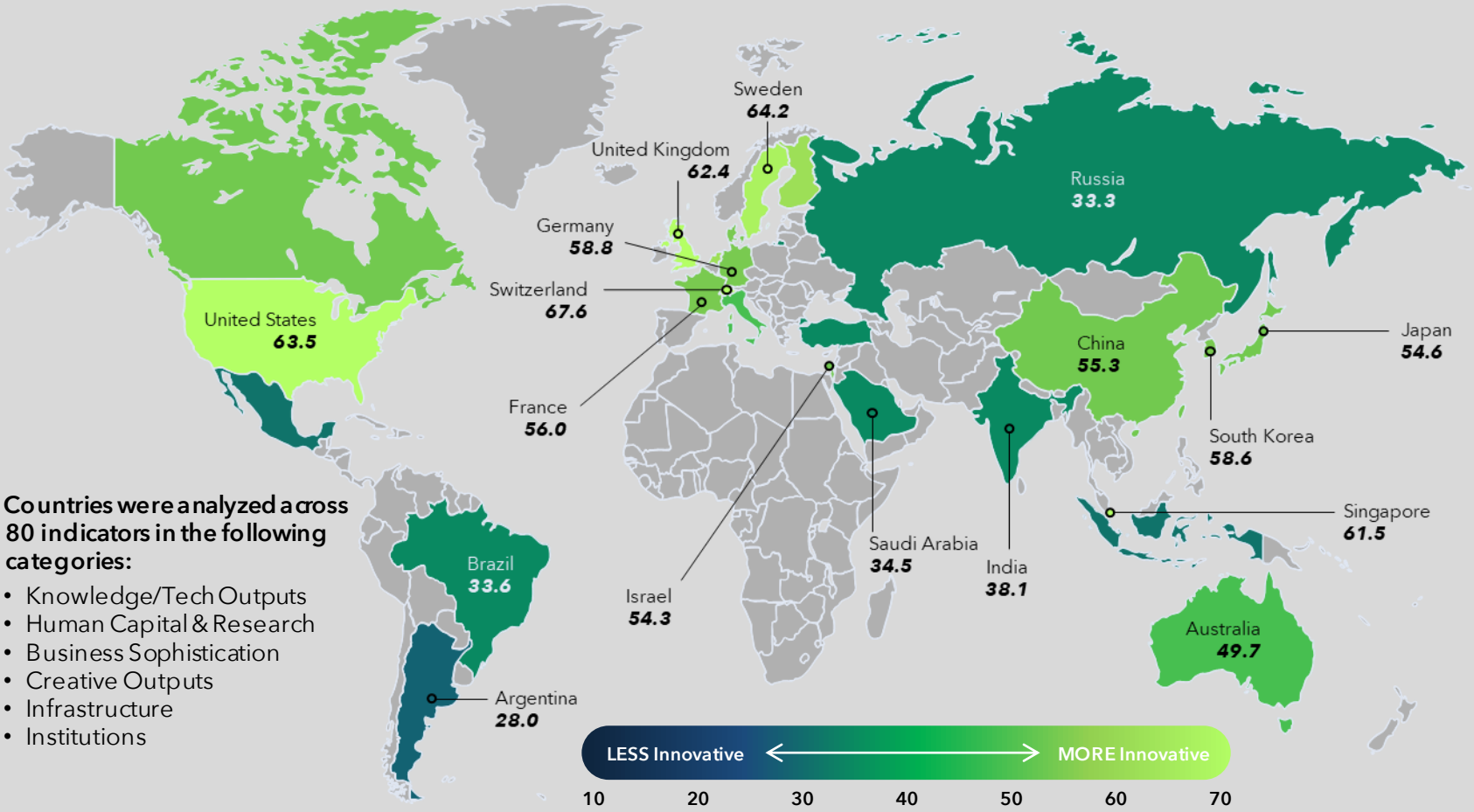
1.	Denmark	100.00
2.	Ireland	99.71
3.	Switzerland	99.13
4.	Singapore	97.44
5.	Netherlands	95.58
6.	Taiwan	93.11
7.	Hong Kong	92.05
8.	Sweden	91.86
9.	USA	91.14
10.	UAE	90.52
11.	Finland	89.73
12.	Qatar	89.72
13.	Belgium	89.69
14.	Norway	88.43
15.	Canada	88.21
16.	Iceland	86.74
17.	Saudi Arabia	86.06
18.	Czech Republic	83.48
19.	Australia	83.02
20.	Luxembourg	82.46
21.	China	82.10
22.	Germany	80.47
23.	Israel	78.84
24.	Austria	78.16
25.	Bahrain	77.82
26.	Estonia	76.84
27.	Malaysia	75.75
28.	South Korea	75.71
29.	UK	75.48
30.	Thailand	74.54
31.	New Zealand	73.30
32.	Lithuania	71.67
33.	France	71.05
34.	Indonesia	70.75
35.	Japan	67.84
36.	Spain	67.22
37.	Kazakhstan	66.11
38.	Kuwait	65.59
39.	Portugal	65.54
40.	India	64.63
41.	Italy	63.32
42.	Slovenia	62.82
43.	Poland	60.48
44.	Chile	60.25
45.	Cyprus	60.21
46.	Hungary	59.85
47.	Türkiye	55.64
48.	Romania	55.34
49.	Greece	55.12
50.	Croatia	54.93

Source: (1) IMD World Competitiveness Ranking. The IMD World Competitiveness ranking presents the 2023 overall ranking for the 64 economies covered by the WCY.

World's Most Innovative Economies

The United States ranked #3 globally, behind Switzerland and Sweden, in the 2023 Global Innovation Index (GII) as part of a comprehensive study by the World Intellectual Property Organization (WIPO).

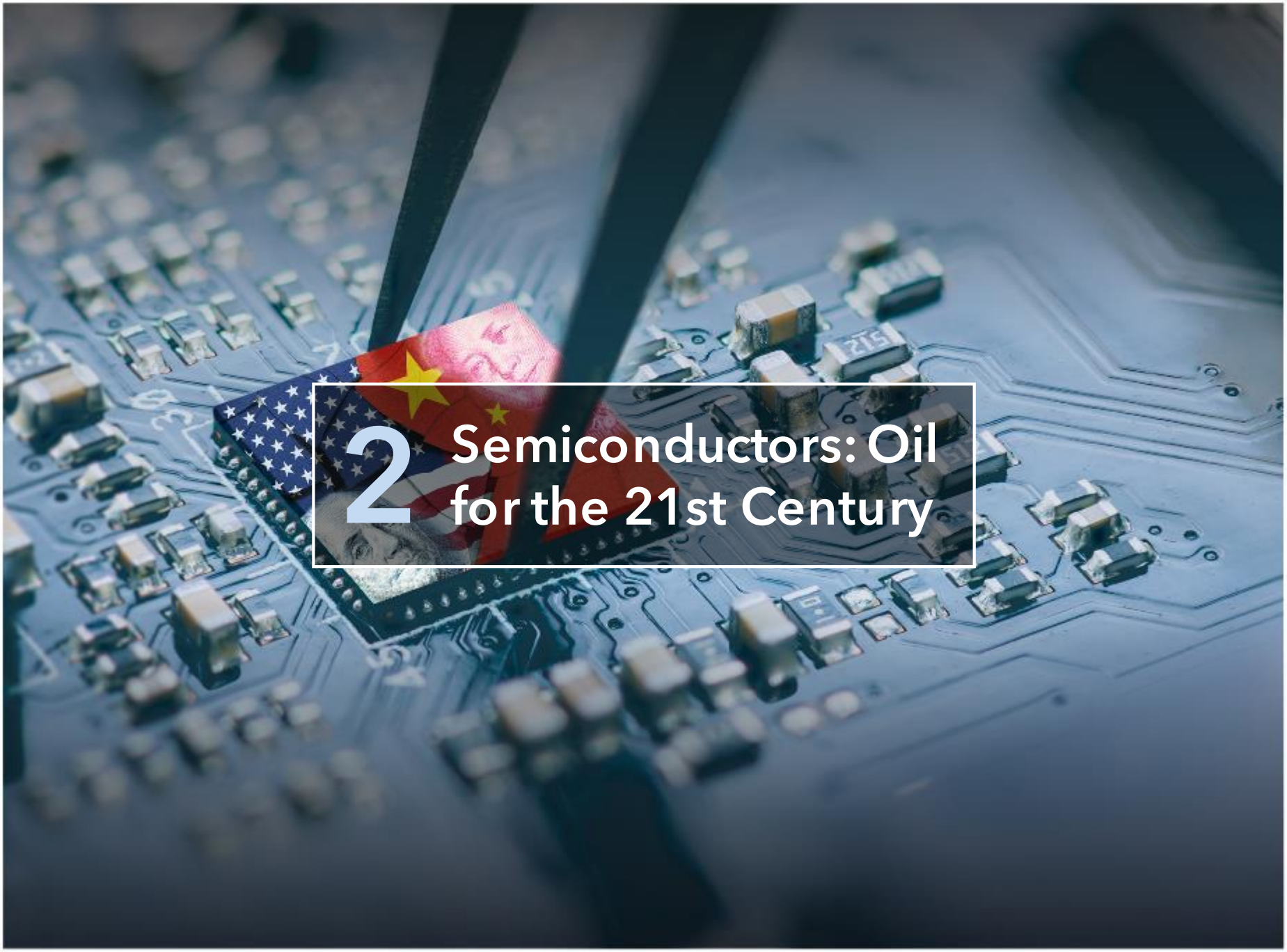
2023 Global Innovation Index



Countries were analyzed across 80 indicators in the following categories:

- Knowledge/Tech Outputs
- Human Capital & Research
- Business Sophistication
- Creative Outputs
- Infrastructure
- Institutions

Source: WIPO, "Global Innovation Index 2023".



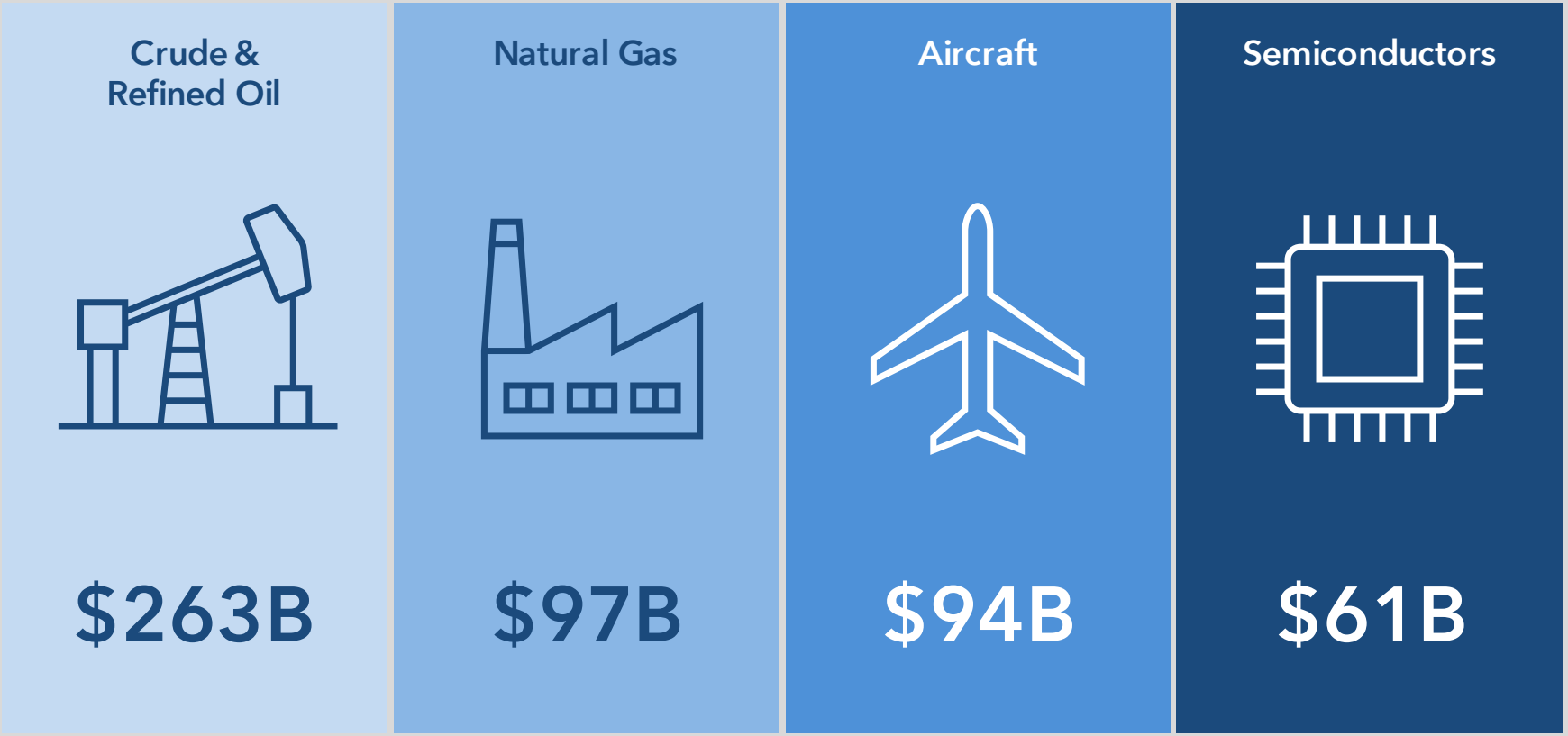
2 Semiconductors: Oil for the 21st Century


“Chip supply chains will shape geopolitics more than oil over the next 50 years.”
Pat Gelsinger, CEO of Intel

Semiconductors are a Leading US Export

Semiconductors were the US' fourth largest export in 2022, totaling $61 bn. Over 80% of semiconductors are sold to customers outside the US.

Top U.S. exports in 2022



Source: Semiconductor Industry Association (SIA), "2023 State of the US Semiconductor Industry."

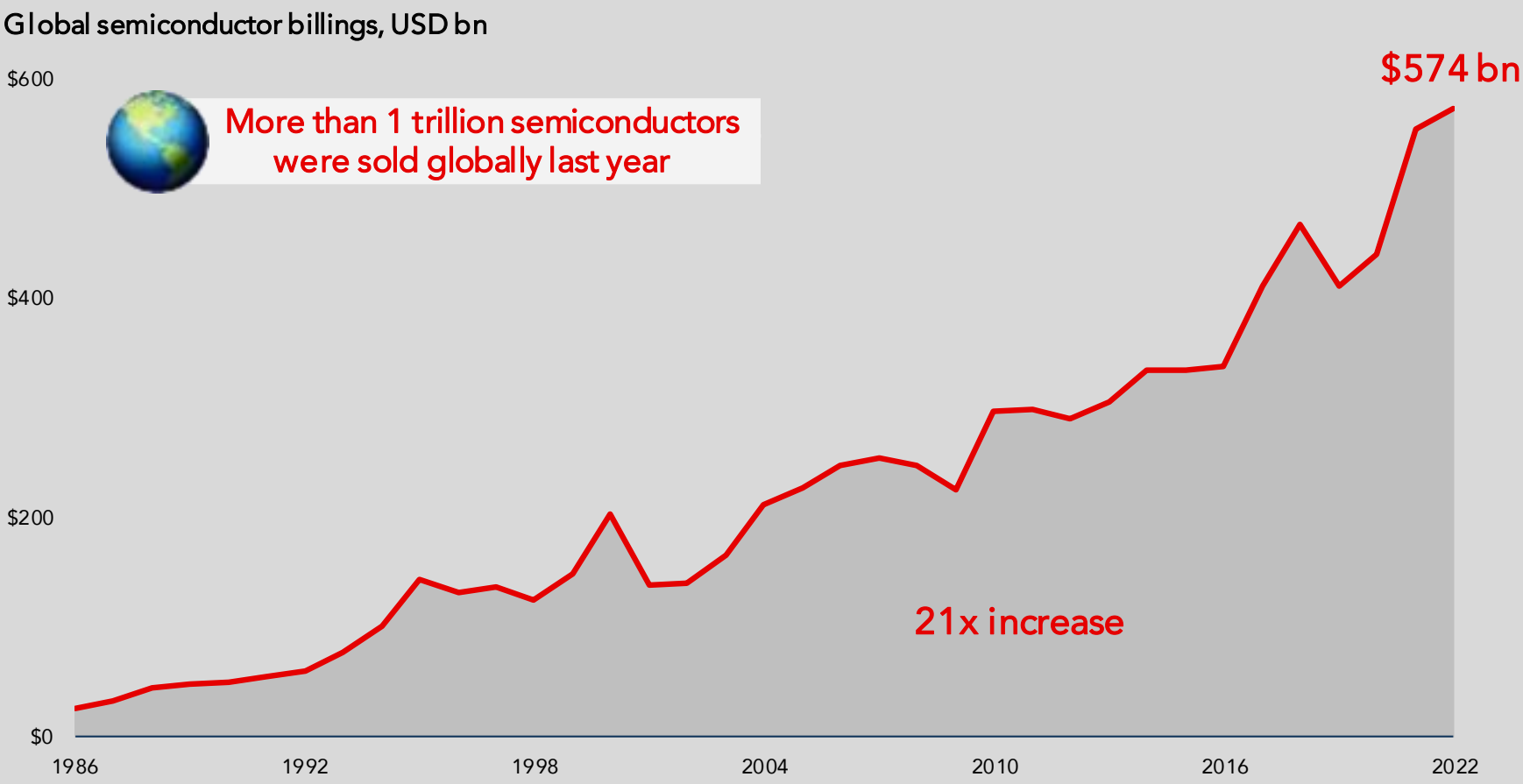
Chips as the New Oil for the 21st Century

Gas-Combustion Vehicle
~ 1,000 Microchips

Tesla Electric Vehicle
~ 3,500 Microchips

$575 Billion Semiconductor Industry

In 1986, worldwide semiconductor sales were just over $26 bn. In 2022, worldwide sales reached a record $575 bn, over 20x larger. As the semiconductor market grew, so too did computing power. Between 1956 and 2015, computing power increased on trillion times due to semiconductor advancements.

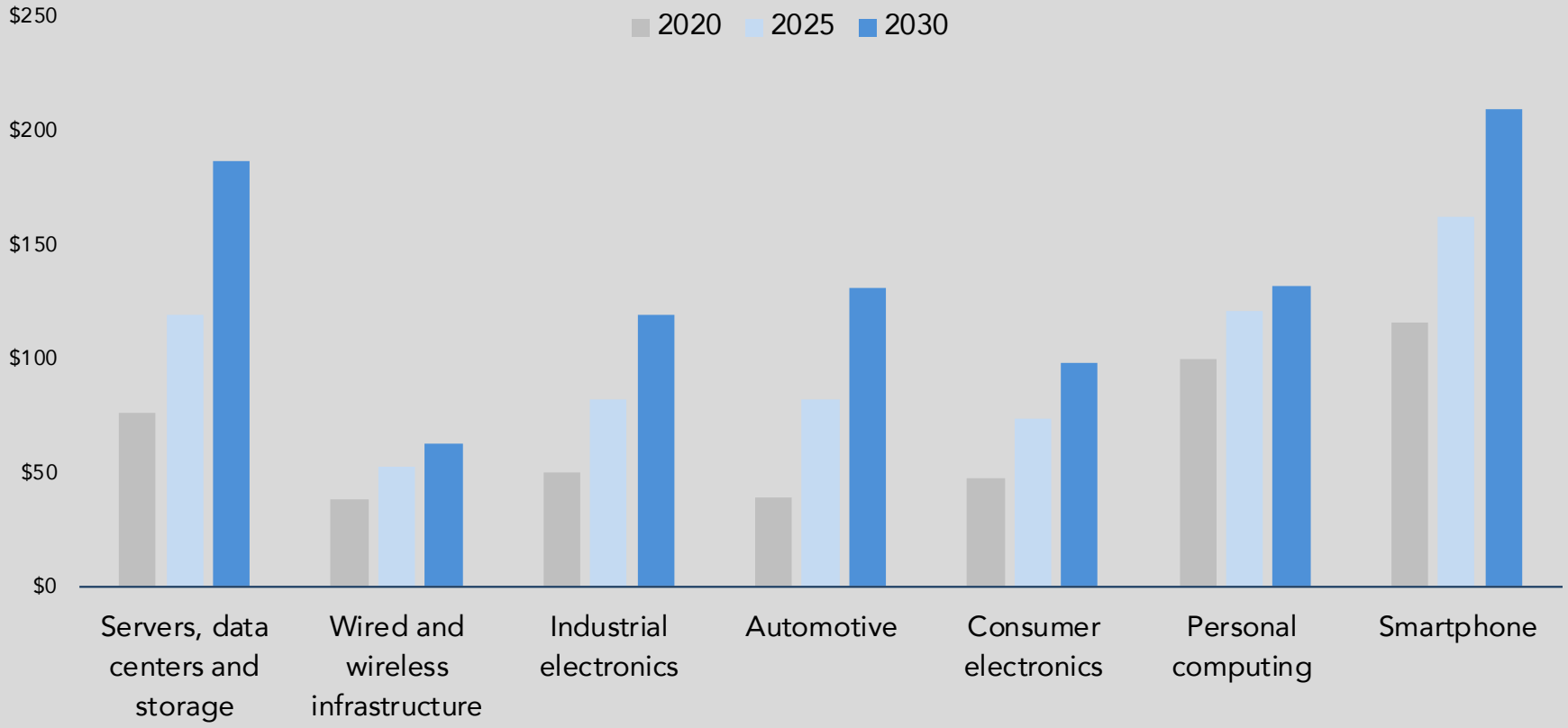


Source: (1) World Semiconductor Trade Statistics (WSTS) Blue Book Data.

$1 Trillion Semiconductor Industry by 2030

In 2021, semiconductor unit sales reached a record 1.5 trillion-unit shipments, or over 140 semiconductors shipped per person on earth. By 2030, chip demand is expected to double and become roughly a $1 trillion global industry.

Semiconductor market size forecast by application, USD bn

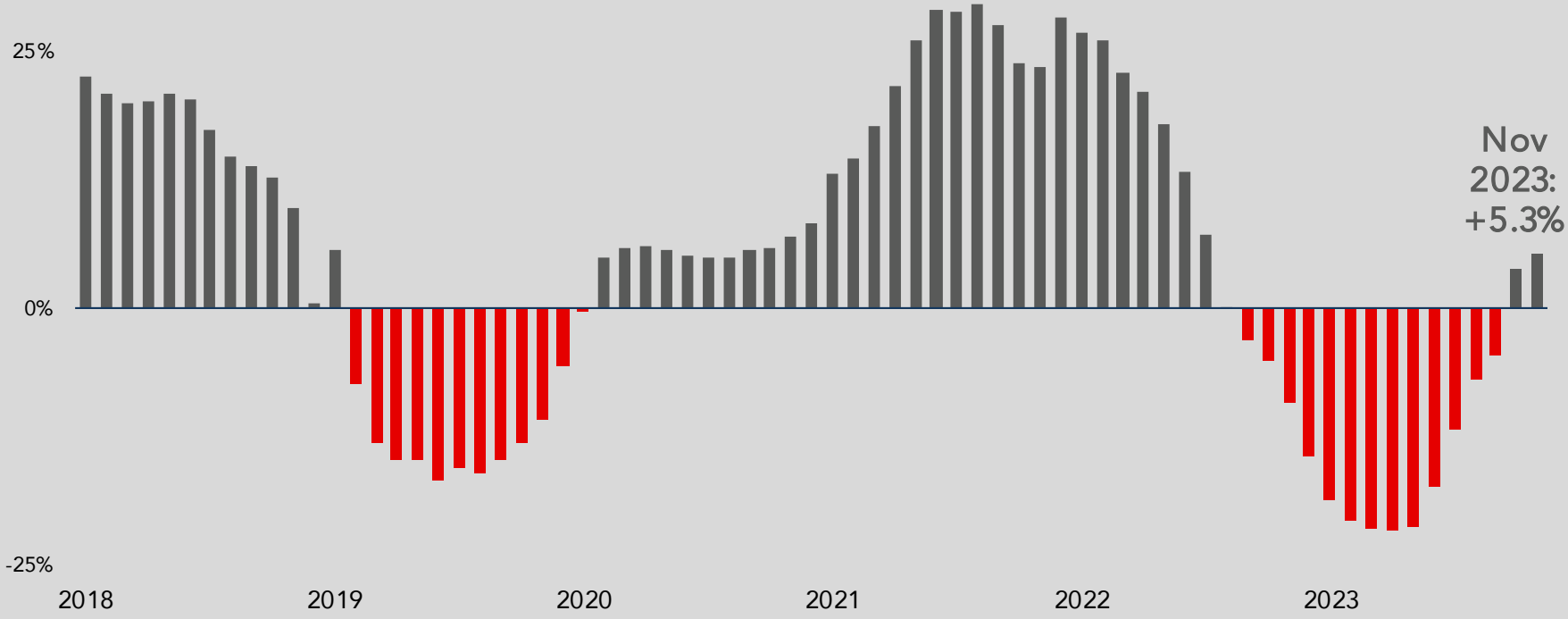


Source: (1) European Council, Infographic, "The EU Chips Act."

Highly Cyclical Industry

Historically a cyclical industry, global semiconductor sales have had more than a dozen recessive-growth periods since the integrated circuit market emerged in the early 1960s. Following a nearly 10% decline in 2023, the WSTS is forecasting a 13% rebound in global chip sales in 2024 to $588 billion on inventory rebuild and increased demand from emerging, high growth segments such as artificial intelligence.

Global semiconductor industry sales, y/y

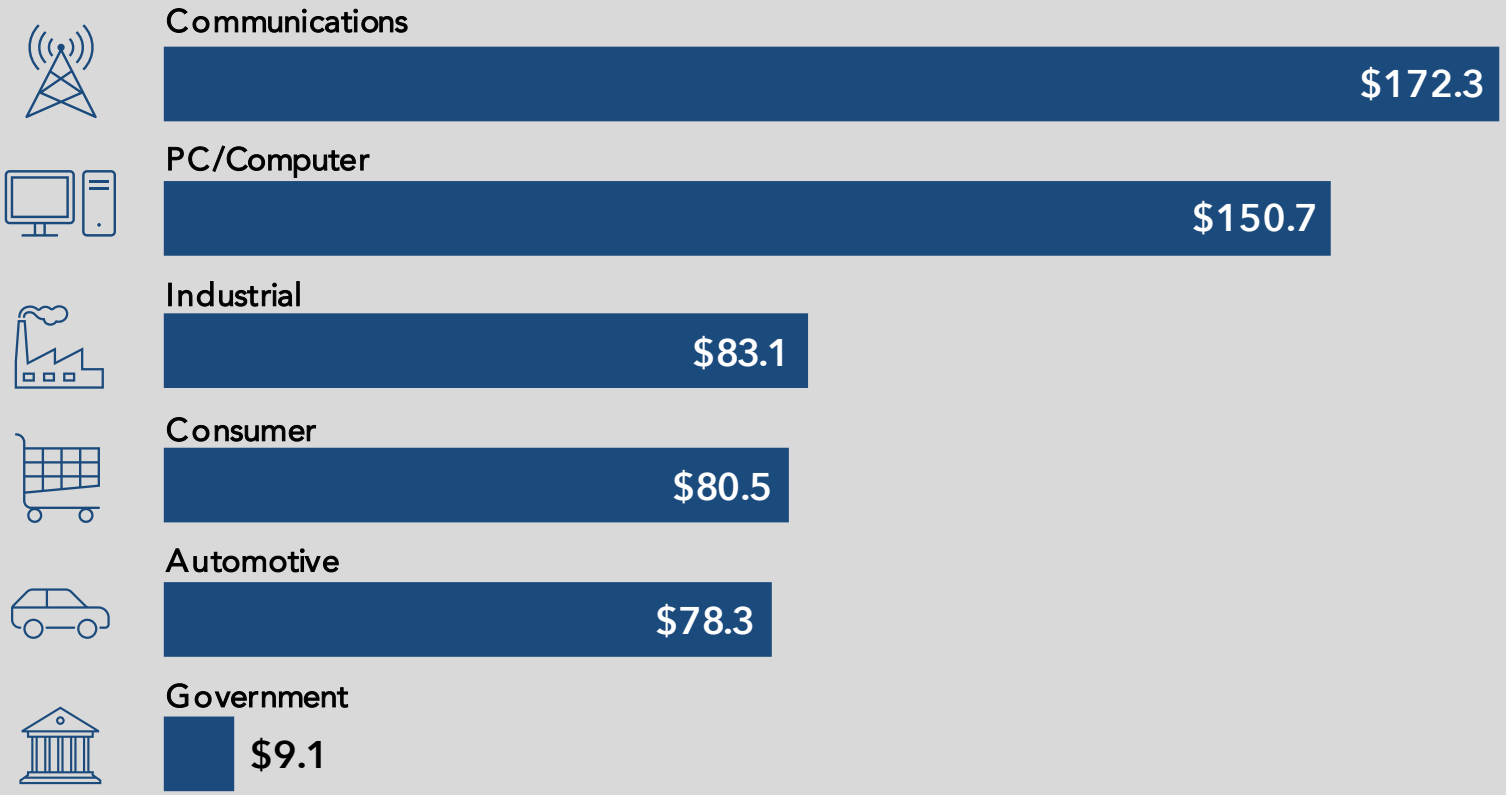


Source: (1) SIA. Bloomberg. Data as of January 2024.

Semiconductor Demand Drivers

Semiconductors have become an essential component of virtually every aspect of daily life and are the essential fuel for future technological developments. Innovations in chips have enabled transformative technologies such as artificial intelligence and autonomous vehicles while also driving advancements in life sciences and healthcare.

2022 total global semiconductor demand by end use, USD bn



Source: (1) Semiconductor Industry Association (SIA), "2023 State of the US Semiconductor Industry."

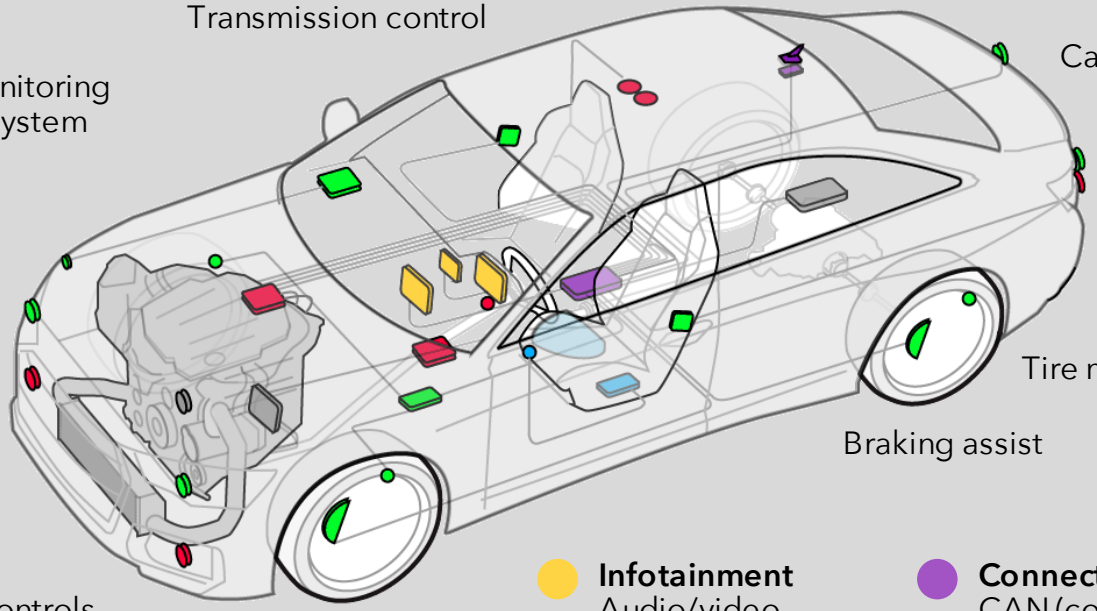
Semiconductors Essential to Auto Manufacturing

As vehicles become more technologically advanced, semiconductors have become a more critical piece of the manufacturing process. A modern vehicle uses roughly 1,000 – 3,500 chips, on average, to control everything from the airbags to AV displays and navigation.

Safety
Airbag controls
Collision-avoidance
Parking-assist
Power locks
Braking-assist
Tire-pressure-monitoring
Traction-control system

Powertrain
Engine control
Fuel-injection system
Hybrid-electric control
Transmission control

Electrical
Starter
Lighting system
Vehicle-diagnostics



Comfort
Window/mirror controls
Seat controls
Climate control

Infotainment
Audio/video
Driver display
Navigation

Connectivity
CAN (controller area network)
Broadband, WiFi, Bluetooth
Over-the-air software updates

Source: Bloomberg "Silicon Valley Answer to the EV Question Calls for Less Silicon" (King, Coppola, September 29, 2021).

Bloomberg

3 Globally Extended, Regionally Concentrated Semi Supply Chain


“Self sufficiency is a fantasy for any large country, even the US and China, when it comes to semiconductor chips.”
Dan Wang, Technology analyst for Gavekal Research

Semiconductor Supply Chain Vulnerabilities

	**75%**	Share of global semiconductor capacity located in East Asia
 	**100%**	Share of most advanced semiconductor manufacturing (nodes below 10 nanometers) located in Taiwan & South Korea
 	**70%**	Share of manufacturing market controlled by just two companies (Taiwan's TSMC & South Korea's Samsung Electronics)
	**12%**	Share of semiconductors made in American factories, down from 37% in 1990
	**$1 tn**	Estimated incremental upfront investment that would have been required to have a fully self-sufficient local supply chain in each region

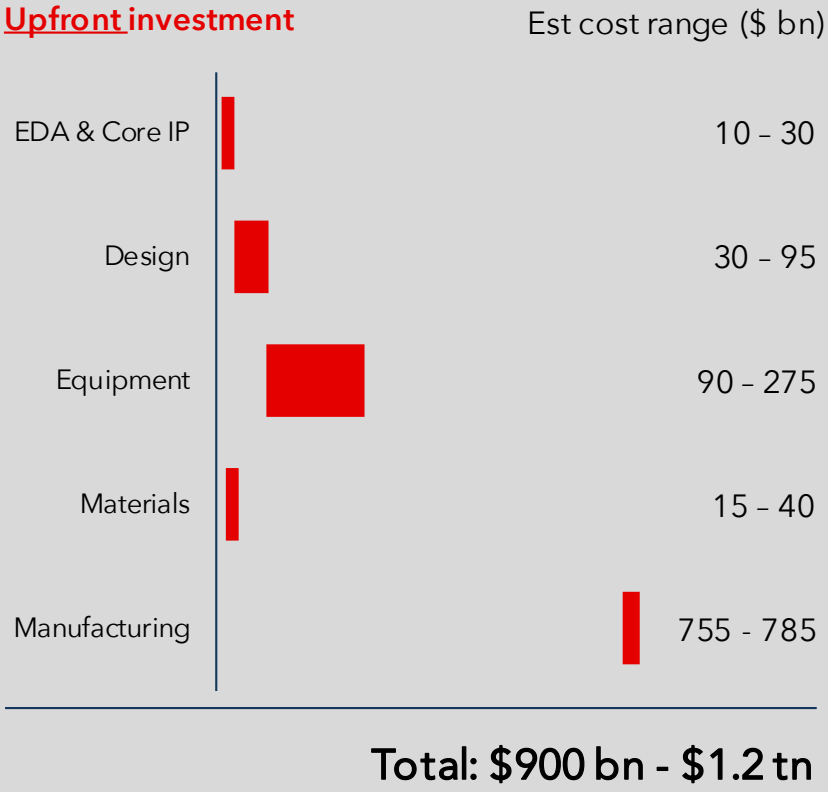
Source: BCG, Semiconductor Industry Association "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era" April 2021.

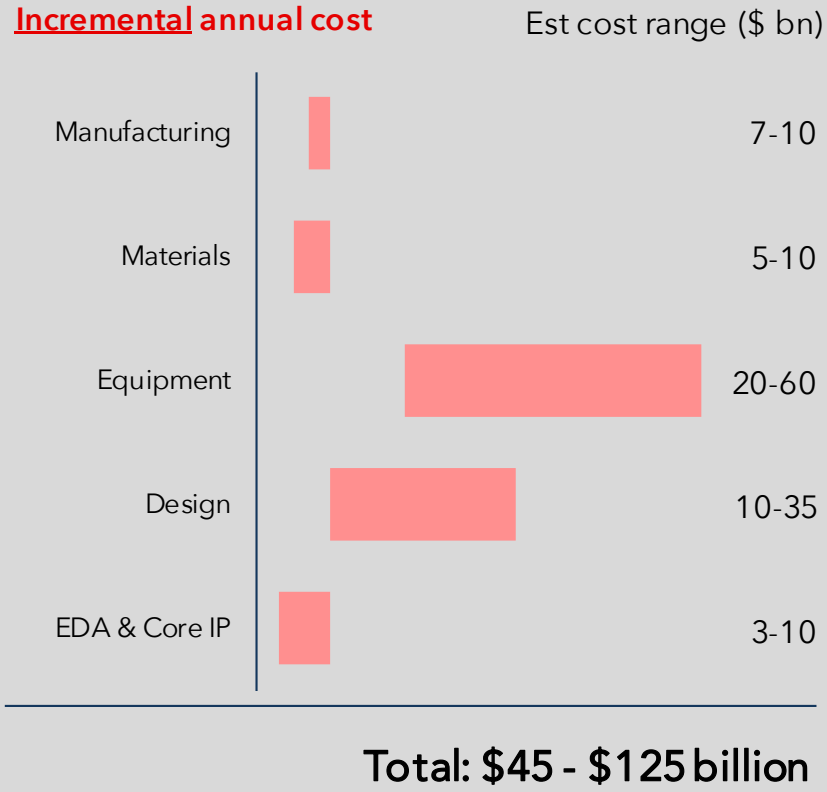
With China's Xi enduring a slowing economy, and President Biden facing an election in 2024, the world's two most powerful leaders took a step in the direction of détente at the APEC summit in San Francisco in November 2023. More tactical than strategic, the temporal de-escalation is unlikely to last in the years ahead.

The Staggering Cost of Semiconductor Self-Sufficiency

While semiconductors are strategically important for both economic growth and national security, developing "self-sufficiency" in every major region would require roughly $1 trillion of upfront investment and up to $125 billion of incremental annual cost

Incremental cost to cover 2019 demand with fully "self-sufficient" localized semiconductor supply chains



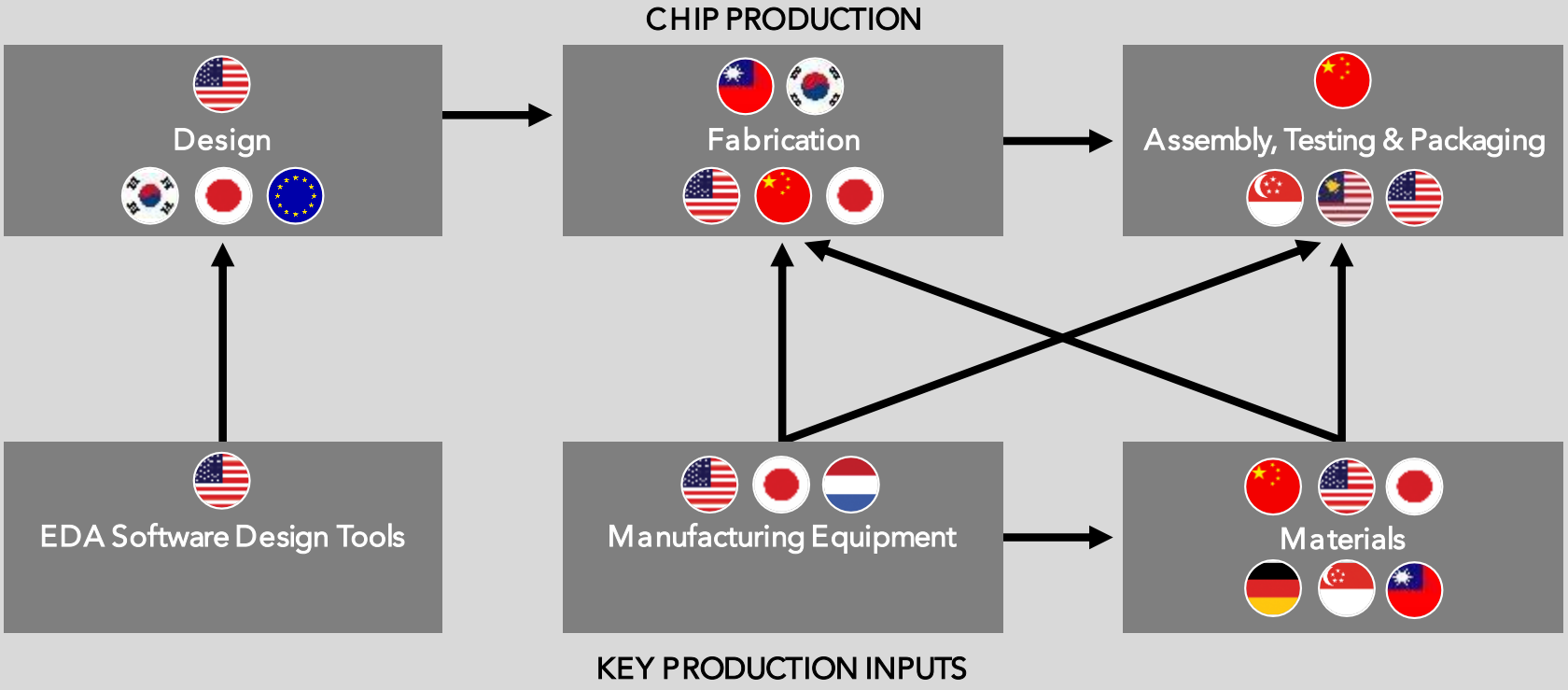


Source: (1-2) BCG, Semiconductors Industry Association "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era". April 2021. Manufacturing includes both wafer fabrication and assembly, packaging and testing. Range defined by number of local companies assumed to be required to meet the local needs in each activity of the value chain.

Globally Extended Semi Supply Chain

Semiconductor production requires the specialized capabilities of several different geographic regions. According to a study by the Center for Security and Emerging Technology, production of a single semiconductor could require more than 1,000 steps and pass through international borders 70 or more times before reaching the end consumer. While the US and its allies (Japan, Europe, Taiwan, South Korea) collectively dominate the supply chain, China is quickly developing its own manufacturing capabilities.

Leadership in the global semiconductor supply chain

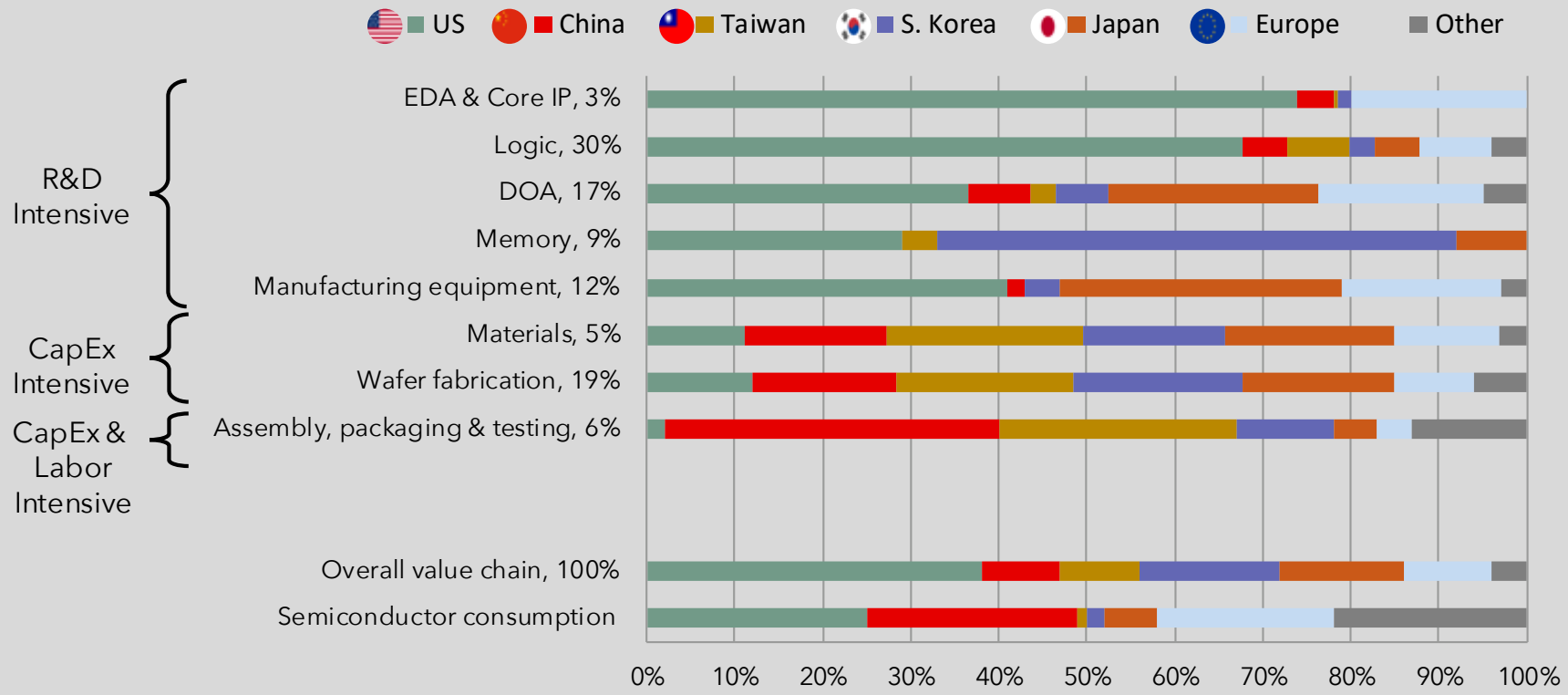


Source: Center for Security and Emerging Technology "The Semiconductor Supply Chain: Assessing National Competitiveness". January 2021.

Regionally Specialized Supply Chain

Each region specializes in a different part of the semiconductor production supply chain. In general, the US leads in R&D intensive activities while regions in Asia focus more on raw materials and manufacturing (which are more capital intensive).

Semiconductor industry value added by activity and region, 2019 (%)

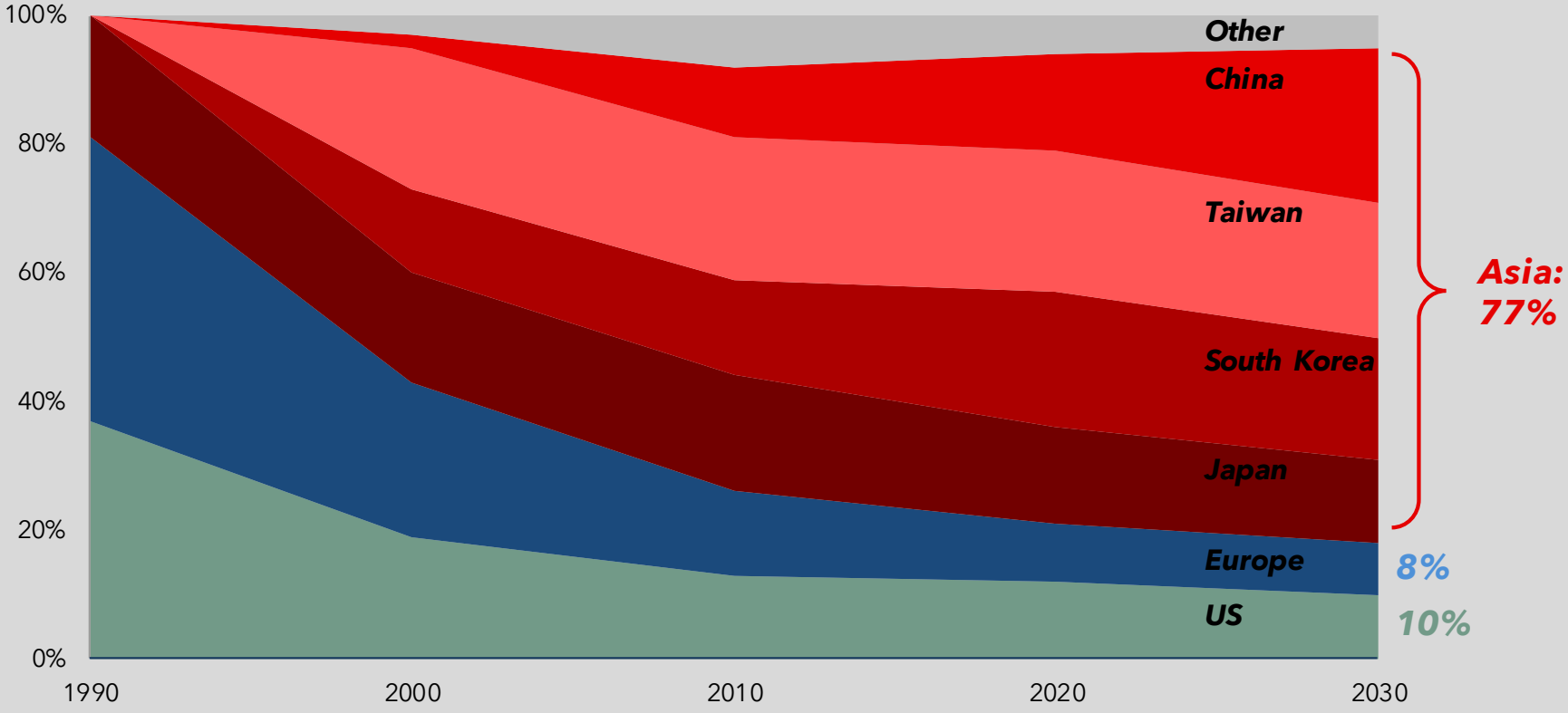


Source: (1) BCG, Semiconductors Industry Association "Strengthening the Global Semiconductor Supply Chain in an Uncertain Era". April 2021. China is mainland china only. BCG analysis with data from SIA WSTS, Gartner, IDC.

US and Europe Losing Manufacturing Share

Over the past 30 years, the US & Europe's share of chip manufacturing has declined from 81% to 21%. Furthermore, over the next decade, global manufacturing capacity is expected to increase by roughly 50%, 40% of which will be in China while only 6% is expected to come from the US. According to a study by BCG, between $20 and $50 billion in US federal grants and tax incentives would be needed to reverse the declining market share trend of the last 30 years.

Global semiconductor manufacturing by location

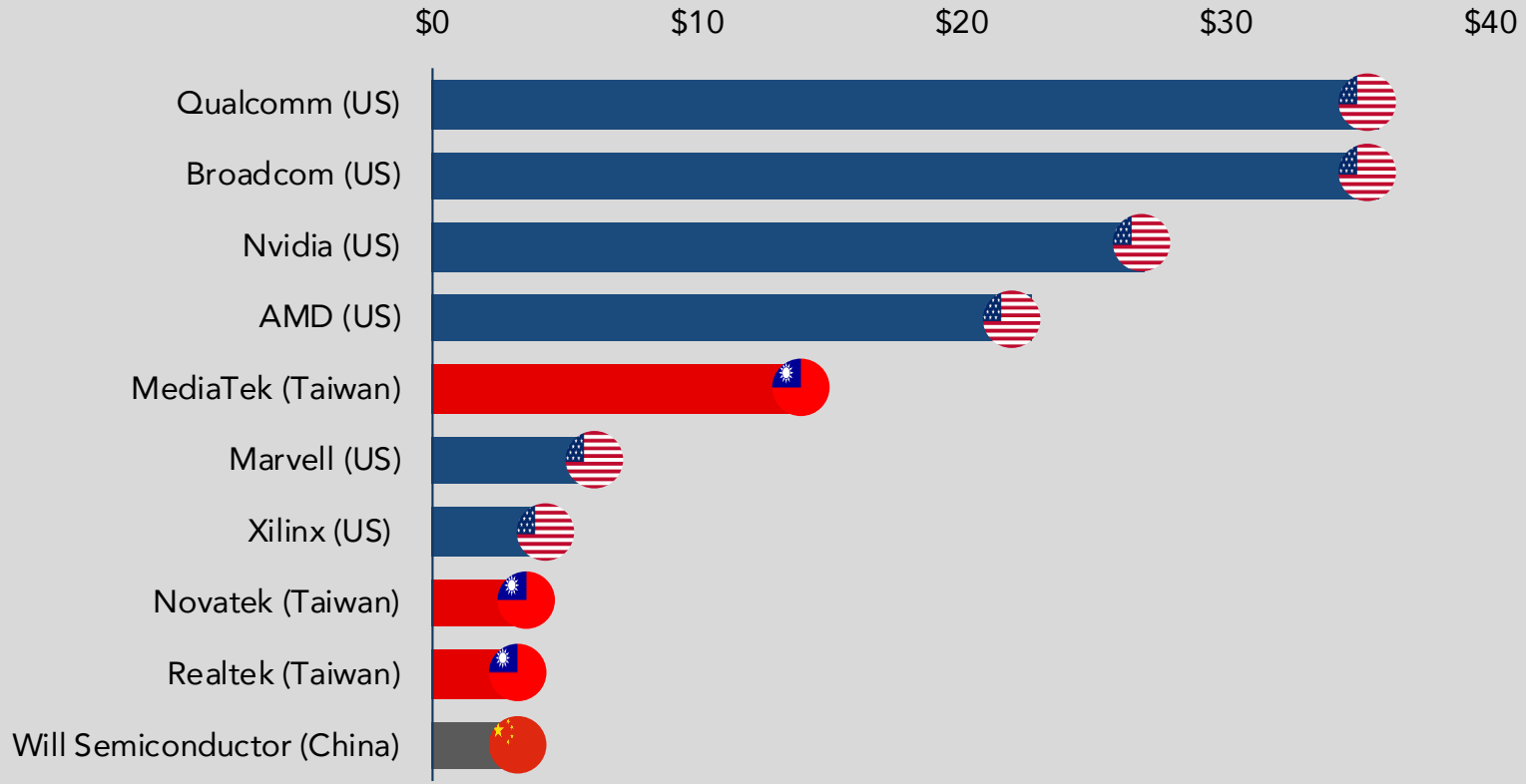


Source: (1) Statista. Boston Consulting Group, "Government Incentives and US Competitiveness In Semiconductor Manufacturing" (September 2020). Semiconductor Industry Association.

US Leadership in Semiconductor Design

Six of the ten largest semiconductor companies, by revenue, are headquartered in the US. These companies work in close partnership and are often dependent on manufacturing capabilities in Taiwan and South Korea or machinery and equipment from Europe and Japan. While semiconductor design is a critical export for the US, the supply chain is highly dependent on intricate relationships with allies overseas.

Top 10 semi design companies by revenue in 2023, USD bn

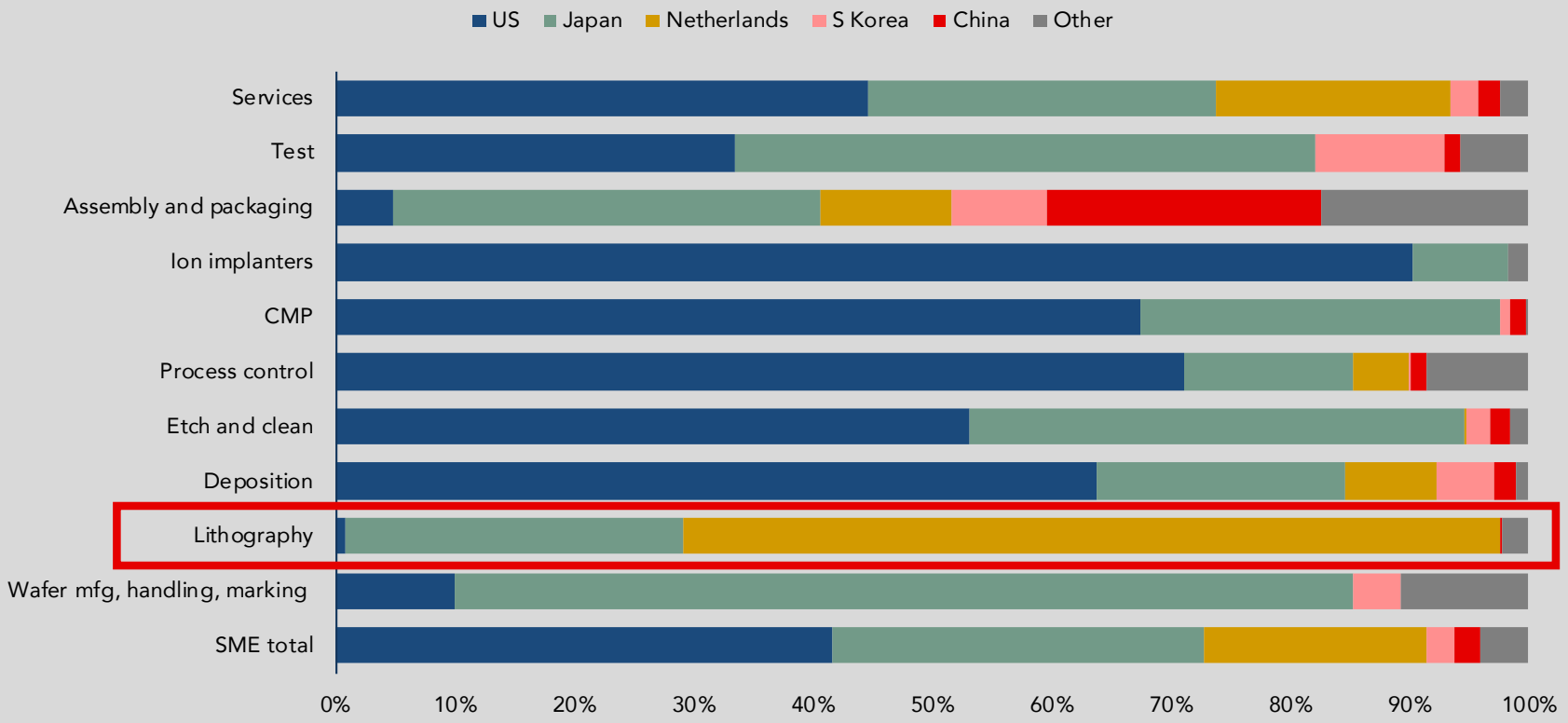


Source: (1) Bloomberg. Data as of February 4, 2024. Marvell, Novatek, and Will Semiconductor 2023 revenues are estimates.

Europe Dominant in Capital Equipment

Highly technical Semiconductor Manufacturing Equipment (SME) is as critical to chip production as the design and fabrication process. Some SME, such as Lithography is almost exclusively produced in Japan and the Netherlands. With the US working closely with allies in Japan and Europe, export controls for key SME could create key "chokepoints" for China's chip production development.

SME country shares by firm headquarters

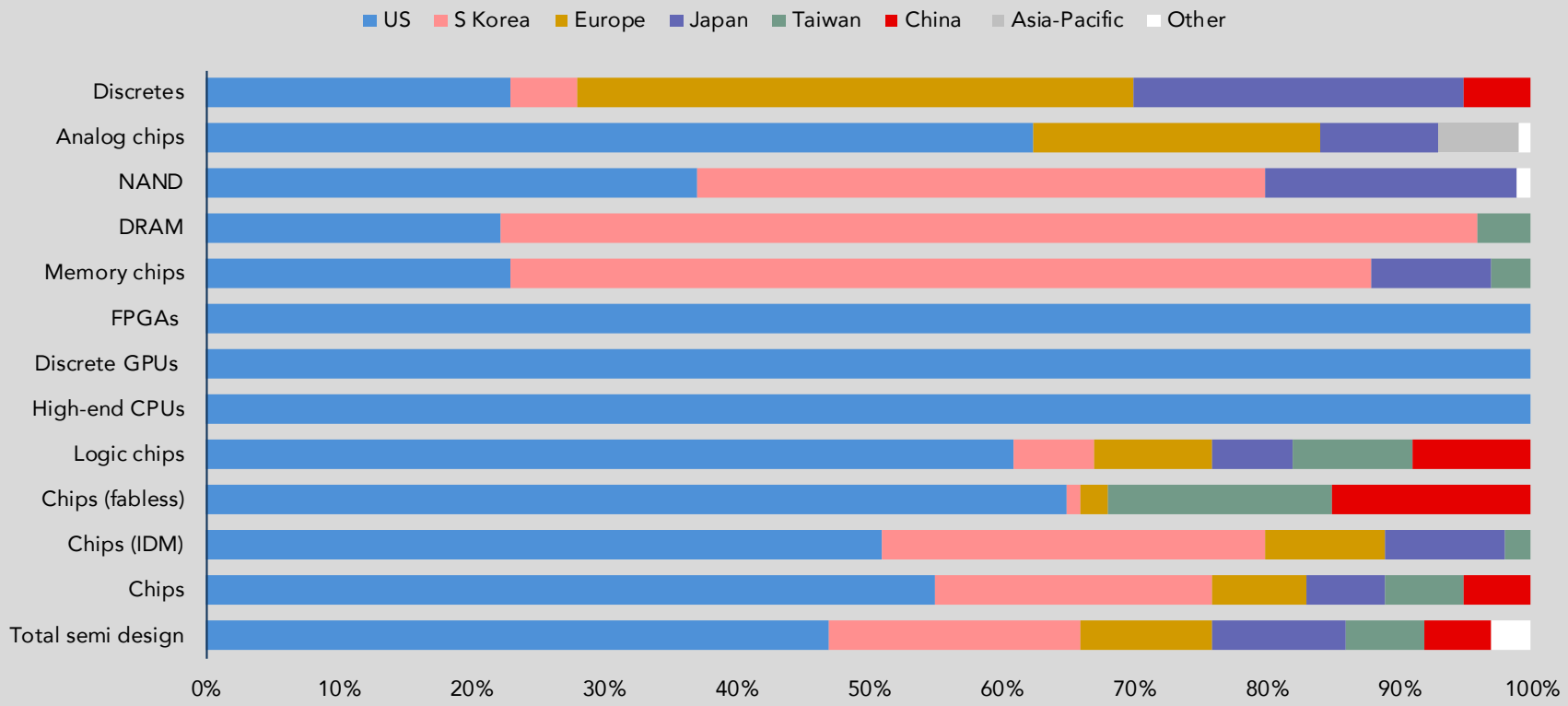


Source: (1)) Center for Security and Emerging Technology (CSET), "The Semiconductor Supply Chain: Assessing National Competitiveness" (January 2021). VLSI Research. 2019 data.

China Still Behind in High Tech Production

While China has taken a large and growing share of production market share, much of that is still in the "lower tech" segment of the production and manufacturing supply chain. The higher tech design and fabrication steps are still dominated by the US and Taiwan, while China has gained share in fabrication of older chips and the less technical assembly, testing and packaging (ATP) process.

Design shares by type and firm headquarters



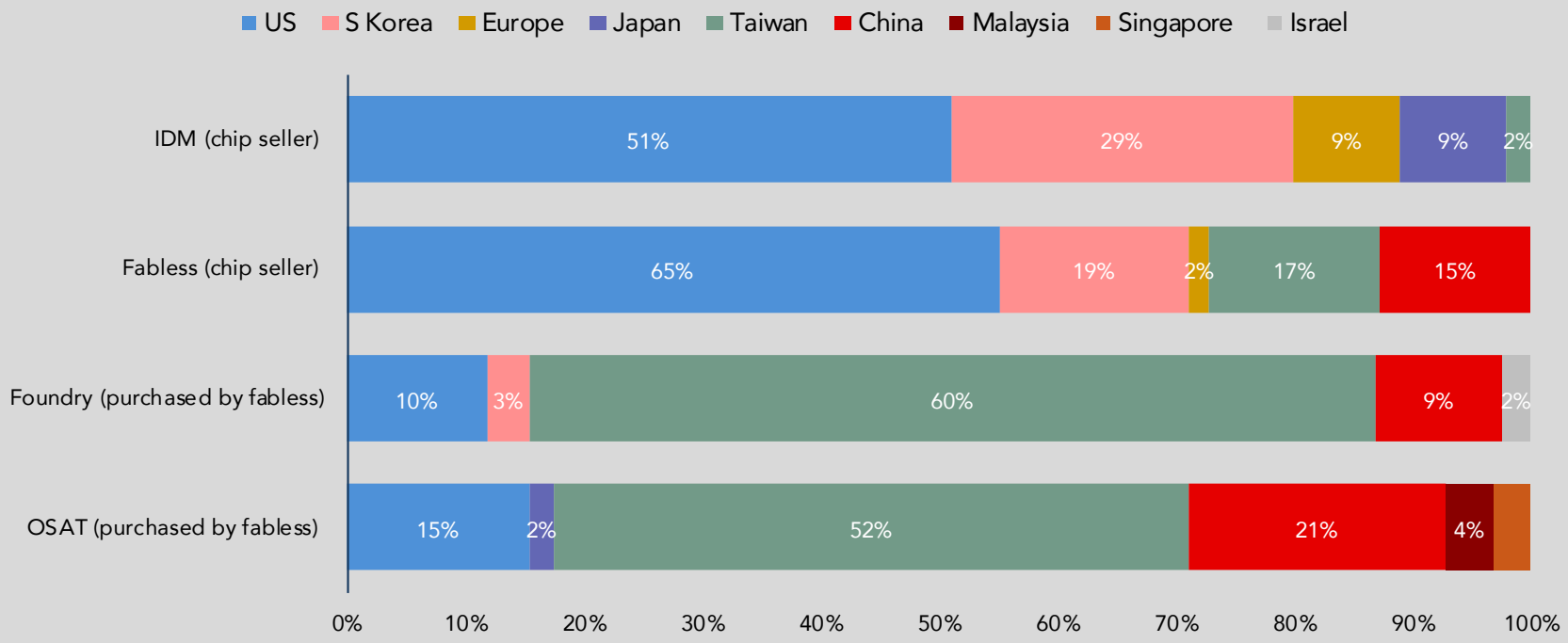
Source: (1) Center for Security and Emerging Technology (CSET), "The Semiconductor Supply Chain: Assessing National Competitiveness" (January 2021). SIA. IC Insights. TrendForce. Financial Statements. China has a small share (<1%) in CPUs, GPUs, and PFGASs. Design share data as of 2019.

Morris Chang, 92 year old Taiwanese-American businessman, and the founder of the largest, most advanced and most important semiconductor company in the world, TSMC.

IDMs vs. Fabless Models

There are three major phases of semiconductor production: (1) design, (2) fabrication, and (3) assembly, testing, and packaging (ATP). Some firms, integrated device manufacturers (IDMs), own all three steps in the process in one integrated firm. Others utilize a "fabless" model whereby a firm will design and sell a chip while outsourcing fabrication services to a foundry and ATP services to an outsourced semiconductor assembly and test (OSAT) firm. The US has the largest market share in the fabless model which relies heavily on cross-border partnerships, particularly with Taiwan and South Korea.

Country shares by business model



Source: (1) Center for Security and Emerging Technology (CSET), "The Semiconductor Supply Chain: Assessing National Competitiveness" (January 2021). SIA. IC Insights. Yole. CSET estimates.

4 Global & US Government Production Incentives

"The US is strategically repositioning for a period of interstate competition. A competition that recognizes that relationship between economic security and national security."

Eric Chewning, American businessman, veteran, former Chief of Staff to the Secretary of Defense and current partner at McKinsey & Company

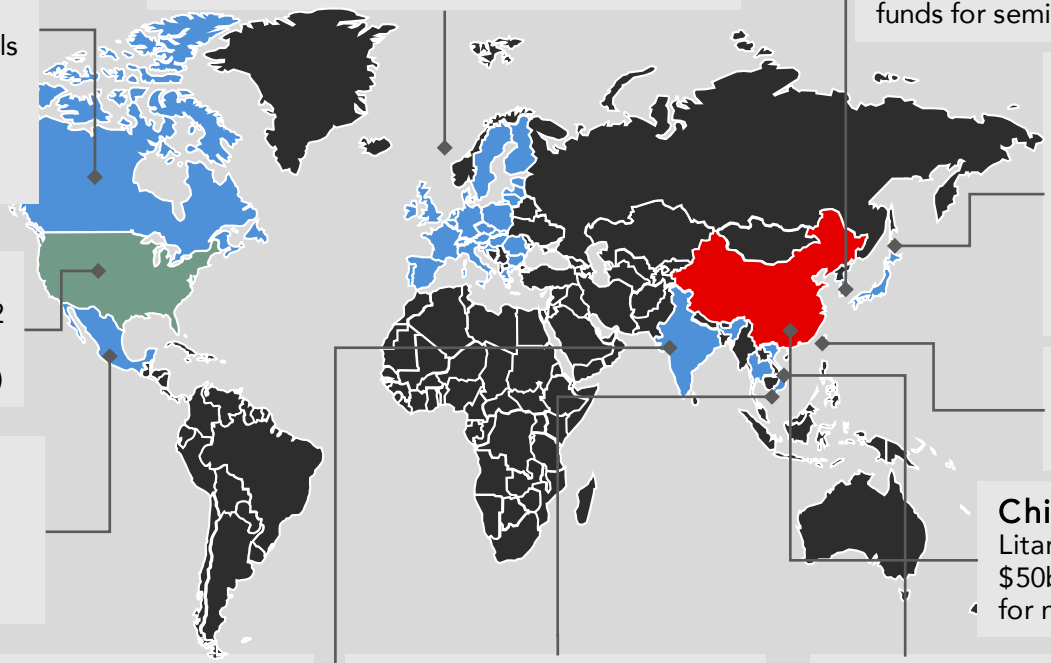
Global Government Chip Incentives

While the US and China have been making great strides in strengthening their semiconductor supply chains, the rest of the world is also working to improve their positions, rolling out their own government incentives for semiconductor investment.

Canada:
2022 semiconductor incentive package for investments in chip design, manufacturing and associated critical materials as well as educational partnerships between universities and design / manufacturing companies

European Union:
2023 EU Chips Act, including €43 bn ($47 bn) targeted support for EU's semiconductor sector

South Korea:
"K-Semi Belt" investment initiative in 2021; "K-Chips Act" tax incentives in 2023; $5 bn of MTIE "super-project" funds for semi R&D.



Japan:
$7bn of 2021 chip funding; $3bn in 2022 for government-led advanced semi JV; $3bn of 2023 funding; $8bn research JV proposal with the US.

United States:
$280bn CHIPS Act in 2022 (R&D and manufacturing; subsidies & tax incentives)

Taiwan:
"Taiwan Chips Act" tax incentives passed in 2023

Mexico:
2022 federal government semiconductor incentive package to attract ATP investment

China:
Litany of tax incentives and $50bn + state investment fund for microchips ("Big Fund")

India:
Revamped $10bn semiconductor incentive package in 2022

Thailand:
2021 preferential tax policy for new semiconductor investment

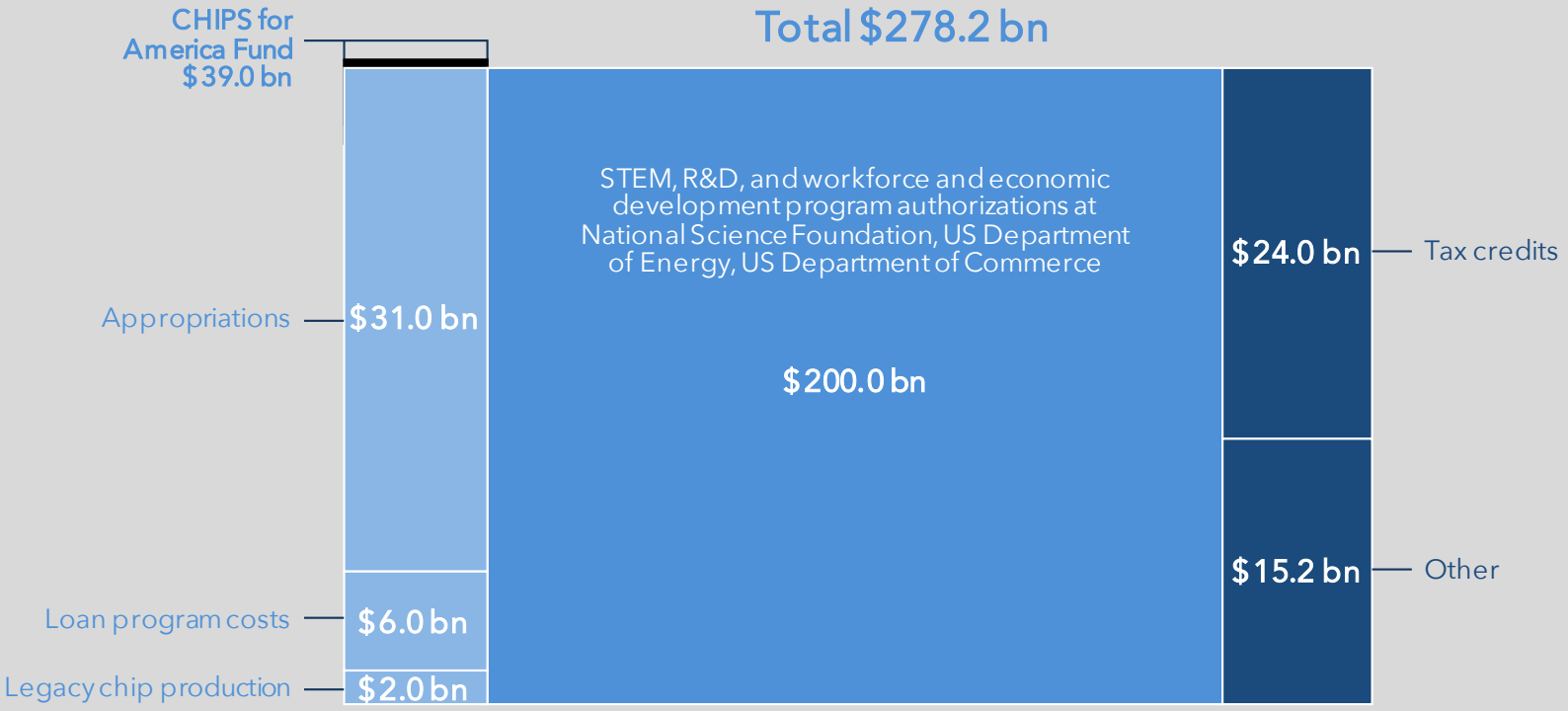
Vietnam:
Semiconductor-specific incentives, including 0% corporate income tax for chips firms

Source: (1) Semiconductor Industry Association (SIA), "2022 State of the US Semiconductor Industry."

The $280 Billion US CHIPS Act

Policy support for the semiconductor industry out of Washington has increased over the last few years through various acts including the Infrastructure Investment & Jobs Act, the Inflation Reduction Act and the Creating Helpful Incentives to Produce Semiconductors (CHIPS) & Science Act. More specifically, The CHIPS Act directs $280bn in spending over the next ten years with $200bn specific for R&D and commercialization. $52.7bn is for semiconductor manufacturing, R&D and workforce development with another $24bn worth of tax credits for chip production.

CHIPS and Science Act breakdown



Source: McKinsey & Company, "The CHIPS and Science Act: Here's what's in it" (October 2022).

McKinsey & Company

$230 Bn Investment in New Semiconductor Capacity

The CHIPS Act has spurred heightened investment in US semiconductor capacity. Over $230 bn of new or expanded semiconductor projects are currently in process across the US. The announced projects touch on every part of the semiconductor value chain.

Source: (1) Semiconductor Industry Association. WSJ, "Chips are the New Oil and America is Spending Billions to Safeguard Its Supply" (January 1, 2024). $230 bn only includes projects with announced dollar value of expansion or new project.

January 21, 2022 | Read

REUTERS

Technology

Intel's $20 bln Ohio factory could become world's largest chip plant

October 19, 2023 | Read

azcentral.

TECH

Taiwan Semiconductor Manufacturing Co. nearing manufacturing start date in north Phoenix

October 6, 2022 | Read

PR Newswire

IBM and CEO Arvind Krishna Welcome President Biden to Poughkeepsie Site, Company Plans to Invest $20 billion in the Hudson Valley Region Over 10 Years

September 1, 2022 | Read

FIERCE Electronics

SENSORS

Micron to build $15B memory fab near its Boise HQ

November 24, 2021 | Read

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ELECTRONICS

Samsung to open another chip plant in Texas, valued at $17B

October 4, 2022 | Read

COMPUTERWORLD

Micron to build largest chip factory in US history

September 10, 2022 | Read

Chatham Journal Newspaper

RALEIGH

Wolfspeed selects North Carolina for 445 acre manufacturing campus

September 10, 2022

November 2, 2023 | Read

The Salt Lake Tribune

Utah officials welcome Texas Instruments semiconductor plant to Lehi, as state's 'greatest' economic investment

June 19, 2021 | Read

Forbes

GlobalFoundries Building New Malta Fab And Expanding Current Capacity

July 18, 2023 | Read

NEWSROOM

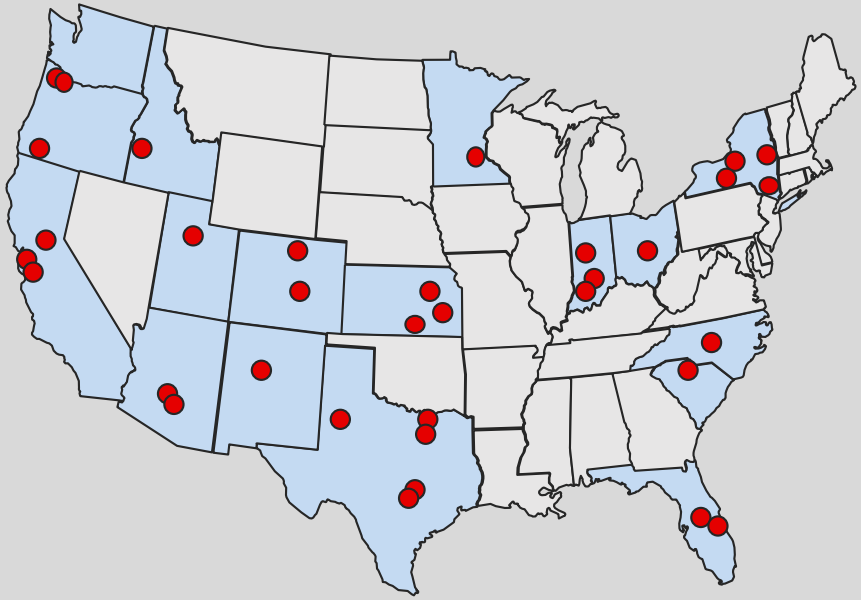
OREGON-BASED ROGUE VALLEY MICRODEVICES TO OPEN MICROFABRICATION FACILITY IN PALM BAY

US Investment in Semiconductor Fabrication Plants

Since the CHIPS Act was originally introduced in summer 2020, semiconductor companies have announced dozens of new manufacturing, equipment and materials projects. According to the Semiconductor Industry Association, there are over 40 new chip projects underway to expand domestic manufacturing capabilities.

Announced new and expanded semiconductor projects

● Semiconductors



Company Name	State	Investment
● TSMC	AZ	$40 billion
● Amkor	AZ	$2 billion
● Intel	AZ	$20 billion
● Bosch	CA	
● Akash Systems	CA	$62 million
● Western Digital	CA	$350 million
● Broadcom	CO	
● Microchip Technology	CO	$880 million
● Rogue Valley Microdevices	FL	$25 million
● SkyWater Technology	FL	
● Micron	ID	$15 billion
● Trusted Semiconductor Solutions	IN	$34 million
● Everspin Technologies	IN	
● NHanced Semiconductors	IN	$236 million
● Reliable Microsystems	IN	$7 million
● SkyWater Technology	IN	$1.8 billion
● MediaTek	IN	
● EMP Shield	KS	$1.9 billion
● Radiation Detection Technologies	KS	$4 million
● Integra Technologies	KS	$1.8 billion
● Polar Semiconductor	MN	$420 million
● Wolfspeed	NC	$5 million
● Intel	NM	$3.5 billion
● Menlo Microsystems	NY	$50 million
● GlobalFoundries	NY	$1 billion
● IBM	NY	
● Micron	NY	$20 billion
● Intel	OH	$20 billion
● Rogue Valley Microdevices	OR	$44 million
● Microchip Technology	OR	$800 million
● Intel	OR	
● Analog Devices	OR	$1 billion
● Pallidus	SC	$443 million
● X-FAB	TX	$200 million
● Samsung	TX	$17.3 billion
● Texas Instruments	TX	$6 billion
● Texas Instruments	TX	$30 billion
● NXP	TX	$2.6 billion
● Texas Instruments	UT	$11 billion
● Analog Devices	WA	

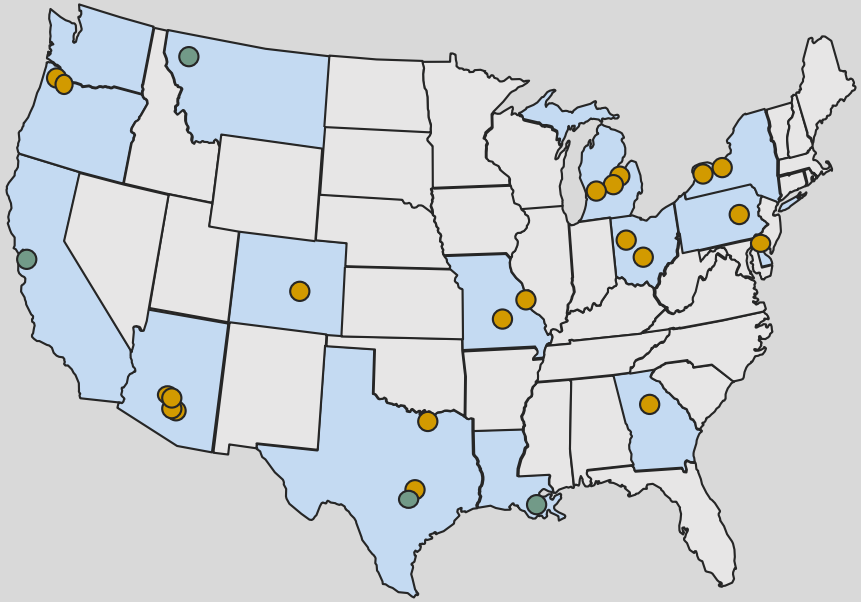
Source: (1) Semiconductor Industry Association (SIA). Last updated January 23, 2024.

US Investment in Semiconductor Fabrication Plants

The projects underway represent new and expanded existing fabs as well as new facilities to supply materials and equipment for manufacturing. The new projects represent over $180 billion in company investments and could create over 200,000 jobs.

Announced new and expanded equipment & materials

Material Equipment



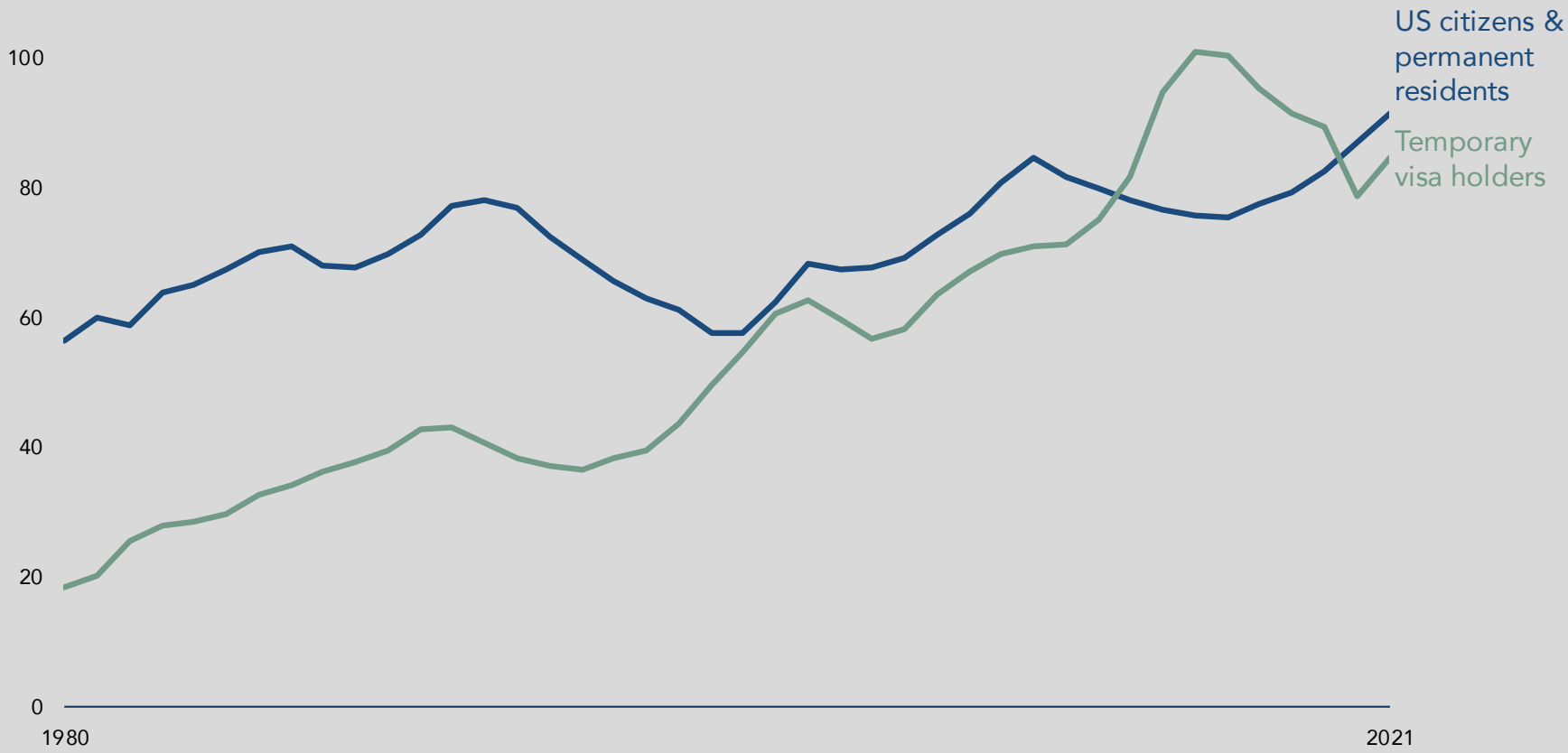
Company Name	State	Investment
JX Nippon Mining & Metal	AZ	
Air Liquide	AZ	$60 million
ASM	AZ	$324 million
Linde	AZ	$600 million
Sunlit Chemical	AZ	$100 million
LCY Chemical	AZ	$100 million
Solvay	AZ	$60 million
Edwards Vacuum	AZ	
EMD	AZ	$28 million
Yield Engineering Systems	AZ	
Fujifilm Electronic Materials	AZ	$88 million
Chang Chun Group	AZ	$400 million
Kanto/Chemtrade JV	AZ	$250 million
Applied Materials	CA	
Entegris	CO	$600 million
DuPont Semiconductor Tech.	DE	$50 million
Absolics	GA	$600 million
K&B Industries	LA	$12 million
Mersen USA	MI	$70 million
Mersen USA	MI	$10 million
SK Siltron CSS	MI	$300 million
Hemlock Semiconductor	MI	$375 million
Brewer Science	MO	
GlobalWafers (MEMC)	MO	$300 million
Applied Materials	MT	
Corning	NY	$139 million
Edwards Vacuum	NY	$319 million
Tosoh SMD	OH	$20 million
Chemtrade	OH	$50 million
Mitsubishi Gas Chemicals	OR	$372 million
EMD	PA	$300 million
Schunk Xycarb	TX	
GlobalWafter (GlobiTech)	TX	$5 billion
Applied Materials	TX	
Shin-Etsu Handotai America	WA	

Source: (1) Semiconductor Industry Association (SIA). Last updated January 23, 2024.

Engineering “Gap” a Rising Challenge

The US CHIPS bill allocated $53 billion toward semiconductor research and development. In tandem with the bill, US semiconductor companies are investing over $200 billion in new manufacturing capacity. However, slowing growth in US engineering graduates could present a larger problem for continued innovation and development of the most advanced chips.

Citizenship of graduate students and postdoctoral appointees in US engineering programs, thousands

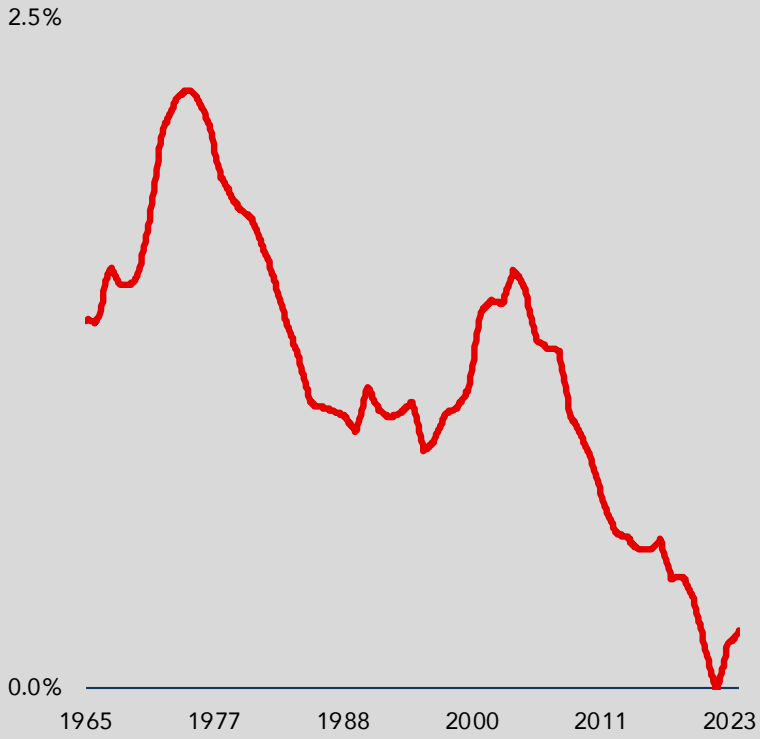


Source: (1) National Center for Science and Engineering Statistics. Table 1-3c.

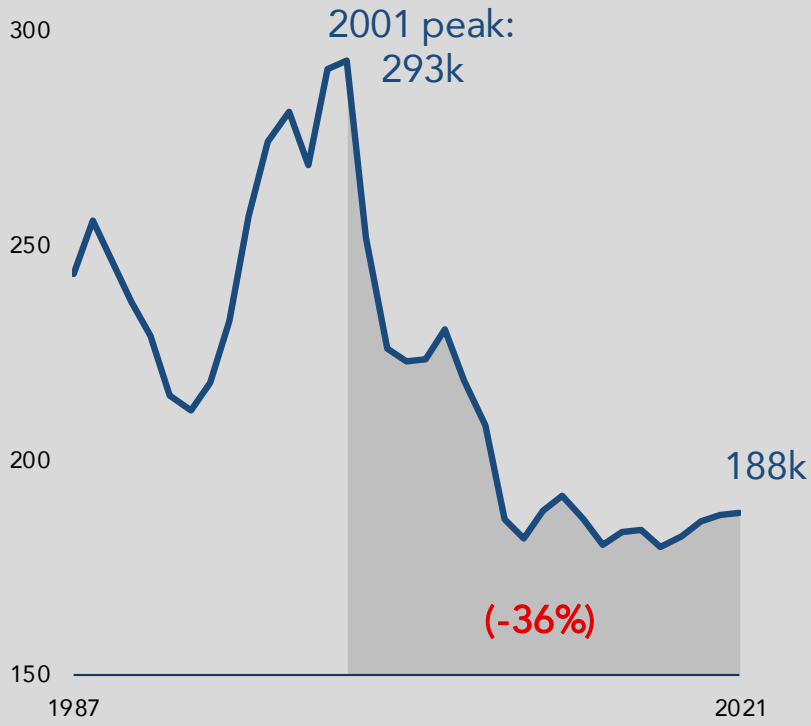
US Labor Shortfall

The US semiconductor industry currently employs roughly 277,000 technicians. Secretary of Commerce, Gina Raimondo, expects roughly 100,000 additional technicians will be needed to staff the new plants expected to come online following the CHIPS Act. The additional hiring needs come as working age population growth slowed to 1.7 million people between 2017 – 2022 vs. growth of 11.9 million between 2000 – 2005. To combat the labor shortage, several semiconductor companies have launched partnerships with universities and technical programs to develop students' specific skill sets.

Annual change in US working age population



US employment in the semiconductor industry, thousands

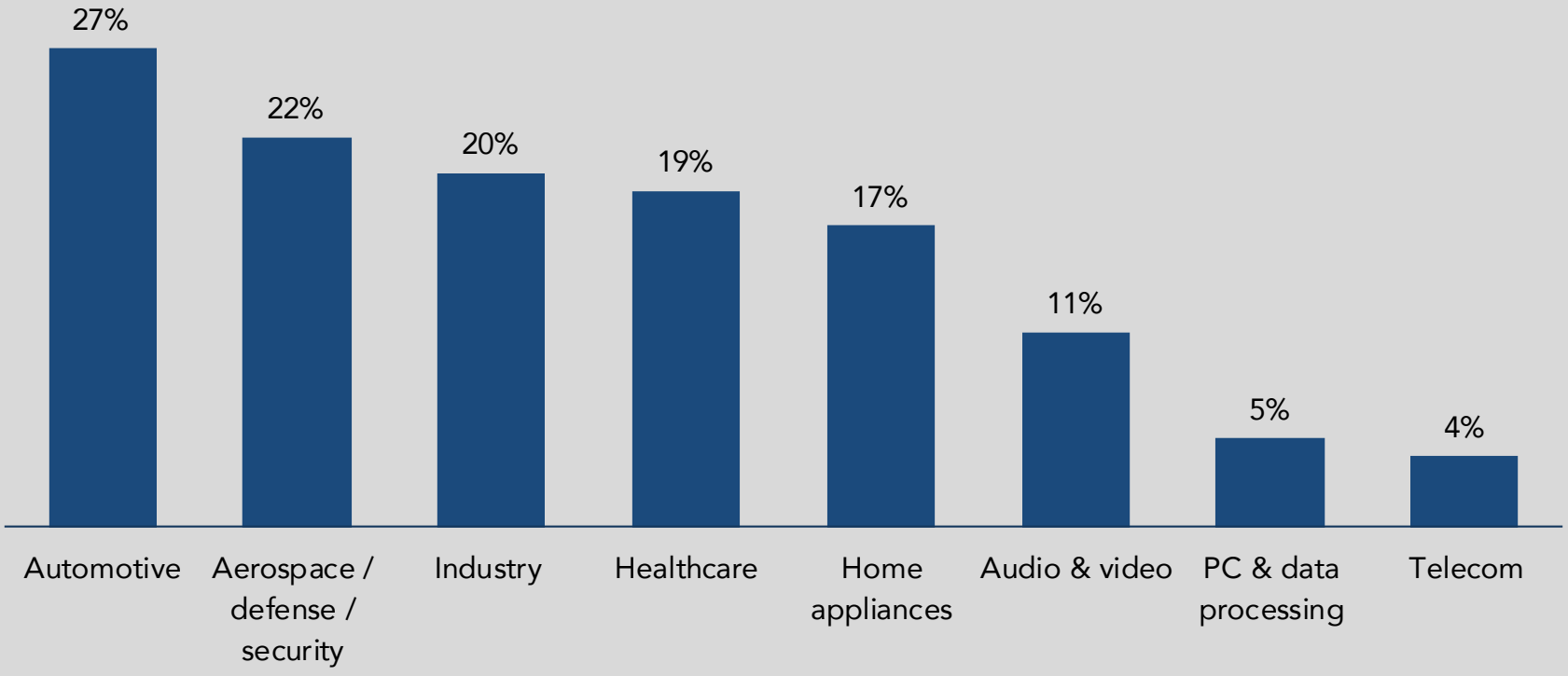


Source: (1) Federal Reserve Bank of St. Louis. 5 year rolling average. Data as of January 30, 2024. (2) Bureau of Labor Statistics. USA Facts.

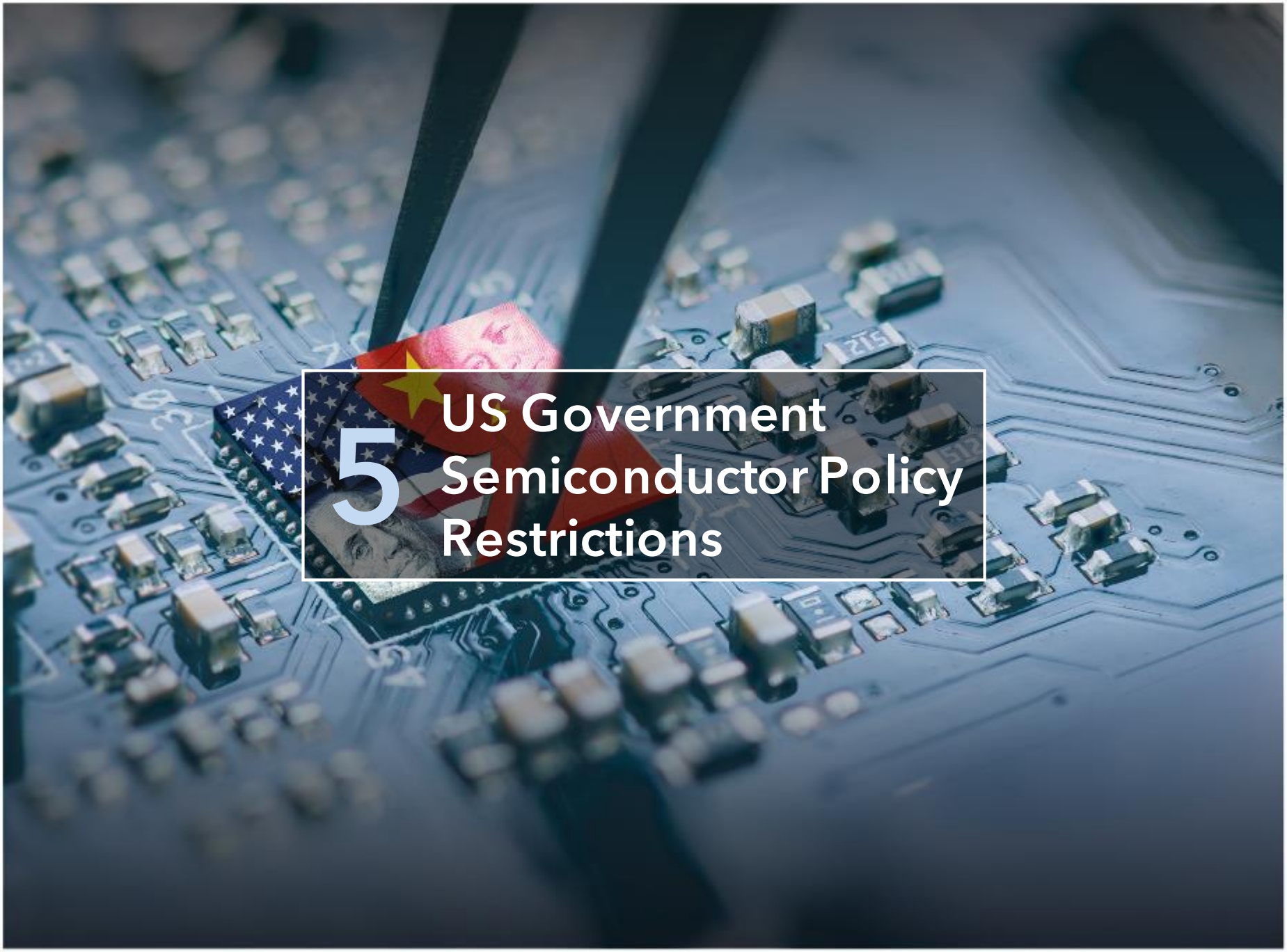
The €43 Billion EU Chips Act

In 2020, Europe accounted for roughly 10% of global microchip production. As the US, China and other economies globally build up their semiconductor design and production capabilities, so too is Europe hoping to increase its share of the global chip market. The European Union has reached a preliminary agreement on the EUR 43 bn EU Chips Act with the goal of doubling the bloc's share of global chip production and utilizing those chips to power their green transition.

Europe's market share of chip production, by sector



Source: (1) European Council, Infographic, "The EU Chips Act."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US Government Semiconductor Policy Restrictions


"Technology is now at the heart of a contest between the United States and China for global pre-eminence which is likely to shape the global geo-political landscape for at least the first half of the twenty-first century."
Nigel Inkster, Former Director of Operations for the British Secret Intelligence Service, SIS (MI6)

US Commerce Dep't Action in October 2022

On October 7, 2022, the US Department of Commerce announced a myriad of new technology restrictions, including restrictions on semiconductor exports to China. The new restrictions prohibit certain semiconductor chips from being exported to China if they are produced with US equipment, regardless of where production occurs. The chips restricted include logic chips under 16 nanometers, DRAM chips below 18 nanometers and NAND chips with 28 layers or more (relatively advanced chips). The US Commerce department also added 31 Chinese companies to the "Unverified List" for 60 days which could trigger additional restrictions going forward.

October 7th additions to the Commerce Department's "Unverified List"

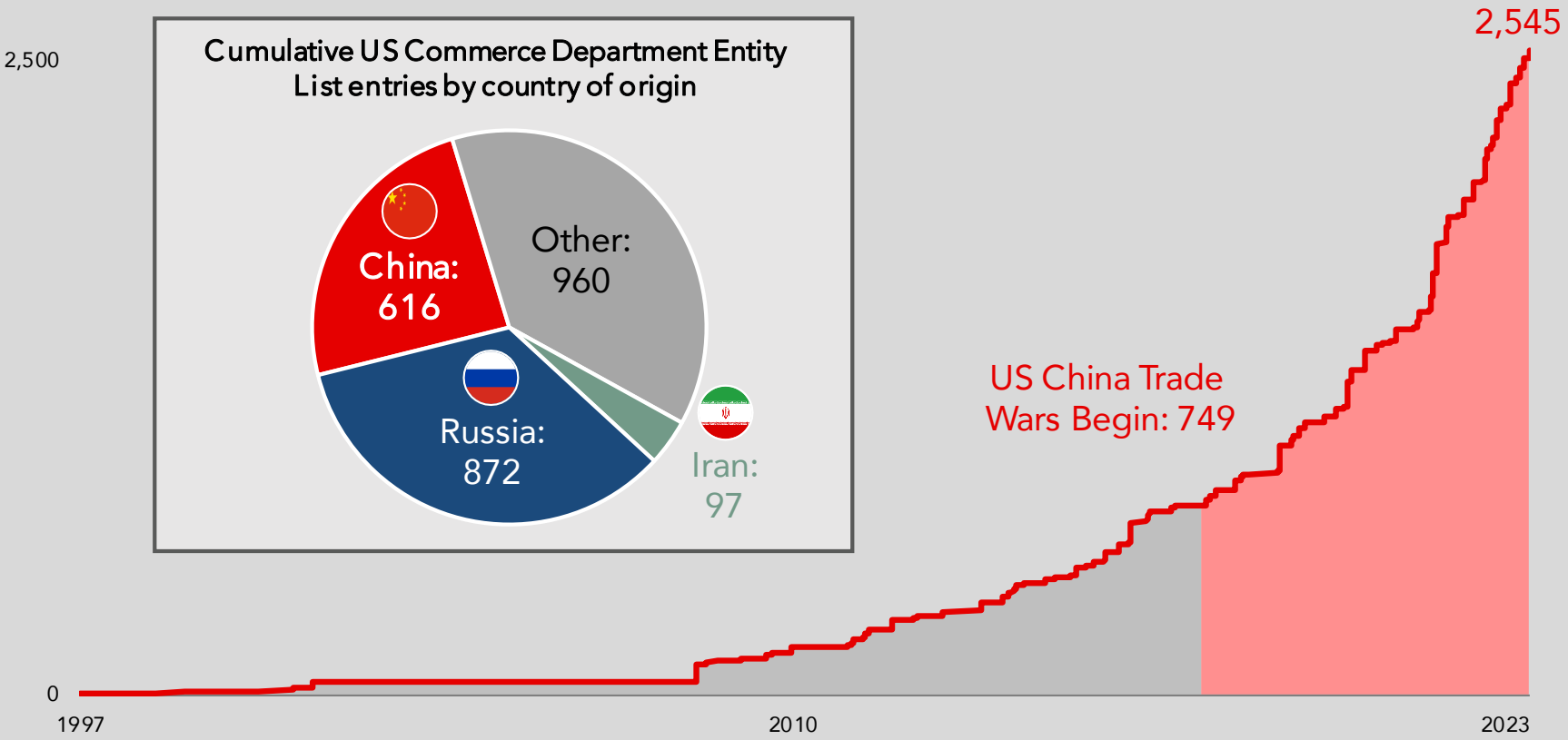
1. *Beijing Naura Magnetoelectric Technology Co., Ltd.*
2. *Beijing PowerMac Company*
3. *CCIC Southern Electronic Product Testing Co., Ltd.*
4. *Chang Zhou Jin Tan Teng Yuan Machinery Parts Co., Ltd.*
5. *Institute of Mineral Resources, Chinese Academy of Geological Sciences*
6. *Chinese Academy of Science (CAS) Institute of Chemistry*
7. *Chongqing Optel Telecom*
8. *Chongqing Xinyuhang Technology Co., Ltd.*
9. *Dandong Nondestructive Electronics*
10. *DK Laser Company Ltd.*
11. *Foshan Huaguo Optical Co., Ltd.*
12. *GRG Metrology & Test (Chongqing) Co., Ltd.*
13. *Guangdong Dongling Carbon Tech. Co., Ltd.*
14. *Guangxi Yuchai Machinery Co., Ltd.*
15. *Guangzhou GRG Metrology & Test (Beijing) Co., Ltd.*
16. *Jialin Precision Optics (Shanghai) Co., Ltd.*
17. *Lishui Zhengyang Electric Power Construction*
18. *Nanjing Gova Technology Co., Ltd.*
19. *Ningbo III Lasers Technology Co., Ltd.*
20. *Qingdao Sci-Tech Innovation Quality Testing Co., Ltd.*
21. *Shanghai Tech University*
22. *Suzhou Sen-Chuan Machinery Technology Co., Ltd.*
23. *Tianjin Optical Valley Technology Co., Ltd.*
24. *University of Chinese Academy of Sciences*
25. *University of Shanghai for Science and Technology*
26. *Vital Advanced Materials Co., Ltd.*
27. *Wuhan Institute of Biological Products Co., Ltd.*
28. *Wuhan Juhere Photonic Tech Co., Ltd.*
29. *Wuxi Hengling Technology Co., Ltd.*
30. *Xian Zhongsheng Shengyuan Technology Co., Ltd.*
31. *Yangtze Memory Technologies Co., Ltd.*

Source: (1) Bloomberg. Data as of October 13, 2022. Federal Registrar, "Revisions to the Unverified List; Clarifications to Activities and Criteria That May Lead to Additions to the Entity List"

US Commerce Department's Entity List

Since inception in 1997, the US Commerce Department's Entity List has grown to over 2,500 entities and sub-entities. Members of the Entity List are subject to specific licensing requirements which may limit their ability to transact with US entities. Since the trade wars began in 2018, and Russia invaded Ukraine in 2022, China and Russia based companies have dominated new additions to the list.

Cumulative additions to the US Commerce Department Entity List (1997 – 2023)



Source: (1-2) Commerce Department. Includes entities and sub-entities but removes duplicate entities. Entities added to the list multiple times are included from their first effective date. Excludes entities with no specified effective date. Data through December 2023. China figures include Hong Kong. Undated entries excluded.

US CHIPS Act Restrictive Measures

The Biden administration and US Commerce Department have outlined tight restrictions on new operations in foreign entities of concern (China, Russia, Iran and North Korea) by chipmakers that get federal funds to build in the US.

Restrictions on companies using federal funds from the CHIPS & Science Act

- Prohibits recipients of CHIPS incentives funds from using the funds in other countries
- Limits recipients of funding from engaging in joint research or technology licensing efforts with a foreign entity of concern that relates to a technology or product that raised national security concerns
- Restricted from adding more than 5% to existing capacity and $100k of investment to any single plant making advanced logic chips (more sophisticated than 28 nanometers) in countries of concern
- Limits on adding new production and expanding production capacity beyond 10% of legacy facilities in foreign countries of concern
- Classifies list of semiconductors as critical to national security and subject to tighter restrictions
- Reinforces US export controls and applies a more restrictive threshold to prevent China from purchasing and manufacturing advanced chips that would enhance their military capabilities

Source: (1) Bloomberg Government, "Biden Stunts Growth in China for Chipmakers Getting US Funds" (March 22, 2023). US Commerce Department, "Commerce Department Outlines Proposed National Security Guardrails for CHIPS for America Incentives Program."

Restrictions Emanating From US-Dutch-Japan Chip Alliance

In October 2022, the United States unilaterally announced strict export controls on semiconductor technology to China. While US export restrictions have a significant near-term impact on China's chip manufacturing capabilities, to have a more meaningful and longer-term impact, the US needed support from key allies. The Netherlands and Japan are dominant producers of critical chip production equipment necessary for mass-production of semiconductors. In January 2023, the Biden Administration secured a deal with the Netherlands and Japan on semiconductor export controls.

NETHERLANDS

- Announced export controls on Deep Ultraviolet (DUV) lithography systems (critical to semiconductor manufacturing)
- The announcement does not refer to the US, Japan or China but instead lays out three strategic goals
  - Prevent Dutch goods from contributing to undesirable end use
  - Prevent unwanted long-term strategic dependences
  - Maintain Dutch technological leadership

JAPAN

- Announced export controls on 23 types of advanced semiconductor manufacturing equipment
- Export controls effective from July 2023
- The announcement did not explicitly reference China or an agreement with the US and Netherlands

Source: Center for Strategic & International Studies "Clues to the US-Dutch-Japanese Semiconductor Export Controls Deal Are Hiding in Plain Sight"; "Japan and the Netherlands Announce Plans for New Export Controls on Semiconductor Equipment".

Semiconductor Showdown with China

Selected US – China technology sector policy actions

 President Trump	May 2019	US national security order to ban Huawei
	Feb 2020	US bans government purchases of Huawei gear
	Jun 2020	US FCC designates Huawei & ZTE as national security threats
	Nov 2020	Executive order prohibiting Americans from investing in 31 tech firms
	Dec 2020	4 additional Chinese technology companies added to blacklist
 President Biden	Mar 2021	US FCC blacklists 5 Chinese telecom companies
	Apr 2021	US Commerce Department blacklists 7 Chinese supercomputing entities
	Apr 2021	US Senate Foreign Relations Committee approves the Strategic Competition Act of 2021
	Jun 2021	US Senate passes the Innovation and Competition Act of 2021
	Jul 2021	US adds 23 Chinese companies to economic blacklist
	Oct 2021	US FCC revokes China Telecom America's services authority
	Nov 2021	US blacklists over a dozen Chinese quantum computing companies
	Dec 2021	US OFAC adds China's top AI firm to the US's investment blacklist
	Dec 2021	US Treasury Department blacklists 8 Chinese technology firms
	Dec 2021	US Commerce Department adds 24 more Chinese entities to its "entity list"
	Feb 2022	US House of Representatives passes America Competes Act
	Feb 2022	US adds 33 Chinese entities to its "unverified list"
	Mar 2022	The United States Trade Representative (USTR) doubles down on competition with China in annual report
	Mar 2022	SEC releases list of five Chinese companies for possible delisting from US stock markets

Source: (1) Veda Partners (Treyz). China Briefing "US – China Relations in the Biden Era: A Timeline" (Dezan Shira & Associates).

Semiconductor Showdown with China

Selected US – China technology sector policy actions

President Biden

Mar 2022	SEC adds Weibo to list of Chinese companies for possible delisting from US stock exchanges
Aug 2022	US passes CHIPS & Science Act
Aug 2022	The US adds another seven China entities to its export control list
Aug 2022	US and China securities regulators reach agreement on auditing of US-listed Chinese companies
Oct 2022	Commerce Dept. issues two new rules on restricting US & foreign firms shipping high-end microchip manufacturing equipment to China
Oct 2022	Commerce Dept. adds 31 Chinese entities to the "unverified list"
Oct 2022	US announces restrictions on US citizens and green card holders working for certain Chinese semiconductor & AI companies
Dec 2022	US announces ongoing talks with Japan and Netherlands to restrict advanced chip exports to China
Dec 2022	US Congress proposes bill to add Huawei and other Chinese telecom companies to Treasury "specially designated nationals" list
Dec 2022	US Congress proposes ban on Chinese-linked social-media platform TikTok
Dec 2022	Commerce Department adds 36 Chinese companies to "entity list"
Feb 2023	Commerce Department adds 6 Chinese entities to a sanctions list for their support of China's military efforts
Mar 2023	Commerce Department adds 28 Chinese companies to "entity list"
Apr 2023	US Department of Commerce imposes export controls on 12 more Chinese companies
Aug 2023	President Biden issues executive order restricting US investments in Chinese tech
Oct 2023	US commerce department adds 32 Chinese entities to export control list for alleged support to Russia's Military
Nov 2023	US further tightens export controls of advanced chips to China

Source: (1) Veda Partners (Treyz). China Briefing "US – China Relations in the Biden Era: A Timeline" (Dezan Shira & Associates).

6 Assessment of China Semiconductor Policy

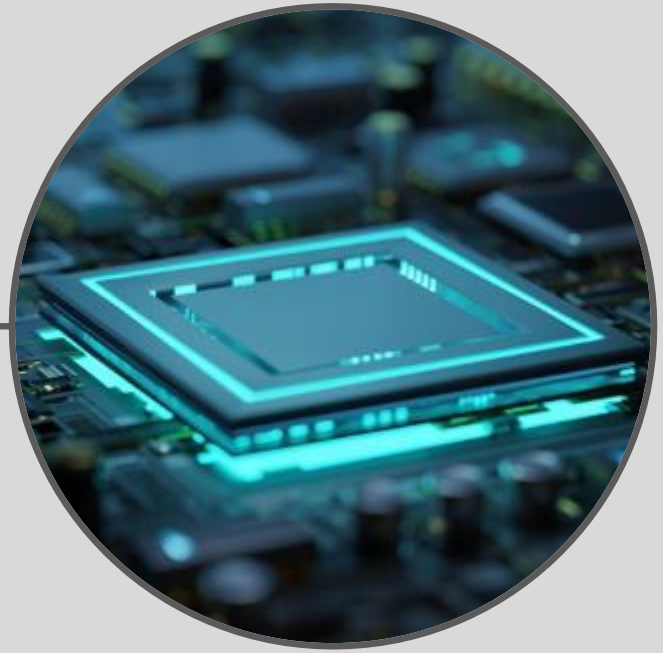
"China produced a greater share of total world GDP than any Western society in 18 of the last 20 centuries. As late as 1820, it produced over 30% of world GDP, an amount exceeding the GDP of Western Europe, Eastern Europe, and the United States combined."

Henry Kissinger, former US Secretary of State, in "On China"

China's Twin Technology Deficits

More so than most other areas, China notably lags US and western innovation in two fundamental, core technology arenas: software and advanced microprocessors.

Software

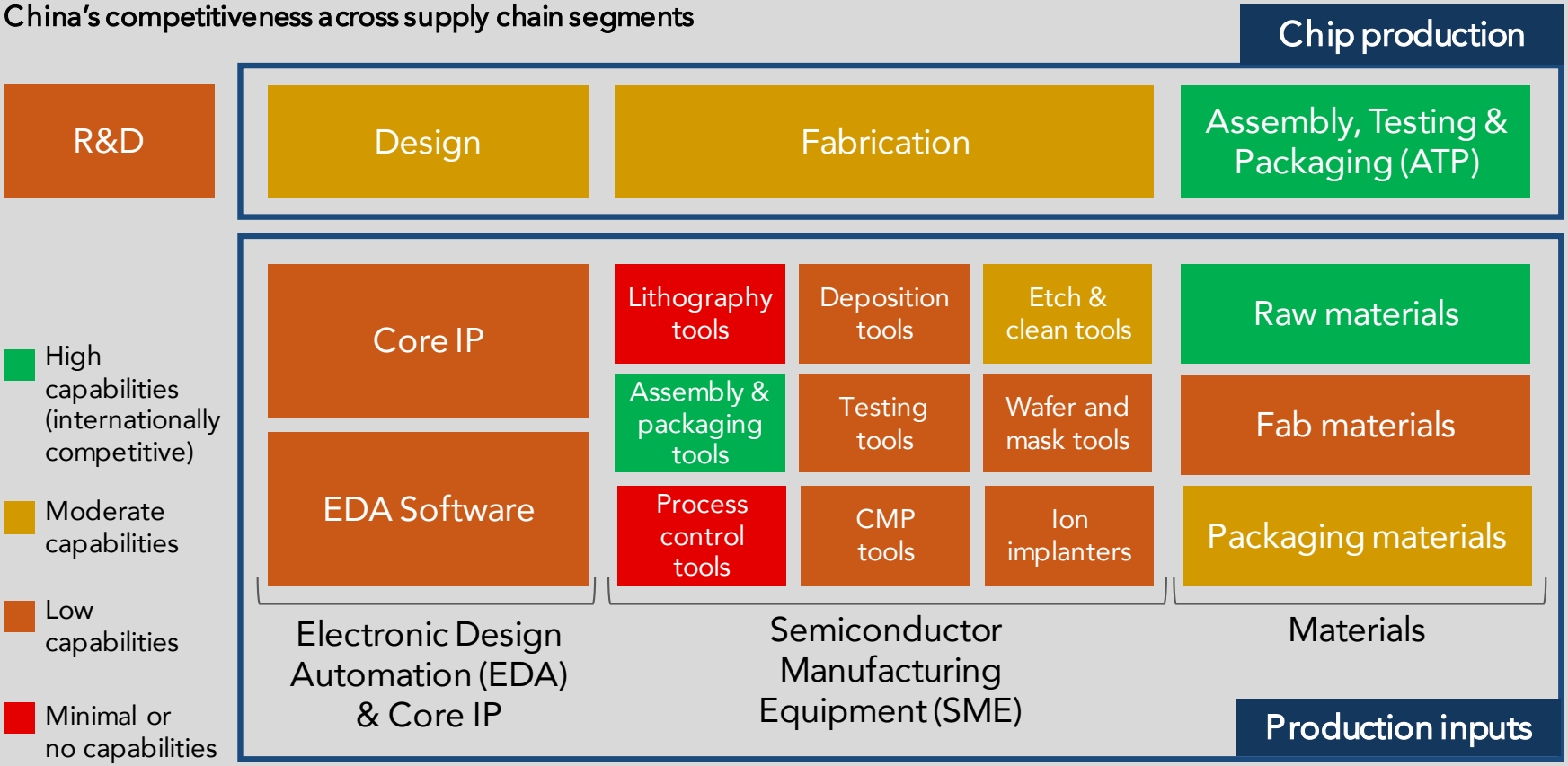


Advanced Semiconductors

China's Bottleneck Challenges

Mainland China is a key component of the global semiconductor supply chain, particularly as it pertains to raw materials supply and assembly and packaging. While China is working to build out capabilities in the design and advanced technology fabrication segments of the supply chain, significant "chokepoints" exist. China is reliant on the US and its allies for critical items, such as design and manufacturing equipment.

China's competitiveness across supply chain segments

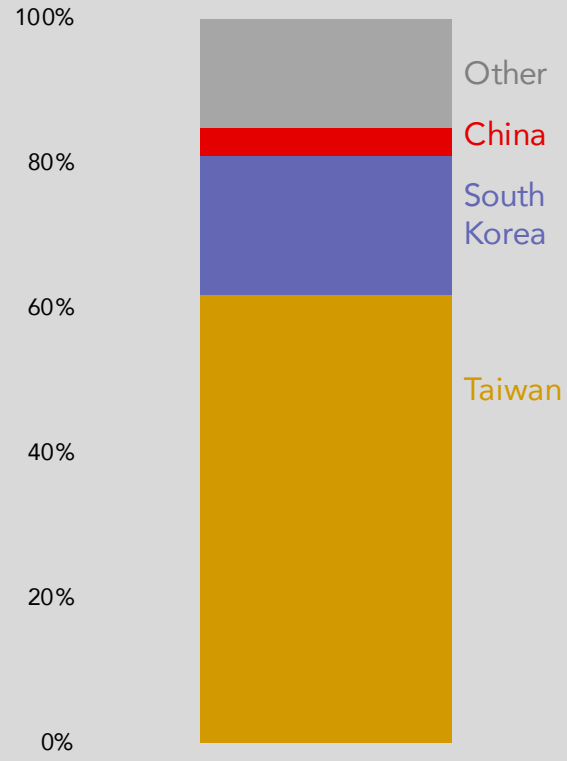


Source: (1) Center for Security & Emerging Technology (CSET), "The Semiconductor Supply Chain: Assessing National Competitiveness" (January 2021).

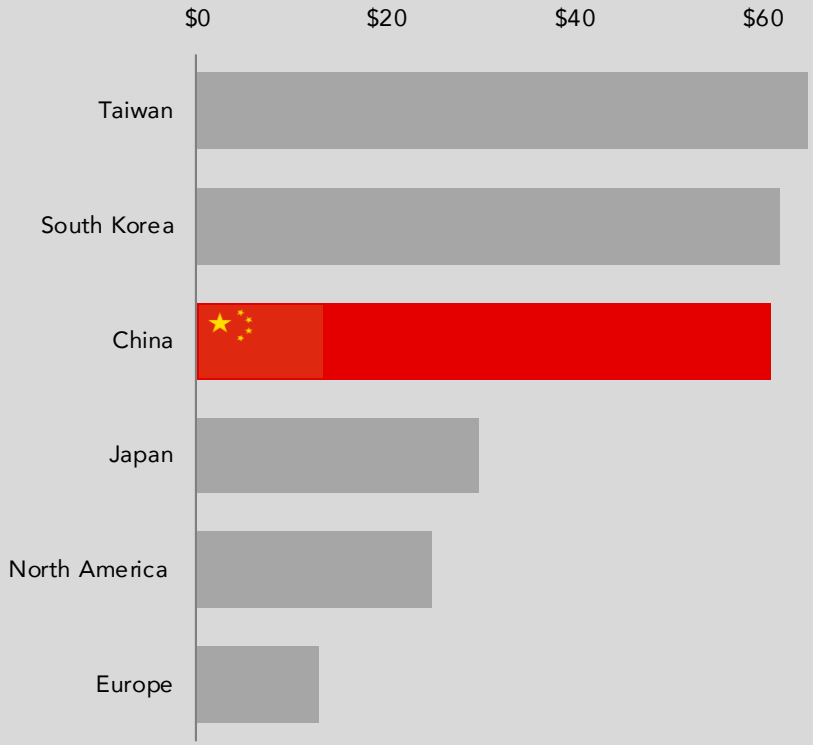
China Playing Catch-Up in Semi Manufacturing

Today, China represents less than 5% of global semiconductor manufacturing, and has zero market share in the manufacturing of the most sophisticated chips. However, in an effort to prioritize economic self-sufficiency, Beijing has announced plans to add 40% of new global semiconductor capacity by 2030.

Global market share for semiconductor foundry manufacturing, by country



Forecast spending on semiconductor fabrication equipment, 2019-2022, USD bn

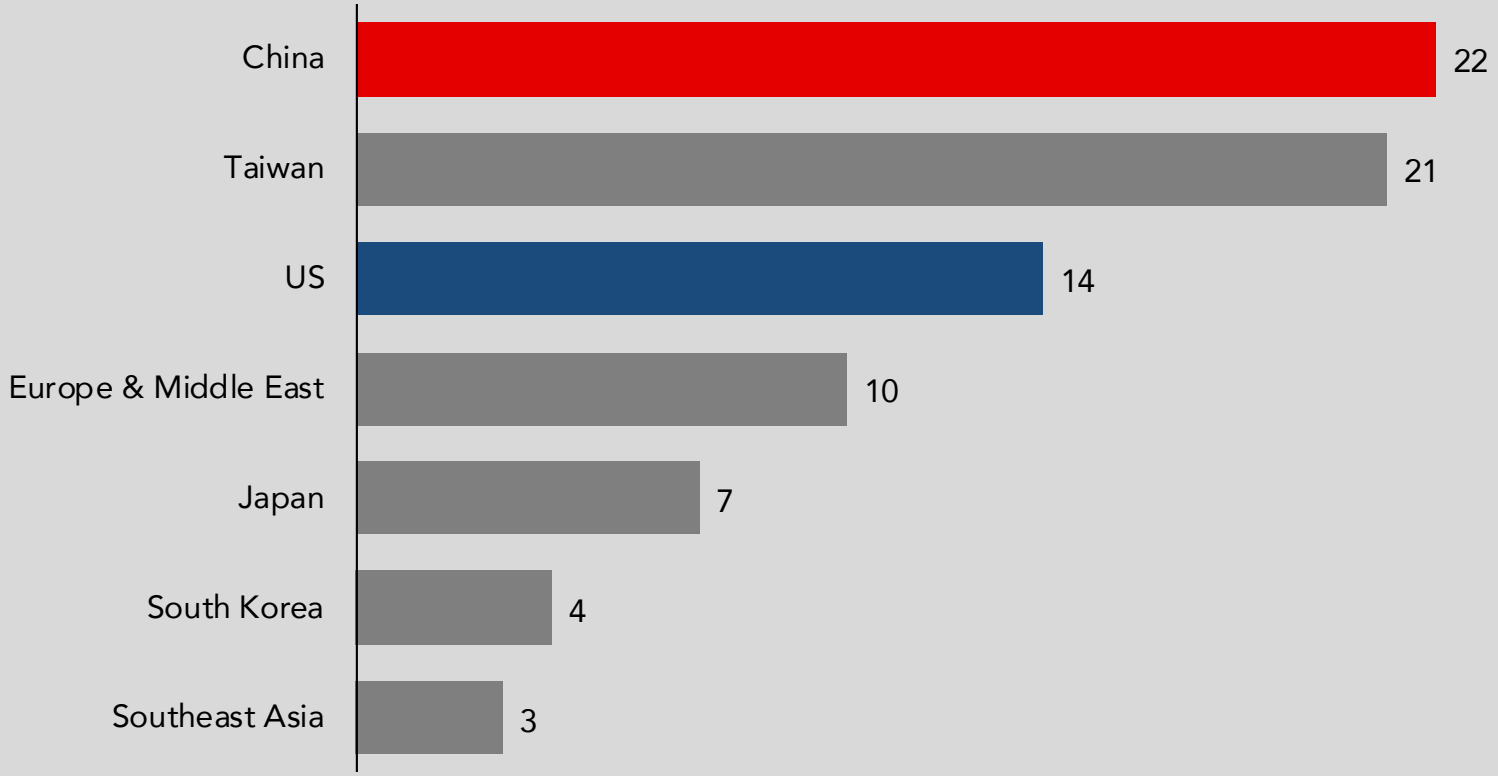


Source: (1-2) FT, "Fortress China: Xi Jinping's Plan for Economic Independence" (September 15, 2022). Enodo Economics. Gavekal Dragonomics.

Rapid Expansion of New China Semi Facilities

Japan, Europe and the US have each passed government incentives to expand domestic chip production in recognition of the role semiconductors play in national security. China, however, has plans to build semiconductor capacity at two-three times its global peers in the years ahead. Despite the rapid build-out, chip manufacturing requires a complex and interconnected supply chain that goes well beyond new foundry facilities.

Number of new chip facilities between 2021 and 2025

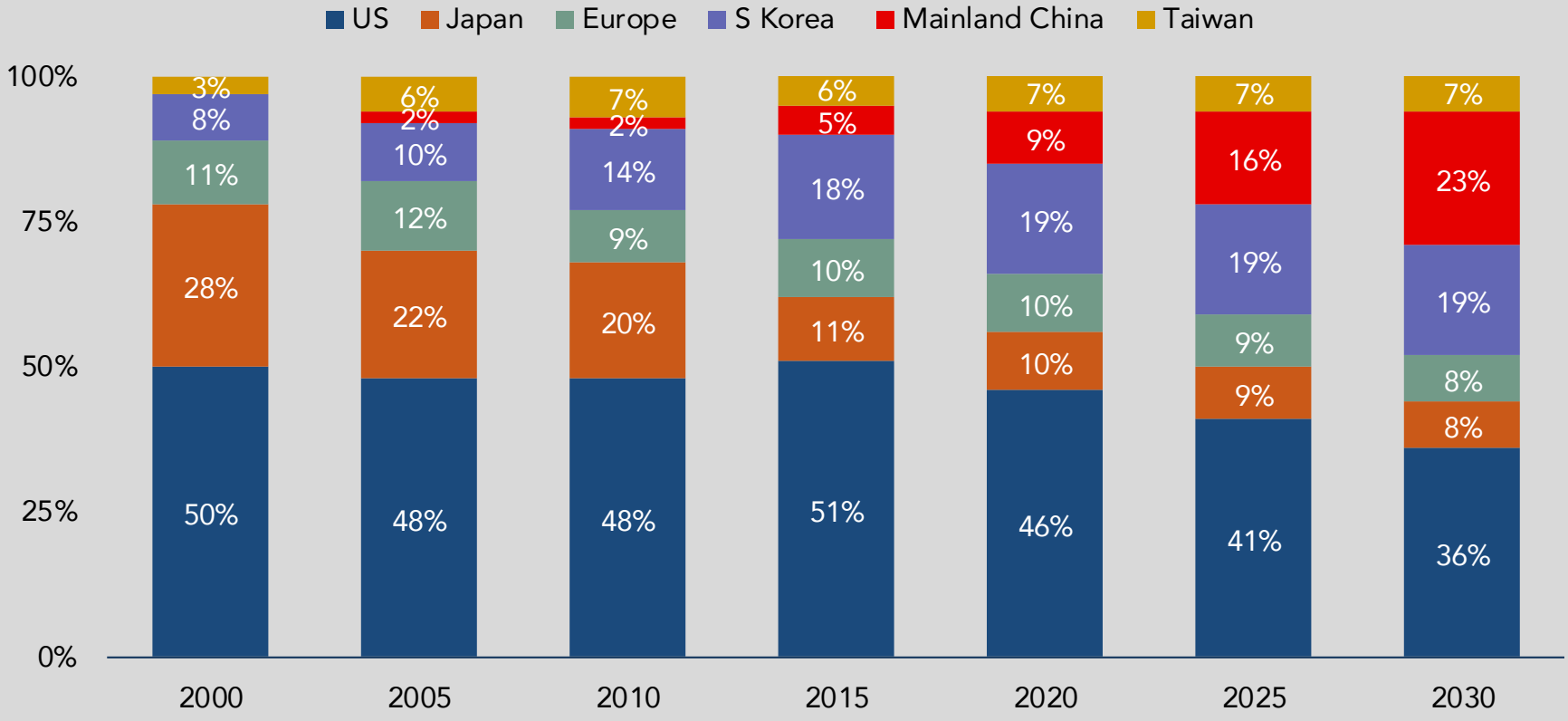


Source: (1) SEMI. Data as of September 2022. FT, "The Global Microchip Race" (December 13, 2022).

China Building Out Design Capabilities

In 2022, the US held 48% market share in semiconductor R&D, design, and processing technology, more than double any other country. However, design capabilities are of paramount importance to China's goal of improving semiconductor supply chain value add. China has increased its share of chip design from zero in 2000 to just over 10% today and is expected to more than double that share again by 2030.

Design market share by region of company headquarters

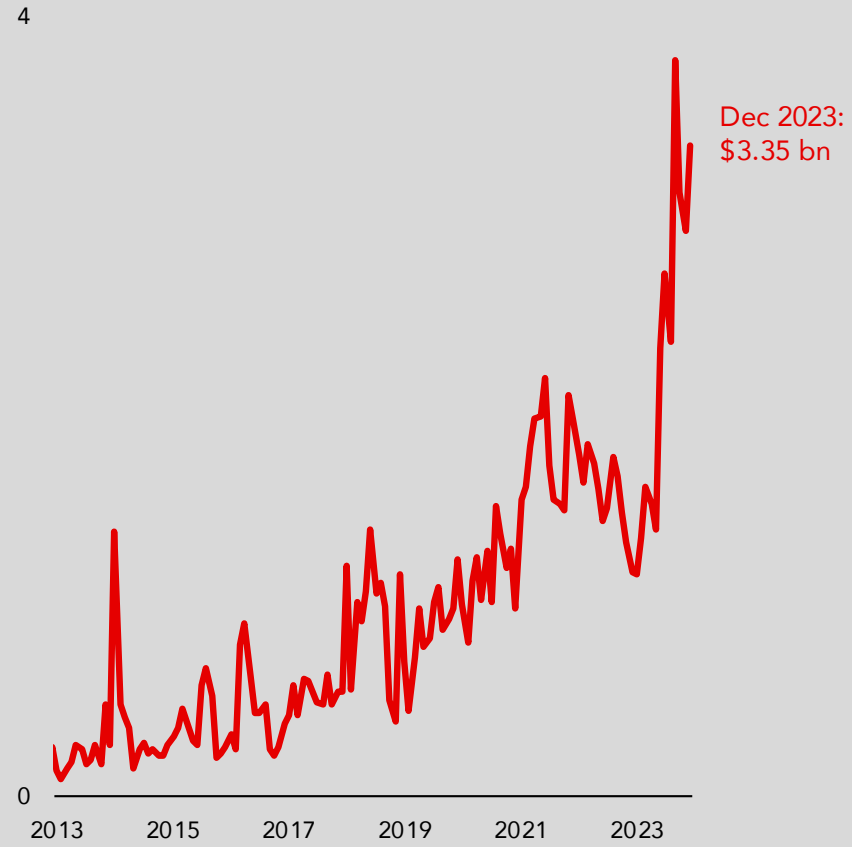


Source: (1) Semiconductor Industry Association (SIA), "2022 - State of the US Semiconductor Industry."

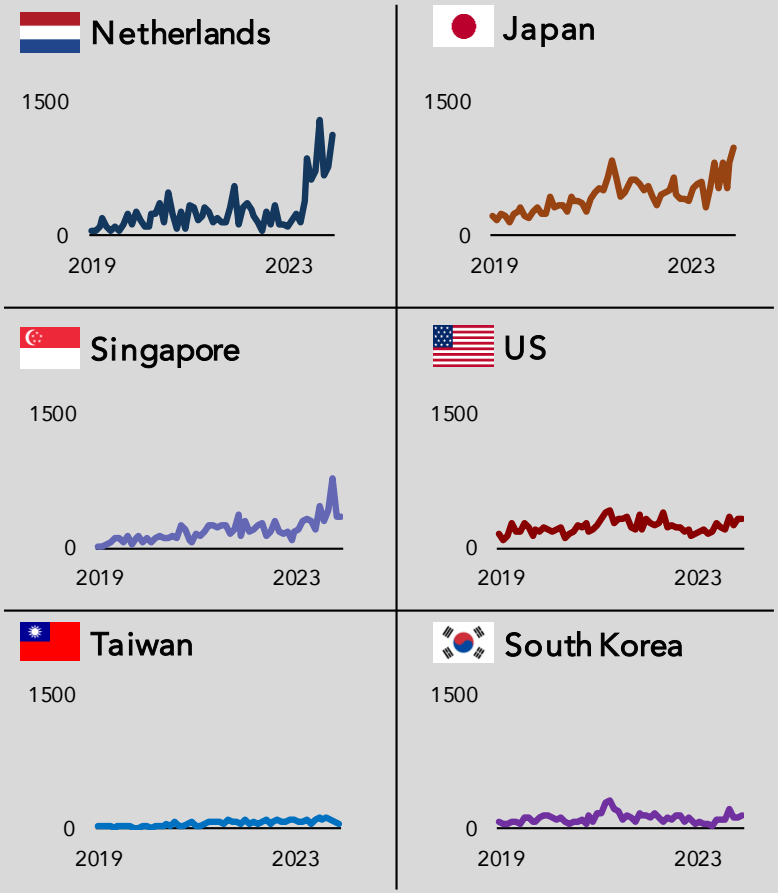
China's Record Chip Equipment Imports

In 2023, China's chip equipment imports hit records for two consecutive months, totaling nearly $5bn, up 70% from the same period the year prior. Imports from the Netherlands and Japan have surged, despite recently imposed export restrictions in an effort to slow China's technological advancement.

China's imports of equipment for manufacturing semiconductor devices, USD bn



China manufacturing equipment imports by country



Source: (1-7) China's General Administration of Customs. China imports by country is equipment for manufacturing semiconductor devices. **In millions*

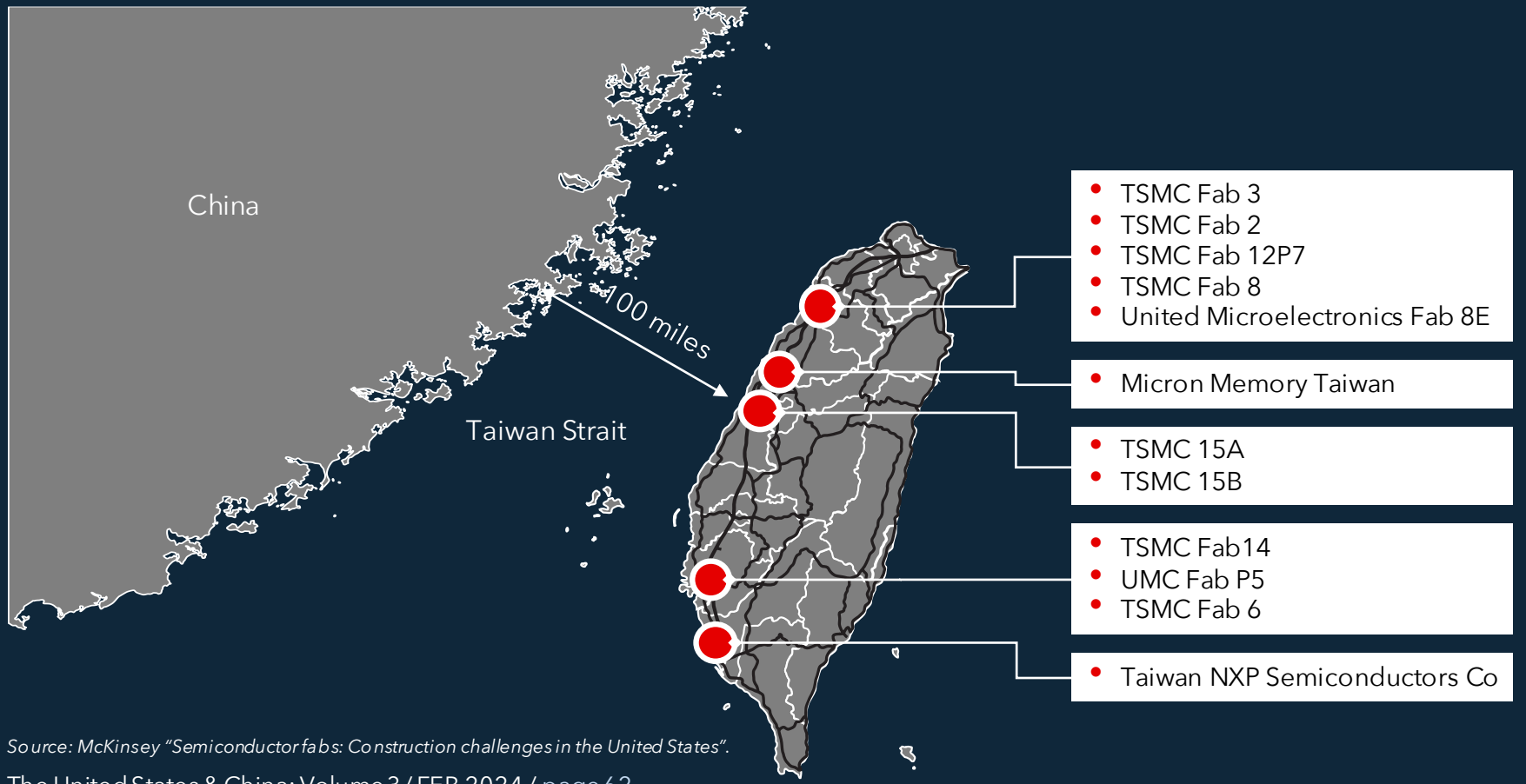
7 Taiwan Risk Assessment

“History is always unfinished in the sense that the future always uses the past in new ways.”

Peter Gay, in his Style in History (1974)

Taiwan's Silicon Shield

Taiwan is responsible for over 20% of global semiconductor manufacturing, over 60% of advanced semiconductor production (<10 nanometer) and over 90% of the world's most sophisticated chips (< 3 nanometer). While Taiwan's high tech exports are critical for China, it is a mistake to assume that Beijing's strategic rationale for unification is driven by access to technology. History, culture and geopolitics are more formidable drivers. Nonetheless, with Taiwan's fabs located on the western coast of Taiwan less than 100 miles from the mainland, global chip supply is highly exposed to China -Taiwan tensions. Historically, Beijing has never sanctioned Taiwan's semiconductors or high tech exports.



Source: McKinsey "Semiconductor fabs: Construction challenges in the United States".

Timing Considerations for Potential China-Taiwan Conflict

Taiwan has been the centerpiece of the CCP's political priorities for decades, and a source of discord between Washington and Beijing. A defining feature of President Xi Jinping's foreign policy has been his assertiveness regionally, and this includes an abandonment of China's decades-long gradualist approach to absorbing Taiwan. It appears increasingly likely that President Xi, age 70, will seek to secure his place in Chinese history by resolving the "Taiwan question" during his political lifetime.

Timing Considerations for a Potential China-Taiwan Conflict

- **President Xi's political lifetime** (age 70, health considerations)
- **Resolution of China's key strategic vulnerabilities** (oil, semiconductors, military)
- **Preparedness of China's military** (corruption, technology, relative strength)
- **Complexity of a Taiwan invasion** (cyber, ballistic missiles, critical infrastructure, amphibious, special ops, response assessment, propaganda narrative)
- **Political leadership in the West** (US President, strength of regional alliances)

2027 will mark the 100th Anniversary of the People's Liberation Army (PLA) and the end of President Xi's 3rd term. While a milestone to be watched closely, many China experts believe this may still be too soon for a China-Taiwan military event.

In the summer of 2023, at the age of 100, former US Secretary of State Henry Kissinger (now deceased), made his remarkable final journey to Beijing, China, where his wisdom and counsel had always been welcome over the prior five decades.

The Economic Cost of a Taiwan War

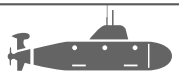
Bloomberg's Economics team has modeled the potential cost of a military conflict in Taiwan across two scenarios. In both cases - a Taiwan blockade and a Taiwan war - they have projected a cost to the global economy of $5 and $10 trillion, respectively. The corresponding 5% and 10% contractions in global GDP would precipitate a global recession, and dwarf the cost of other recent conflicts including Ukraine, Gaza, the Gulf War and 9/11. The economic impact assessment takes into account the disruption to semiconductor supply chains, shipping, trade sanctions and tariffs, cyber-security and financial markets.

Global GDP deviation from pre-crisis trend

Source: (1) Bloomberg. IMF. Israel-Hamas war, Taiwan blockade, and Taiwan war are Bloomberg Economics estimates.

US-China Military Assets

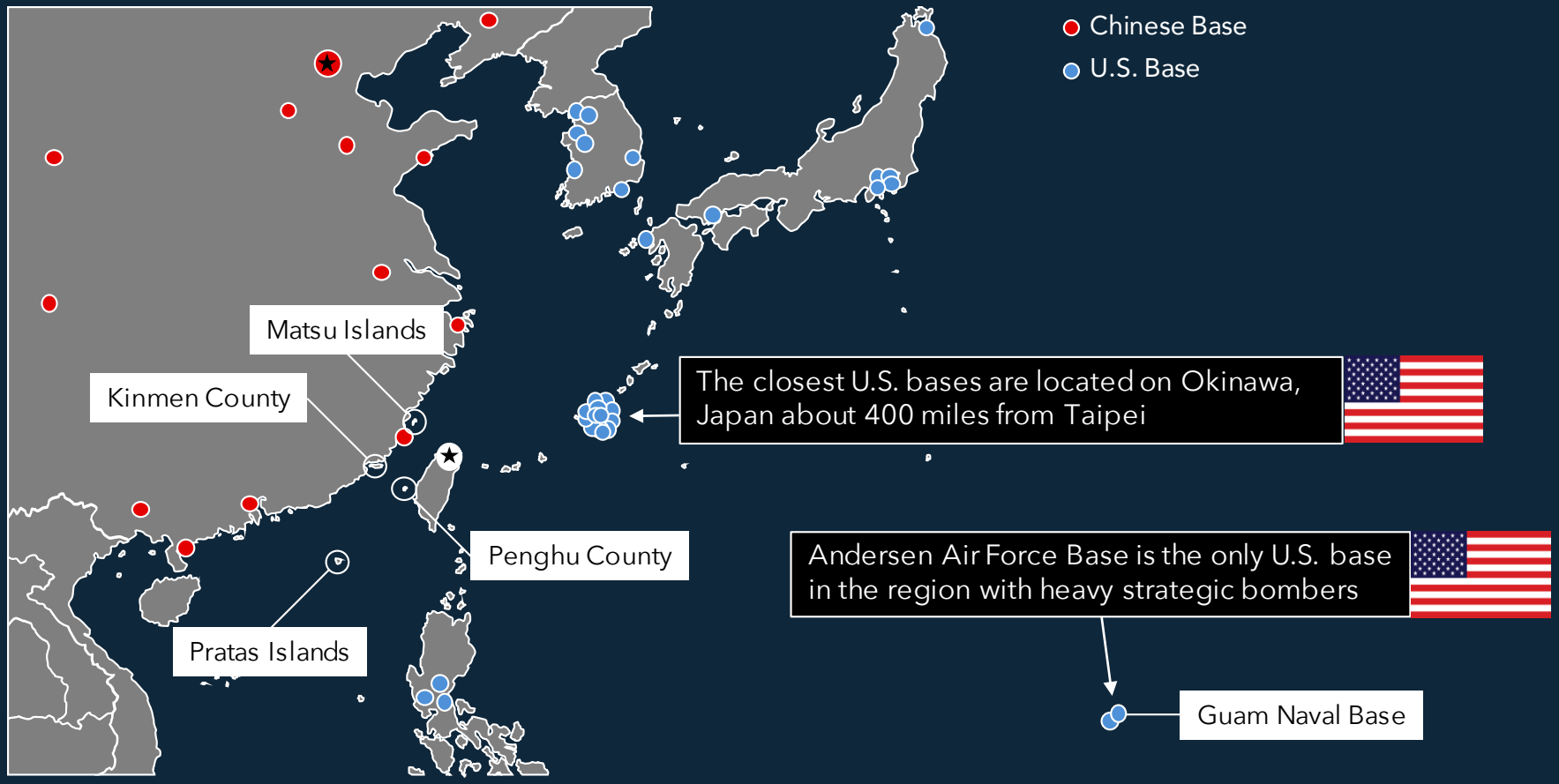
China today boasts the world's largest Army and the largest Navy (as measured by # of ships). While the US remains the world's most dominant military power, President Xi Jinping has accelerated the modernization and expansion of China's military with the explicit aim of becoming the dominant regional power in the South China Sea and winning a war in the Taiwan Strait, if needed.

	US	China
Annual military spend (gross dollars, bn)	$877 bn	$292 bn
Annual military spend (% of GDP)	3.5%	1.6%
 Nuclear arsenal (# of warheads)	5,244	410
 Active military personnel	1,395,350	2,035,000
 Active aircraft carriers	11	3
 Destroyers	92	50
 Frigates	0	43
 Submarines	68	78
 Fighters/attack planes	2,757	1,570
 Main battle tanks	5,500	4,950

Source: (1) SIPRI 2022. Global Firepower. Federation of American Scientists (FAS). WiseVoter.

US-China Taiwan Military Tensions

At its narrowest point, the Taiwan strait is just 100 miles. However Taiwan also has numerous outlying islands which could be early targets if China were to launch an invasion. Whether or not an invasion is launched, military activity in and around the Taiwan Strait remains high as both the US and China have numerous military bases in the region.

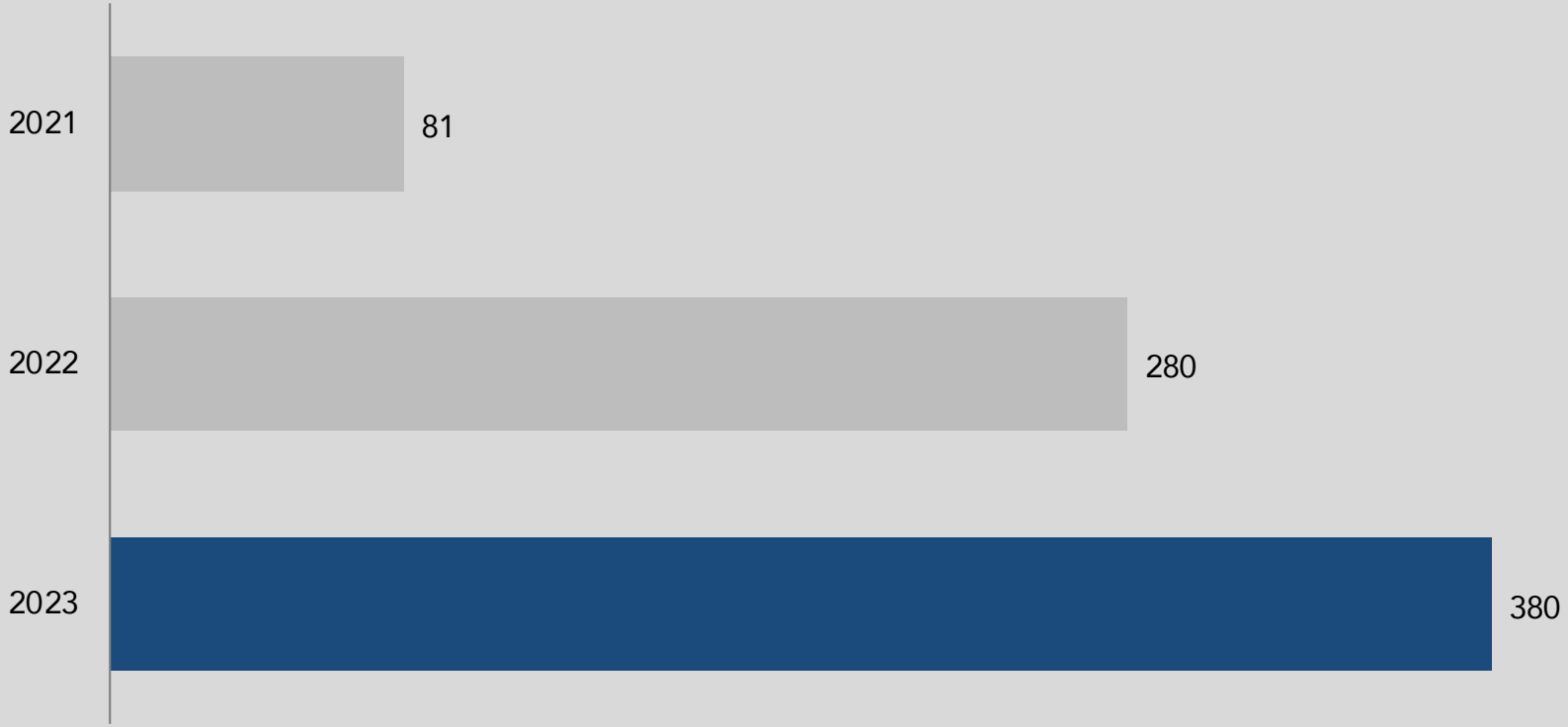


Source: The Chinese Invasion Threat, Natural Earth, International Institute for Strategic Studies, US Department of Defense, GlobalSecurity.org.

Chinese Incursions into Taiwan Air Defense Zone

In 2023, China sent warplanes into Taiwan's air defense zone over 4.5x more often than just two years prior. President Xi Jinping has said that China is not preparing for war with Taiwan, but Taiwan's annual defense report highlights new airfields, fighters, and drones being built and stationed along China's eastern and southern coastline, along the Taiwan Strait.

Average monthly number of China's warplanes near Taiwan



Source: (1) Bloomberg, "Taiwan is not ready for a war with China: Balance of Power". 2022, 2023 data are according to a written report prepared by Taiwan's Defense Ministry to lawmakers; 2021 number is based on daily public data from the Taipei ministry and calculated by Bloomberg.

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Role

Tom Joyce is a Managing Director and Capital Markets Strategist within MUFG's global capital markets and investment banking business. Based in New York, Tom heads a team that creates customized analytical content for multi-national S&P 500 companies. His team provides in depth analysis on the impact of economic, political, public policy and regulatory dynamics on the US credit, foreign exchange, rates and commodities markets.

Experience

Tom has over 25 years of Investment Banking experience in New York, London, Hong Kong, and San Francisco. Over the last 15 years, Tom created and built the Capital Markets Strategy role, advising corporate C-Suite executives (Boards, CEOs, CFOs, and Treasurers) on the pervasive macro forces driving markets. Tom also presents at dozens of corporate events each year including Board meetings, CEO ExCo sessions, CFO and Treasury off-sites, corporate leadership events and conferences.

Education

Tom's educational background includes a year of study at Oxford University from 1991 - 1992, a Bachelor of Arts in Political Science from Holy Cross College in 1993, and a MBA from Kellogg Business School, Northwestern University in 2000.

Personal

Tom resides in New Canaan, CT with his wife and four sons, where he serves on the Board of Trustees of the New Canaan Library as well as the Holy Cross College President's Council.

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Role

Hailey Orr is a Managing Director in MUFG's Capital Markets Strategy group within the global capital markets and investment banking business. The team provides market based content for corporate clients to assist in strategic decision making. Focus areas include the impact of economic, political, public policy and regulatory dynamics on the US credit, foreign exchange, rates and commodities markets.

Experience

Hailey has a decade of Wall Street experience, including three years as a Consumer Sector Specialist in Equity Sales and seven years as a Capital Markets Strategist. Hailey is also a member of MUFG's Inclusion & Diversity Council and has devoted years to participating in and developing Wall Street recruiting programs.

Education

Hailey graduated with honors from the University of Michigan's Ross School of Business with a BBA and a minor in International Studies.

Personal

In March 2020, Crain's New York Business Magazine named Hailey one of the "Rising Stars in Banking and Finance".

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Experience

Stephanie has spent over six years as a Capital Markets Strategist. She is an active member of the University of Michigan recruiting team and is focused on the diversity recruiting effort at MUFG. Stephanie is also a part of MUFG's DEI, Culture & Philanthropy (DCP) Council.

Education

Stephanie graduated with honors from the University of Michigan's Ross School of Business with a BBA.

Personal

Stephanie is actively involved in NYC's iMentor program, mentoring high school students with their journey to college graduation. She also volunteers at Experience Camps, a free summer camp program for grieving children.

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Experience

Angela previously interned at MUFG working in Capital Markets within the Equity Capital Markets and Leveraged Finance divisions. She is also an active member of the Carnegie Mellon University recruiting team.

Education

Angela graduated with honors from Carnegie Mellon University's Tepper School of Business with a BS in Business Administration with an additional major in Statistics and a minor in Media Design. She was a member of Alpha Kappa Psi business fraternity and the Undergraduate Entrepreneurship Association.

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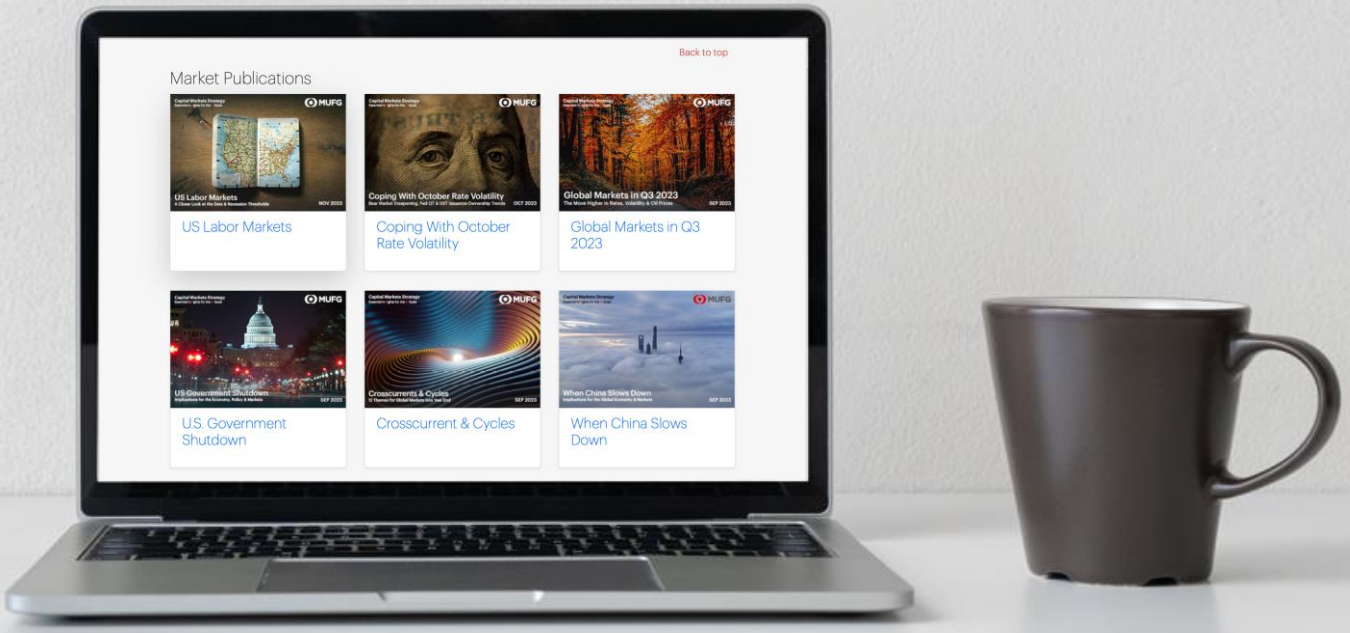

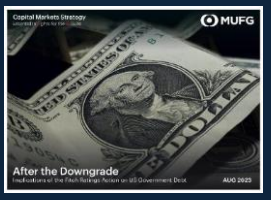

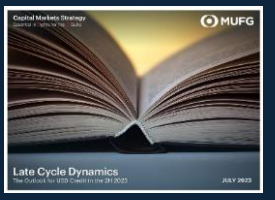

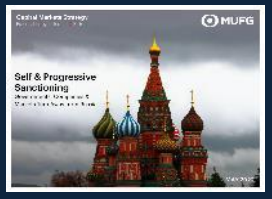

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