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Industry Insights Report: **Semiconductors**

#GreaterPHXtogether

 Greater Phoenix
Economic Council

Report Highlights

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Greater Phoenix has solidified its position as a major U.S. semiconductor manufacturing hub, thanks to a strong legacy of advanced manufacturing, a growing technology sector, skilled workforce investment and collaborative R&D around emerging technology.

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Global supply chains are becoming more diverse as firms seek to reduce supply chain vulnerabilities and mitigate the effects of rising geopolitical tension among major producer nations.

03

Semiconductor manufacturers struggle to meet a growing need for STEM workers as they compete with other technology sectors for talent.

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Key technologies such as 5G and advanced telecommunications, autonomous and electric vehicles, and materials science influence the semiconductor manufacturing industry's evolution in unprecedented ways.

05

Greater Phoenix will emerge as a global semiconductor hub through continued investments in basic and applied R&D, skilled workforce development and supply chain reinforcement.

The Future of Semiconductor Manufacturing

Semiconductors are the backbone of an increasingly complex and technologically sophisticated global economy. They are in nearly every modern electronic device and the use of semiconductors continues to increase thanks to emerging innovation with artificial intelligence (AI), 5G, internet-of-things (IoT), automated vehicles (AV), electric vehicles (EV) and quantum computing. Semiconductors are currently the world's fourth most traded product after crude and refined oil, and cars.ⁱ Global semiconductor sales amounted to more than \$40 billion in April 2021 alone and annual sales are expected to grow by nearly 20% in 2021.ⁱⁱ

As the industry evolves, several key factors will influence the future of semiconductor manufacturing:

- Localization and diversification of production and supply chains
- Advanced engineering talent demand
- Increasing computing capacity requirements of advanced technologies including 5G and beyond, autonomous mobility, and quantum computing

Greater Phoenix is one of America's legacy semiconductor hubs and has capitalized on these industry trends to build up its position.

A Major U.S. Semiconductor Manufacturing Hub

Greater Phoenix has been a leading market for semiconductor companies since 1949 when Motorola first opened a facility in the region. In 1955, Motorola's Phoenix laboratory developed the first commercial high-power transistor (used in car radios), laying the foundation for Greater Phoenix's semiconductor industry. As the utility and demand for semiconductors grew over the decades, Greater Phoenix's ecosystem matured in size and diversity.

Today, Greater Phoenix is home to more than 75 semiconductor and related device manufacturing

operations that employ nearly 20,000 people.^{iv} Industry leaders anchor this rich ecosystem, including Intel Corporation, ON Semiconductor, NXP Semiconductors, Microchip Technology, and many others. Greater Phoenix's status as a semiconductor hub was further cemented in 2020 when Taiwan Semiconductor Manufacturing Company (TSMC) selected the region for a new advanced manufacturing campus, starting with a \$12 billion investment and 2,000 high-paying jobs. In March 2021, Intel announced it would invest \$20 billion in Greater Phoenix to build two new fabs

at its Ocotillo Campus, creating 3,000 new jobs. In addition to these transformative investments, GPEC's current business prospect pipeline includes 40

semiconductor manufacturers and related supply chain firms that could bring another 10,000+ jobs and \$45 billion in capital investment to the region.^v



Greater Phoenix is Positioned for Success

In an industry known for cyclical volatility, the semiconductor sector employment in Greater Phoenix has remained on a steady upward trajectory in recent years – a trend that is expected to significantly increase in the future as more major global players and their suppliers expand to the region.



Semiconductor and Related Device Manufacturing	Jobs (2010)	Jobs (2020)	Job Change	Job % Change
Portland	22,274	27,990	5,717	25.67%
San Jose	27,513	27,548	35	0.13%
Phoenix	17,688	19,623	1,935	10.94%
Dallas	16,843	16,207	(636)	-3.78%
Austin	8,536	10,762	2,226	26.08%
Los Angeles	7,602	6,103	(1,498)	-19.71%
Albany	265	3,217	2,952	1115.81%
San Francisco	2,805	2,164	(641)	-22.86%

Source: Emsi Regional Comparison Tables, Q2 2021

Changing Global Supply Chains

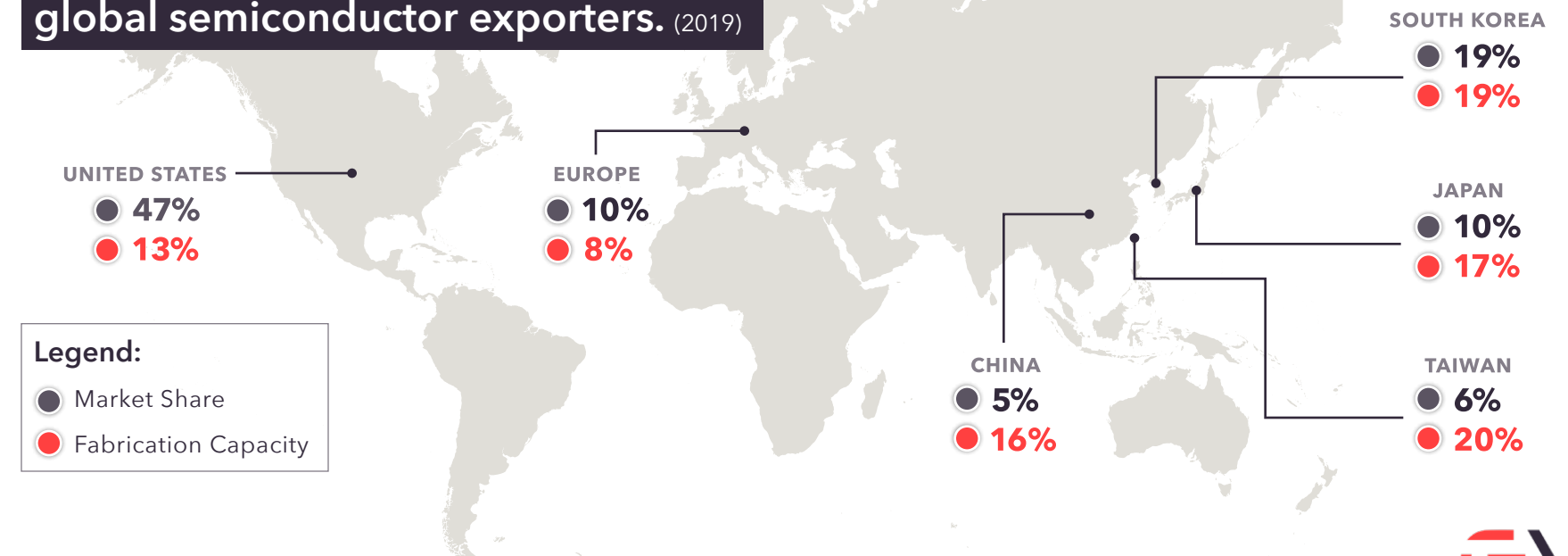
The complexity and capital intensity of semiconductor development and the need for high volume production have resulted in high degrees of industry agglomeration in just a few key regions worldwide. The U.S. remains the global leader for semiconductor design and R&D, and U.S. firms still account for nearly 50% of global chip sales. However, the U.S. accounts for just 13% of global chip manufacturing, down from 37% in 1990.^{vi} This includes 19% of silicon wafers produced for discrete, analog and optoelectronics and sensors (DAO) and just 5% of wafers produced for memory.^{vii} More than 80% of production now occurs in Asia — specifically China, Taiwan and South Korea. Furthermore, all leading-edge chips, those with 10-nanometer (nm) transistors and smaller ones essential for emerging technology, are only produced in South Korea and Taiwan.^{viii}

Rising geopolitical tension and the effects of the COVID-19 pandemic have highlighted vulnerabilities and national security concerns around existing supply chains. It is estimated

there are currently more than 50 points across the semiconductor supply chain where a single region holds more than 65% of the global market share^{ix} — meaning a single point of failure in the chain could have global catastrophic outcomes. Consequently, there is growing interest by governments, consumers and firms in the diversification of manufacturing

supply chains outside of Asia. As more producers consider expanding operations in North America and Europe, Greater Phoenix will remain a top contender due to its thriving semiconductor ecosystem driven by proximity to west-coast technology hubs, coastal ports of entry and the massive North American microelectronics consumer base.

Market share of domestic firms and wafer fabrication capacity in major global semiconductor exporters. (2019)



Labor Market Challenges

Semiconductor manufacturing requires a high-skilled STEM labor force. The broader manufacturing landscape is currently undergoing a transformation thanks to Industry 4.0 technologies such as automation, robotics, AI, IoT and big data analytics.^x An analysis of nationwide job postings by semiconductor and related device manufacturers between July 2020 and June 2021 indicated high demand for specialized engineering and management roles, including^{xi}:

- Application Engineers
 - Data Science Engineers
 - Industrial Engineers
 - Machine Learning Engineers
- Manufacturing Engineers
 - Process Engineers
 - Software Engineers

Manufacturing technologies drive demand for new skills and talent, but many manufacturers admit to not taking proactive steps to build talent development strategies. The industry has also faced difficulties recruiting new talent, especially millennial workers. A 2018 workforce study conducted by Deloitte and SEMI found that most semiconductor manufacturing executives feel the industry suffers from a poor brand image relative to other technology firms and sectors. The survey also identified employee retention issues and a perception that a career in the semiconductor industry is not as attractive as that of other technology industries.^{xii}

Greater Phoenix Labor Force

Occupations in High Demand from Semiconductor Manufacturers	Jobs (2020)	Location Quotient (2020)	Projected Jobs (2025)	Projected Job Change % (2020-2025)	Regional Degree and Certificate Completions (2019)
Software Developers and Software Quality Assurance Analysts and Testers	25,663	1.17	29,971	17%	4,677
Computer Systems Analysts	9,936	1.15	10,977	10%	6,582
Mechanical Engineers	3,543	0.81	3,785	7%	964
Electrical Engineers	3,355	1.23	3,641	9%	1,116
Computer Hardware Engineers	1,543	1.59	1,613	5%	1,242
Materials Engineers	311	0.85	333	7%	587
Chemical Engineers	148	0.38	173	17%	1,661

Source: Emsi Occupation Tables, Q2 2021; SEMI/Deloitte 2017 Workforce Study

Skilled STEM Workforce

Greater Phoenix firms benefit from a fast-growing skilled workforce thanks to an influx of young millennial workers and a robust higher education ecosystem that produces thousands of STEM graduates each year. Local students can choose from computer science and engineering programs at multiple institutions, including:



20%

of the 250 initial hires recruited from around the U.S. for TSMC's new Phoenix fab, hold a degree from an Arizona university.^{xiii}

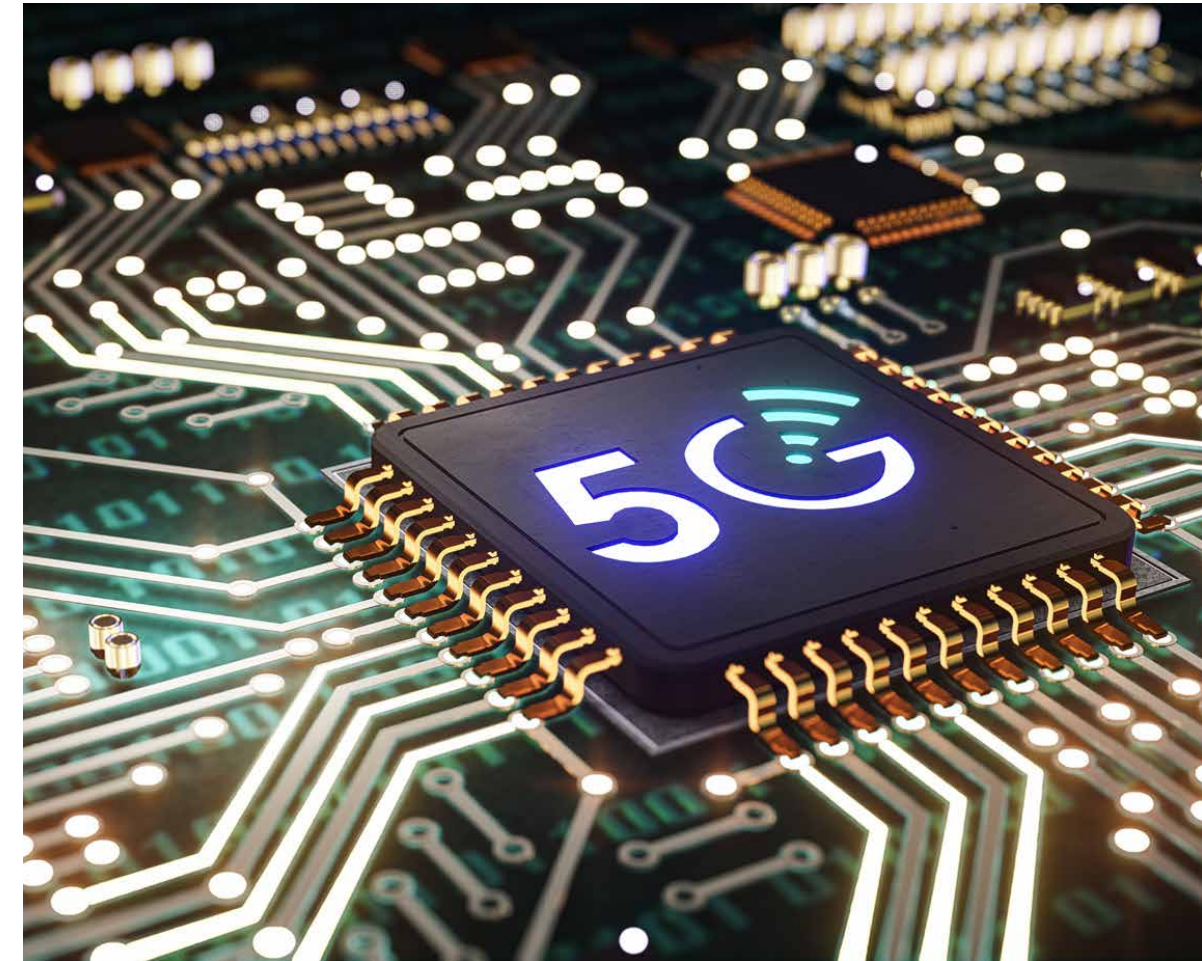


Key Technologies & Trends Influencing the Semiconductor Industry

5G

In 2019, Phoenix became one of 20 U.S. cities to rollout 5G, kicking off unprecedented local demand for 5G-capable chipsets for mobile phones, laptops, autonomous vehicles, smart sensors and more. The subsequent boom in 5G-enabled technologies, including AI, AVs, smart infrastructure and industrial IoT, will have cascading effects on semiconductor manufacturing for years to come. 5G smartphones are expected to account for more than 70% of the global smartphone market by 2024^{xiv} and it is forecasted that there will be more than 125 billion installed IoT devices worldwide by 2030.^{xv} Currently, 5G smartphone processors require

leading-edge 7nm and 5nm chips, which are produced exclusively in Taiwan and South Korea. However, with TSMC's planned expansion, Greater Phoenix will be the first location outside of East Asia to fabricate 5nm chips needed for 5G mobile devices. Demand for computing capacity will continue growing exponentially. Although 5G is barely two years old, the industry has already begun R&D on 6G technology, which is expected to enable unprecedented capabilities in virtual reality, wireless connectivity and AI. Future developments in telecommunications technology will continue pushing the limits of semiconductors.



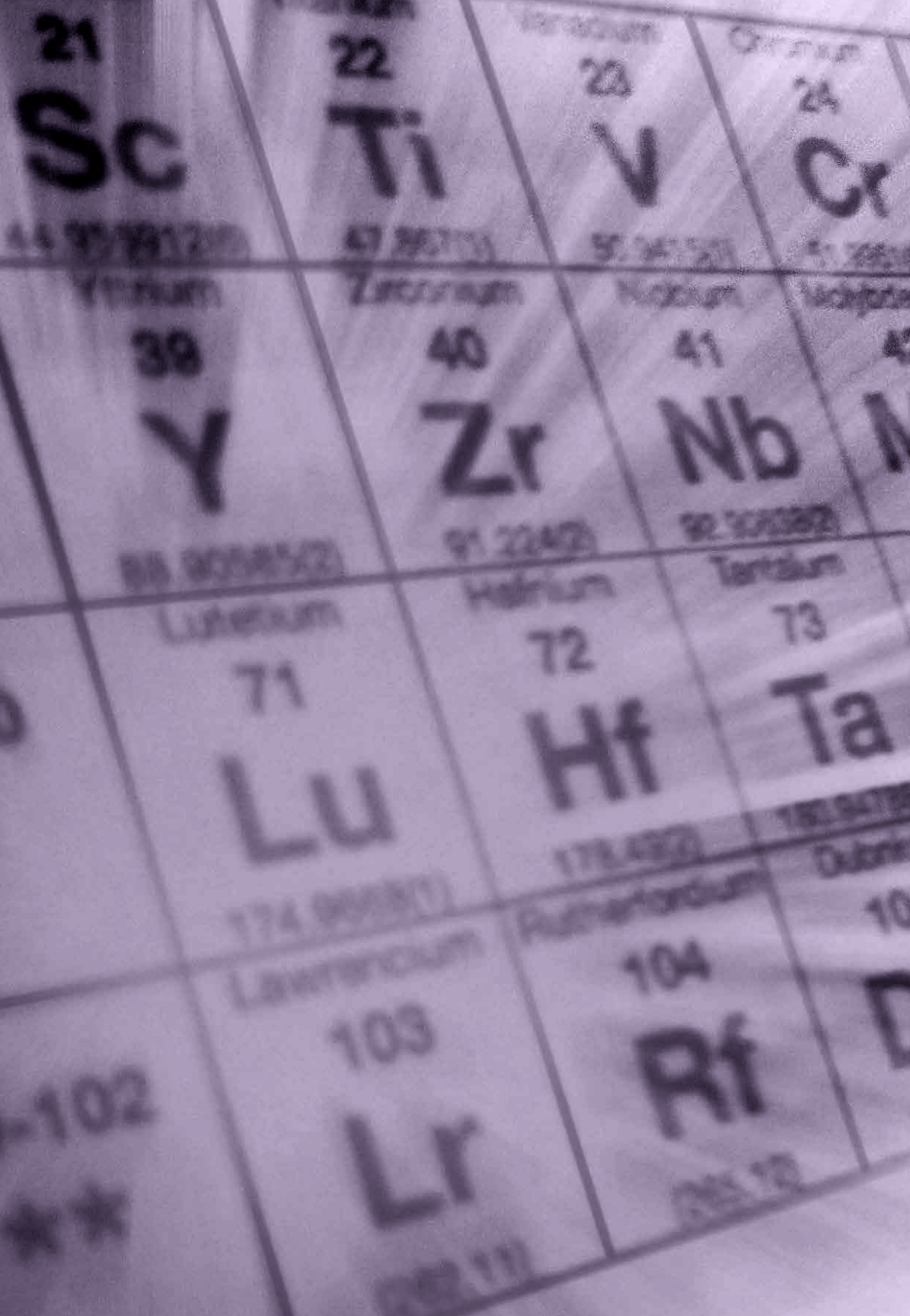


Autonomous and Electric Vehicles

Semiconductor and automobile manufacturing have been tightly linked since the first transistor radios were installed in cars in 1955. Now the typical vehicle contains as many as 1,400 semiconductors.^{xvi} That number is expected to increase with the growth of electric, autonomous and highly connected vehicles that require advanced sensors, communication modules, data

processing and high-speed connectivity. Since 2015, Greater Phoenix has become a hotbed of AV innovation that includes Intel, Waymo, Local Motors, GM Cruise Automation and Nuro. Greater Phoenix is also an emerging hub for electric vehicle manufacturing that includes innovative and high-growth startups like Lucid Motors, Nikola and ElectraMeccanica. As AV and EV

technology require more specialized chips and in greater quantities, Greater Phoenix is a desirable market for semiconductor manufacturers looking to collaborate on R&D and capture these growing market segments. Intel is already doing so through its Chandler, Ariz.-based Advanced Vehicles Lab, which is currently developing new AV systems and technologies.



Advanced Materials

Semiconductor technology is quickly approaching the limits of silicon-based wafers, leading manufacturers to explore a range of alternative materials and systems. Greater Phoenix remains on the cutting edge of many of these technologies.

- **Gallium Nitride (GaN)**

GaN is growing in popularity due to its high conductivity and ability to sustain higher currents, making it a more efficient and less power-hungry alternative to silicon. The intense data processing demands of Industry 4.0 technologies like 5G, AI and quantum computing are accelerating manufacturers' development and adoption of GaN-based semiconductor components. For example, to meet the exploding demand for 5G, NXP Semiconductors completed a \$100 million upgrade to its Chandler manufacturing site in 2020, allowing the production of GaN semiconductor components essential for 5G cellular towers and other critical energy applications.^{xvii} Roughly 250 additional firms adjacent to NXP's Chandler facility are involved in GaN R&D and production.^{xviii}

- **Single-Layer Materials**

Groundbreaking advancements are being made around single-layer or two-dimensional (2D) materials—crystalline solids consisting of a single-layer of atoms that can be layered onto silicon or other substrates. Leading researchers expect 2D compounds like Graphene to help lay the foundation for quantum computing, new energy generation and storage applications, and analog sensor technology. Arizona State University's School for Engineering of Matter, Transport and Energy (SEMTE) is pioneering new methods for scalable fabrication of 2D materials with the financial backing of the U.S. Department of Energy and the National Science Foundation.^{xix}

Recommendations

To ensure Greater Phoenix's continued growth as a premier global semiconductor hub, a regional approach towards collaborative, pre-competitive scientific research, workforce development and supply chain strengthening is critical. America's historic leadership in semiconductors was partly due to strong public and private R&D investment that allowed domestic firms to remain on the cutting edge. While substantial federal investment remains critical to the broader industry, local collaboration in basic and applied R&D can push Greater Phoenix to the forefront of global semiconductor technology. Additionally, the continued growth of the local semiconductor ecosystem will require a robust skilled workforce.

Leverage ongoing STEM investments like the New Economy Initiative (NEI)

Holistic approaches to STEM investment promoting collaborative R&D and workforce development are critical to maintaining global competitiveness. NEI seeks to appropriate \$165 million towards workforce development, education and industry research competitiveness to prepare Arizona for the Industry 4.0 economy. A portion would go towards making ASU's Ira A. Fulton Schools of Engineering a top 15 engineering college and Greater Phoenix one of the largest producers of technology and engineering talent in

the country. The NEI would also fund the establishment of five additional Science and Technology Centers (STCs) that would focus on extreme environments, energy and materials, communication technologies, advanced manufacturing and human performance. These STCs would bring together faculty and industry leaders to collaborate on basic and applied research, develop workforce development programs, and create long-term partnerships.^{xx}

The Arizona budget for FY22 includes an ongoing appropriation of an additional \$35 million to Arizona's public universities for targeted workforce development and post-secondary

attainment but falls well short of the \$165 million requested.^{xxi} The growth of continued investments in these critical areas will benefit not just Greater Phoenix but the economic competitiveness of Arizona and the U.S.

Advocate for new federally-funded semiconductor R&D programs in Greater Phoenix

In December 2020, Congress passed the Creating Helpful Incentives for Producing Semiconductors (CHIPS) for America Act as part of the annual National Defense Authorization Act (NDAA). In addition to subsidies for

domestic semiconductor manufacturing, the CHIPS Act authorizes a wide range of R&D initiatives, including the establishment of a new National Semiconductor Technology Center (NSTC) and the formation of a national network for microelectronics R&D focused on the exploration and prototyping of new materials, devices and architectures. In June 2021, the Senate passed the U.S. Competition and Innovation Act (USICA) which, if signed into law, will allocate \$52 billion to fund the provisions approved in the CHIPS Act.

“Greater Phoenix is a prime location for federally supported semiconductor R&D initiatives.”

Pending the enactment of the USICA, Greater Phoenix is a prime location for federally supported semiconductor R&D initiatives. Greater Phoenix has a robust and growing research ecosystem bolstered by Arizona’s three public universities, which account for

more than \$1.4 billion in annual research expenditures. The University of Arizona ranks 19th in research expenditures among public universities, while Arizona State University ranks in the top ten in the country for R&D among universities without a medical school.^{xxii} Greater Phoenix is home to multiple technology corridors in Phoenix, Chandler, Tempe, Mesa and Scottsdale, Ariz., fostering collaborative innovation among public and private firms. These assets, combined with the presence of global semiconductor leaders, make Greater Phoenix the premier location for hosting a new semiconductor R&D initiative.

Support regional business attraction efforts within the broader electronics manufacturing sector

A targeted strategy to grow the region’s downstream electronics manufacturing sector, including efforts to capture Foreign Direct Investment, would add depth to Greater Phoenix’s semiconductor cluster and strengthen the U.S. microelectronics sector.

The distribution of the semiconductor manufacturing supply chain is consistent with the geographic footprint of electronics manufacturers and end-users that consume the bulk of semiconductor devices.^{xxiii} Producers want to be near their customers. However, semiconductor packaging and testing are labor-intensive and have smaller profit margins. Consequently, nearly all packaging and testing occur in low-cost labor markets in Asia. Because of Asia’s dominance in “back-end” production, U.S. printed circuit board technology is an estimated 20 to 30 years behind Asia, leaving domestic supply chains unprepared for next-generation electronics manufacturing and packaging.^{xxiv}

The current disturbance of global semiconductor supply chains, coupled with rising demand for specialized chips by North American auto producers, alternative energy firms, and retail microelectronics consumers, leaves the U.S. better positioned to capture these critically important “back-end” production segments.

Endnotes

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