COLUMBIA UNIVERSITY

Rebuilding America's Semiconductor Industry: How State Governments Can Drive Domestic Capacity and Maximize the CHIPS Act

A Columbia SIPA Capstone Project

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Introduction

Semiconductors are critical components in the technology we depend on for modern life. In 2020, we saw how fragile this supply chain can be. When COVID-induced semiconductor shortages shut down an entire Ford factory for a year because they couldn't get the right microchips for their window-wipers, entire lines of cars couldn't be sold. While the industry was pioneered and historically dominated by U.S. companies, in the past 40 years much of the actual fabrication has been outsourced to East Asia via *the fabless model*. In this model, U.S. firms cut their physical factories and focused entirely on generating designs that could be produced cheaply in East Asia – production heavily subsidized by foreign governments. Within a few decades, the U.S. went from being one of the largest makers of semiconductors to having a fraction of global market share.

The CHIPS and Science Act passed on August 9, 2022, provides over $50 billion in federal funding to re-shore semiconductor industrial capacity that has been effectively shipped overseas, and assures capital markets that the U.S. government takes seriously the risk of losing dominance in the semiconductor market. While the process of reversing off-shoring after decades is daunting, the challenges it presents are achievable - specifically because semiconductor manufacturing is a *great business*. Many companies seek to take advantage of the highly educated workforce and proximity to customers (faster prototyping, lower delivery costs, etc.) found in the United States.

For the CHIPS Act to succeed, it is not sufficient for the federal government to financially incentivize companies. Most of the difficult long-term work required to educate workers and make the industry sustainable will require the leadership of state governments. The decentralization of state governments provides a natural laboratory for exploring unique approaches to the same problem and enables states to learn from each other. Developed properly in a state, these semiconductor fabrication plants (fabs) have the potential to create many high-paying jobs and opportunities to accrue generational wealth for communities across the country.

Section I: How can states attract and grow the onshore semiconductor industry?

Our research has distilled the semiconductor industry's major needs to what we call the "core four." To onshore to the U.S., companies need: (1) access to talent; (2) geographic clustering; (3) corporate financial incentives; and (4) financial viability.

Access to Talent: Due to the rapidly-changing nature of semiconductor production, fabs require a highly educated workforce with staff including the Ph.D., Masters, Bachelors and Associate levels to oversee production, manage complex machines and chemicals and maintain high-tech facilities. Fabs must operate on a 24/7/365 model to be cost effective and require a bottom-up approach driven by capable workers on the floor who can leverage their education and take initiative to optimize processes and debug issues as they come up.

- *University and Workforce Development Capacity* - Having a large, educated workforce connected with academia and with experience in industry is a recipe for further innovation and startups in a state. States should be supporting innovative academic institutions, professors and research labs that can seed startups in a state's geographic area. Continuing education also aids with workforce retention, by giving a wider range of engineers the knowledge necessary to grow their careers in the semiconductor industry. For Intel's planned Ohio megasite, of the 3000 projected positions, 50% of jobs require 1 to 2 year degrees, 25% require bachelor's degrees, and 5% require PhD degrees (the other 20% have floating requirements).

- *Economic Environment to Retain a Highly Trained Labor Pool:* - Location plays a major role in attracting and maintaining a talented workforce. Factors like the median income tax, the availability and price of housing and the quality of schools and life are important considerations for professionals deciding whether to move to or remain in a given state. Thus, these considerations also matter for private industry executives when locating their semiconductor manufacturing investments.

- *Openness to Immigrant Talent:* Foreign talent plays a significant role in the semiconductor industry, with around 40% of high-skilled semiconductor workers having been born abroad.[1] As the semiconductor industry pushes Congress for federal immigration reforms that more efficiently provide green cards to high-skilled foreign workers, states should similarly consider whether state-level benefits or their lobbying efforts are attracting high-skilled foreign labor and their families.

Recommendation 1-A: Create **lab-to-fab** partnerships between universities, and the fabs themselves. A partnership can involve a PhD or masters student doing half of their multi-year program on-site in the fab directly learning the machinery involved and innovating on processes as part of their studies. In return, industry can cultivate talent and provide on-the-job training to future employees. This is a two-way street: the university provides the company with a talented, well-trained workforce, and the company provides students with on-the-job learning opportunities. States can enhance contact between private industry and academia in a delicate manner that does not impose a burden on either party.

Recommendation 1-B: Form **inter-state educational alliances**. Because the industry's thirst for talent is so high, states with a limited talent pool should partner with other states to ensure a steady pipeline of talent for semiconductor clusters. Examples: Ohio partnered with Indiana's DePauw University to bring semiconductor talent to the Intel plant. New York partnered with MIT to bring new labs directly into the NY Creates nanotech complex.

Recommendation 1-D: Community colleges are an ideal way to bring underrepresented talent into the semiconductor space. It is an effective mustering point to up-skill a workforce in an area with new safety or process knowledge necessary to work in a fab.

Geographic Clustering: Because of the specialization needed for the workforce, length of the supply-chain, and complexity of the machines necessary to produce semiconductors, there is value in companies clustering together in a single area. For example, Silicon Valley became the world's largest cluster for software development, with Stanford University in its backyard. The world's most advanced microchips come from a single industrial cluster, the *Hsinchu Science Park* complex in Taiwan.[2] This single five square-mile industrial park has over 400 firms housed there including TSMC, raw material suppliers, universities, assemblers, and even end-customers like Apple. This proximity leads to faster prototype development, reduced shipping costs, and a more resilient supply chain. Following this model, states should encourage clustering.

- *Strong Industrial Ecosystem of Suppliers and Customers*: Due to the fact that advanced chips require so many components and raw materials, there is an advantage in terms of speed and flexibility to companies and supply chains. This means raw materials can be shipped in bulk, and suppliers can more easily deliver finished products to customers. The same is true for the semiconductor equipment necessary to build the chips. When troubleshooting, cleaning, refurbishing, or upgrading highly complex machinery in a fab, clustering many users of that machine in a single area is an advantage. It's possible for the company that makes the equipment to station engineers in the cluster to work directly with fabs to meet their needs much more quickly and with faster knowledge-sharing.

- *Existing Regional Semiconductor Industry*: When CHIPS Act recipients are deciding where to locate their manufacturing investments, it's likely they'll gravitate to areas where industry already exists. It is advantageous for new plants to build on the currently existing fab infrastructure clusters in a region. Some of these benefits can include a deep talent pool of already trained engineers, educational infrastructure such as local colleges to train employees, as well as a more resilient local supply chain. Furthermore, fabless semiconductor customers in the U.S. (Nvidia, AMD, Broadcom, etc.) benefit from being able to rapidly iterate on ideas and prototypes. By prototyping in the same region, suppliers and customers can iterate faster and develop better products without waiting.

- *Availability of Water:* Fresh water is a crucial resource for creating semiconductors. For a cluster to be effective it needs a substantial amount of water, which can be challenging in some arid regions. Fortunately, industry sources have indicated that most water used in the process (90%+)

is for cooling – this means it remains relatively uncontaminated which means it can be recycled for use in the plant, or usable as reclaimed water by the community.

- *Environmental Stability:* Different areas in the US face different environmental risks, aggravated by climate change. Since many fab investments are made over a multi-decade time horizon, it's important for states to address long-term risks. Companies in a cluster should be briefed by the state about known risks and given the resources they need to protect themselves since a single break in the cluster's supply chain can shut down all other companies in the cluster.

Recommendation 2-A: States should try to form clusters with other states, or potentially bordering countries. We see advantages with Texas and Arizona partnering for assembly with Mexico, and likewise New York and Ohio finding ways to work with Canada.[3] Canada can provide high-end semiconductor materials and contribute to R&D through its leading universities such as University of Waterloo. Currently, most materials and silicon come from Japan because purity requirements directly translate to more efficient fabs - a role that Canada is well-positioned to fill with its natural resource base. Mexico is well-positioned to test and program U.S.-produced chips and package them into consumer products (see Tesla's gigafactory in the northern Mexico region).[4]

Recommendation 2-B: States should consciously work to cultivate startups that can improve the local cluster if given the right support and connections with customers. Many startups in the space start with academic labs in universities and company spinoffs. States can accelerate their growth by organizing **regional semiconductor trade fairs**, and leveraging state marketing offices. They can also assist with early-stage capital formation by organizing angel investor circles.

Corporate Financial Incentives: For the past 40 years, U.S. semiconductor companies have been put in the difficult position of having to compete against foreign companies which have been heavily subsidized by their respective governments. The ten-year cost-of-ownership of a new U.S. fab runs approximately 30% higher than in Taiwan and South Korea, with as much as 40-70% of the cost differential being attributed directly to government incentives.[5] In 2022, Morris Chang, founder of TSMC said "America's chip manufacturing costs were 50% higher than they were in Taiwan - and [I believe that] was an underestimate, and perhaps a far [higher]."[6] The CHIPS Act levels the playing field by providing a substantial set of financial incentives to the domestic industry. While the funds are distributed by the federal government, state and local governments can also add on and provide companion subsidies to companies.

- *Tax Burden on Companies:* Business-friendly tax environments encourage the kind of large-scale investments in manufacturing that will be necessary to restore domestic semiconductor production capacity. With the costs of semiconductor fabs running into the billions of dollars, tax considerations carry a heavy weight. From 2001 to 2022, under the Chapter 313 Program, Texas offered a tax abatement program that enabled local school districts to provide corporations with billions of dollars in reduced property taxes in exchange for capital investment and the creation of new jobs. Such tax breaks can provide states with a decisive competitive advantage in their manufacturing investment bids.

- *Financial Incentives*: States can provide direct funding to encourage semiconductor companies building in their state, to further reduce costs to build a fab. New York's GreenCHIPS program is an example of a state-driven program with $10 billion in incentives.[7] For a semiconductor company to receive funds from the CHIPS Act, the fab needs to demonstrate support from the state. The degree to which a state demonstrates its support for a project can directly impact the amount of federal funds a project receives. States are uniquely positioned, because of their local knowledge, to be creative in how they work with industry and provide subsidies that go far beyond regular grants. Some examples of these state-specific incentives can be: a) cheaper electricity locked in for a ten year period; b) loans for soil strengthening to support a fab; c) a community college program for talent needs; and d) strategic road infrastructure.

Recommendation 3-A: State financing (grants or tax cuts) can play an important role in making an on-shore fab financially viable, especially if combined with federal CHIPS funding. In competitor economies, fabs are subsidized up to 40% or more by their national governments and can afford lower prices because of this – advantaging them over American fabs.

Recommendation 3-B: Because of the workforce/labor requirements the Dept. of Commerce requires for CHIPS Act funding, states can assist companies (especially smaller suppliers) by providing childcare and helping to organize union labor so the smaller entities can comply with requirements.

Regulatory Clarity: One of the biggest risks faced by the companies looking to build multi-billion dollar fabs is the regulatory environment of the host state. The CHIPS Act team at the Dept. of Commerce does provide guidance on how companies can adhere to federal environmental laws,[8] but it's up to states to do something similar for their states. State regulations can delay a project for months or years which can make or break its financial variability, especially as tech becomes outdated.

- *Environmental Standards:* Because fabs require extensive space, chemicals and raw materials to manufacture, they can easily get bogged down in environmental requirements they need to meet on both a state and federal level. The Dept. of Commerce is providing a team to help companies meet federal standards, but states are also going to be crucial for handling local regulations. Because of their importance, and relative cleanliness compared to other heavy industries, we recommend states take a proactive approach in helping companies meet these standards.

- *Ease of Permitting:* Semiconductor fabs have extensive regulatory demands that fall to the states, some of these include: construction, land use, and environmental permitting. States should proactively provide clarity about requirements so companies know if they are complying. States should reduce unnecessary touch points. While larger companies (TSMC, Intel, etc.) may be able to comply with regulations easily, smaller suppliers which are critical for larger fabs in a region to operate, may have difficulty which can lead to degraded efficiency in the regional supply chain.[9]

- *Infrastructure Needs:* Fabs have extensive needs for power, water, and land to be able to operate effectively. States should be prepared for this, and have growth plans in place for how the facility

can grow as it ramps up production. States should also prepare contingency plans to handle events such as a drought or power shortages and discuss long term expectations for how a fab might affect the local environment.

Recommendation 4-A: States should consider setting up a centralized **"help-desk"** to serve as a hub to coordinate semiconductor-specific questions. Semiconductor companies, both large and small, in the state know that they can contact a single hotline or office to ask questions ranging from environmental and labor inquiries, to infrastructure concerns. The help desk can also direct companies to educational programs for talent needs, and local partners for prototyping.

Recommendation 4-B: States should **plan early and big** when it comes to anticipating the infrastructure needs that the industry might require, especially for a cluster. States should over-provision land and utilities, and think in terms of square-miles, not acres. Plan for double or triple the amount of water/electricity needed, and think in terms of decades. Good planning upfront and the ability to scale can support organic industrial clusters that may not have been foreseen but which grew naturally.

Section II: What are States doing right now?

Arizona

Described by President Biden as "a hub for the technical change that will take place,"[10] Arizona is suddenly on everyone's radar to become the next semiconductor cluster. Its position is the result of diligent bipartisan lobbying of both industry and the federal government to invest in Arizona. The state has created a positive business climate with a strong talent pool, innovative ecosystem, financial incentives, and a favorable regulatory environment. It strategically markets itself to companies looking to relocate by regularly having the governor conduct trips overseas with schools, non-profit organizations and local industries, as well as inviting executives to visit the state with the specific goal to "sell Arizona"[11] by promoting Arizona's business friendly ecosystem. This political effort extends to Washington where state officials work alongside chip manufacturers to lobby for federal policy. The $13 billion in research and workforce grants included in the CHIPS act is a result of this work.[12]

- *An Educated Workforce*: Arizona has developed a robust network of workforce development and acquisition program by bridging the semiconductor industry[13], academia, and the military. The Skillbridge partnership, where service members within six months of leaving the military undertake paid internships, is a prime example of this strong relationship.[14] The talent pipeline is also enhanced by specialized research and training programs with trade schools,[15] Community colleges such as Maricopa, offer specialized partnerships with industry, and larger academic institutions such as Arizona State University (ASU).[16] ASU boasts a fully functional microchip manufacturing facility and has deep partnerships with local manufacturers like Intel to train employees.[17] Arizona also benefits from one of the highest livability indexes in the country, with affordable housing, a low cost of living, and sunny weather that attracts migration.[18] There is, however, no state level effort to help immigrants integrate society and attracting foreign talent to Arizona is not a state priority.

- *Regulatory Clarity:* Arizona's business-friendly environment is also favorable for semiconductor manufacturing. The state has streamlined its tax system and permit systems for new facilities, to encourage investment..[19] Environmental standards are also designed to ensure a balance between environmental protection and economic growth – unfortunately this has led to over-use of the state's water supply. To address this, Arizona triages water during periods of drought and refrains from limiting the supply of water to fabs while cutting the water supply to other industries.[20]

- *Financial Incentives*: Arizona's financial incentives play a key role in attracting semiconductor manufacturers. The state's pro-business policies and low tax rates have helped attract enormous semiconductor companies such as Intel and TSMC to set up manufacturing facilities in the state.[21] In 2019 Arizona's Legislature approved $1 billion in tax breaks to attract semiconductor producers[22] and also offers low property taxes for both workers and companies. Furthermore, the state has created tax credits for jobs,[23] a job-training grants program, and a special fund to offset the costs of firms relocating to Arizona.[24]

- *Geographic Clustering*: Arizona's economy has been conducive to semiconductor manufacturing since the 1980s when manufacturers realized that it had access to Silicon Valley's supply chain and market while offering lower property taxes. In addition, it was more seismically stable than California.[25] Access to Mexico is now also a key factor. Intel, Skyworks Solutions, and Walcom are now planning to expand their Arizona operations to Mexico, and ASU has signed an agreement with Mexico to train semiconductor workers.[26] To meet water demands, Arizona built the Central Arizona Project and developed technology to recycle 98% of water used by fabs.[27]Arizona is also prepared to spend millions in energy, water lines, sewage, roads, and traffic lights to support projects.[28] Phoenix issued $200 million in infrastructure incentives to TSMC,[29]and the city of Chandler spent $30 million in improving its local infrastructure to support Intel's expansion within its city limits.[30]

California

California possesses the largest semiconductor workforce of any state. Its large industrial capacity, originally for the aerospace industry, enables California to rapidly deploy federal funds to stimulate innovation[31]. Instead of competing for large fabs (due to regulation cost), California should focus on smaller fabs that leverage their proximity to fabless companies and enable rapid prototyping for customers. Rather than having to send their prototypes overseas to Asia, California-based fabless companies can work with local fab partners to rapidly iterate in a low-cost way, using high-end technology and leveraging a highly educated workforce to capture a key time-sensitive sector of the industry[32]. Once prototyping is complete, production can shift to large-scale fabs in other states. With its existing network effects, California has the chance to deploy a significant amount of CHIPS Act funding.

- *An Educated Workforce*: UC system has formed a very strong collaboration on technology development. Education institutions including Stanford which focus on innovation and community colleges which can offer apprenticeships have established a multilevel talent structure for California. In 2019, the number of degrees in STEM fields awarded by California's

community colleges became 106,600[33]. This huge number of STEM students has not only supported the rise of Silicon Valley but will also provide a talent pool for high-end manufacturing. The California Department of Education also issued the new Expanded Learning Opportunities Grants (ELO) in April 2021 by allocating $4.6 billion dollars to provide supplementary instruction and support for students who want to receive extra study on STEM subjects[34]. This step will strengthen California's capability to meet the talent needs of semiconductor manufacturing. Meanwhile, the University of California Council of Vice Chancellors of Research, which includes ten UC campuses and three UC laboratories, recently established a University of California Institute of Microelectronics to serve as a clearing house to help remove legal barriers to development of fabs in the state[35]. This institute will help the UC system expedite clustering and strengthen California's competitiveness in three different aspects: 1) ability to train the workforce at all levels, 2) specialty applications and processes and 3) encourage novel R&D[36]. By bridging the research opportunities and existing industrialization, California can amplify its influence on innovation and leverage its large talented workforce.

- *Regulatory Clarity*: Compared with other states, California's regulation is always the most complicated part for those top semiconductor factories. Intel closed its last plant in Silicon Valley in 2008, California has stopped building any big fabs since the 1990s due to regulation costs. These existing legal and regulatory barriers such as the California Environmental Quality Act litigation diminish California's competitiveness in attracting large fab investments[37]. Due to its preemptive development of the semiconductor industry in the past three decades, California already has a lot of regulations on land use, water conservancy, and facility construction. It would increase the administrative cost of these big firms to build new factories in California. Even though the California state government has customized an Employment Training Panel to encourage mid-sized companies to join in funding applications[38]and enhanced the capability of Go-Biz to offer an all-in-one business solution, it is still not enough to reduce the cost of satisfying the legislative conditions.

- *Financial Incentives:* The financial incentive of California would divide into two parts: talent development and technology innovation. Most of its funding is allocated to the UC system and the others are trying to spur R&D. The state legislature is trying to stimulate the terminal outputs by lowering the sales tax of semiconductor products. Meanwhile, California offers funding to strengthen the supply chain of semiconductor manufacturing. The California Competes Act has leveraged a $120 million tax credit to support semiconductor investment[39]. However, without simplifying the regulatory process on land use and water conservancy, the benefits of financial incentives would not exceed the cost of its daily operation.

- *Geographic Clustering:* California would have the strongest clustering among all states. According to the report from SIA (Semiconductor Industry Association), California has 64,421 total semiconductor jobs and 643 semiconductor establishments, which both rank as No. 1 in the U.S.[40] It has the best semiconductor design companies and research centers. As the home to AMD, Broadcom, and Qualcomm, California also has two leading light resources which are SLAC and ALS. Due to the rapid innovation of Silicon Valley, California has become the best

platform for technology commercialization. This integrated industry ecosystem creates an immediate reaction mechanism on the supply chain.

New York

The state of New York hits a number of criteria that makes it an ideal state for a robust semiconductor industry. Endowed with a long industrial heritage, and a giant in the early electronics industry, New York has always been an ideal location for manufacturing activity. Abundant clean water sources, inexpensive energy costs, a large well-educated workforce, and an expansive university system, are among the many benefits that New York has to offer. The state also offers a central location that can facilitate clusters that stretch into New England, the Northwest, and southern Canada.

- *An Educated Workforce:* New York is a leader in mobilizing a large and well-educated workforce to staff fabs.The SUNY (State University of New York) is one of the largest networks of universities and community colleges in the U.S., and is a key enabler of the state's industrial capacity. It has close to 60,000 STEM students in institutions throughout the state[41] that can form the talent and research capacity for fabs. The SUNY system is capable of advanced R&D and managing facilities like "NY Creates," an enormous nanotechnology complex managed by SUNY Polytechnic institute that is a blue-print for *lab-to-fab* projects. NY Creates brings many companies,[42] specifically those in semiconductor equipment such as LAM Research, Tokyo Electron, and Wolfspeed amongst others, under one roof to encourage inter-firm collaboration and push the boundaries of advanced R&D. The Rochester Institute of Technology has also pioneered a co-op system where tens of thousands of students have worked full-time with local industry while pursuing a STEM degree. This successful program, which should be expanded throughout the country, provides companies with a pipeline of talent, and a source of income for students.[43] New York can further enhance this advantage by partnering with elite universities throughout the northeast, such as MIT, Harvard, etc., and working with them to offer on-site research and education in the state's fabs.

- *Regulatory Clarity:* One of the biggest disadvantages NY fabs will face are its complex regulations and high tax rates. Smaller suppliers face a challenging compliance regime in everything from labor law, taxes, environmental regulations, and more. For the state to succeed, it needs to take a proactive approach, beyond just providing generous grants, to helping companies handle regulatory hurdles that may slow down production.

- *Financial Incentives:* NY is the country's leader in terms of robust financial incentives for companies. The Green Chips program alone ($10 billion)[44] is a25% of the size of the entire federal CHIPS Act grants pool ($39 billion). This large pool enables companies in the state, like Micron, to take on larger, more ambitious projects. These larger projects are able to operate more efficiently and can outcompete fabs in other states due to their economies of scale. On top of cash grants, companies also receive tax credits as they meet annual job and investment commitments, are eligible for other tax rebates on R&D, and receive discounted utility service rates. These subsidies aim to anchor a state-wide cluster by attracting a critical mass of suppliers and fabs into the state. The GreenChips program has been very successful so far. Micron has committed to

spending up to $100 billion[45] over the next 20 years on its memory (DRAM) fab which they're building in Clay, NY. Micron is also partnering with local community colleges to offer relevant certificates in semiconductor specific areas[46] to train their workforce. GlobalFoundries has also committed to build an advanced microprocessor fab[47] upstate. Wolfspeed, a North Carolina-based company, has committed to an ambitious silicon carbide facility – an important ingredient for semiconductors – in Marcy, NY, as well. Onsemi and IBM are also expanding their semiconductor presence throughout the Hudson Valley.

- *Geographic Clustering*: Because of the critical mass of educated talent and suppliers, NY already has one of the largest semiconductor clusters in the U.S.. The state also has abundant water, inexpensive power, transportation networks to the midwest and Canada, and a low natural disaster risk. All of these factors enable the cluster to grow far larger than it is currently.

Ohio

Ohio only recently became a state of focus for semiconductor production due to the January 2022 Intel announcement to build a $20 billion semiconductor megasite with two fabs in New Albany, Ohio, near Columbus. Ohio struck the deal before the passing of the CHIPS Act, and their courting of Intel is noteworthy for (1) already having business-friendly policies in place and (2) offering the best *combination* of factors. The city of New Albany has been a crucial partner, especially with the city-run "New Albany International Business Park"[48], which has made the area a nexus for manufacturers, data centers, and integrated supply chain research. This park is a model for the rest of the country to learn from, and independently channels some of the important lessons learned from the Taiwanese science park phenomenon.

In a guest column in The Columbus Dispatch, Intel's Keyvan Esfarjani indicated that Intel selected the New Albany site because it offered the best combination of attributes. Keyvan highlighted the site's proximity to Columbus, Ohio's existing infrastructure, Ohio's capacity for future growth, the talent pipeline from schools in the area, and the fact that it's within a day's drive to every major city in the Midwest, allowing Intel to invest across the region.[49] A representative from JobsOhio, Ohio's economic development non-profit, also pointed to Ohio's affordability and quality of life as motivating factors.[50]

In the Intel deal, Ohio positioned themselves well in anticipation of the CHIPS Act. The deal may have been struck before CHIPS, but it seemingly had CHIPS in mind. While Intel is committed to investing $20 billion across two fabs, they have indicated a willingness to invest a total of $100 billion across eight fabs if CHIPS passed and the appropriate federal incentives fall into place.

- *An Educated Workforce:* Intel has repeatedly pointed to Ohio's strong university system as an important contributing factor, but Ohio has further reinforced this aspect by ensuring its public universities take part in the Midwest Semiconductor Network, a collaborative group of universities in the region focused on semiconductor technology and manufacturing.[51] In turn, Intel is investing $50 million over 10 years in semiconductor education in Ohio.[52] Ohio also has reciprocal income-tax agreements with Indiana, Kentucky, Michigan, Pennsylvania, and West Virginia, allowing companies like Intel to draw talent from across the region.

- *Regulatory Clarity:* From the top down, Ohio's leadership seemed to communicate to Intel that they would receive support around regulatory hurdles. Without this, Intel would have not been so comfortable making such a large land assemblage. This is additionally indicated by Ohio covering the cost of infrastructure, particularly water treatment with the site. While they did not slacken their water regulations, the state is covering the cost of ensuring they are met. JobsOhio has been an important resource for Intel in navigating the regulatory environment, and it is an ideal model to potentially be replicated by other states looking to attract semiconductor fabs.

- *Financial Incentives:* Ohio granted $2 billion in incentives toward the deal, including constructing the wastewater infrastructure needed to keep the plant compliant with environmental regulation.[53] Financial incentives coordinated across the state and local governments contributed heavily to Intel's decision. Ohio had a 15-year economic development income tax incentive in place prior to the Intel deal that was extended to 30 years in concert with the Intel deal. JobsOhio granted $150 million to Intel.[54] Many of the mechanisms, including the income tax credit program and the grants from JobsOhio, were already in place long before Intel chose the site. Additionally, nearly all of the programs, with the exception of the infrastructure projects, won't be paid out until Intel completes construction of the fabs.

- *Geographic Clustering*: Clustering also played a key part in Ohio's attractiveness. 140 companies in Ohio, a key cluster for domestic manufacturing and the auto industry, already do business with Intel.[55] The automotive corridor, a localized driver of chip demand, runs through the heart of Ohio into Michigan and southern Ontario. Intel has mentioned the importance of capacity in the region to sustain cluster growth. Additionally, it is looking at the site as an investment not only in Ohio but in the Midwest – an idea also reflected on the university side through the Midwest Semiconductor Network. The area is also seismically stable, has ample access to water via the great lakes, and is in a low-risk zone for climate-change related disasters.

South Carolina

South Carolina is a state that currently does not have a large footprint in the semiconductor space but is one that we have identified as having an enormous potential. The state is a national leader in advanced manufacturing in a variety of fields ranging from automotive to aerospace. Over the past few decades, the state has attracted a number of highly complex manufacturing operations including the Boeing 787 Dreamliner assembly facility and VW's recently committed (in 2022) $2 billion electric truck plant.[56] The VW plant is a blueprint for how the state can aggressively attract semiconductor production: the state provided $1.3 billion in incentives, which included a $200 million loan to stabilize the soil at the site, and is redesigning the local highway near the plant to better support logistics. South Carolina has shown its ability to punch far above its weight as a small state by nimbly providing the subsidies and financial viability that suppliers need to start building.[57]

- *An Educated Workforce:* The talent pool the state has and the size of the university system (University of South Carolina, and Clemson) is currently too small to sustain rapid growth and clustering in the semiconductor industry. One solution could be a partnership with North Carolina universities and firms in the research triangle. If the University of North Carolina (UNC) can

provide talent and partner with companies in the state, South Carolina can reach the talent pool necessary to support large fabs. Another potential issue that risks South Carolina's growth in the semiconductor space is a culture of "production speed over quality" – stemming from a large non-unionized workforce that needs to be brought into the state rather than developing naturally. In the case of semiconductors, due to the high precision and worker education required, as well as tremendous cost/complexity of machines, South Carolina needs to strengthen its culture of precision, even if that reduces speed of production.

- *Regulatory Clarity*: The state government of South Carolina has taken a very pro-business approach in regards to regulatory clarity. As an example, "South Carolina Business One Stop"[58] is an office dedicated to answering regulatory questions, helping businesses apply for necessary licenses, and reducing barriers that can slow growth.

- *Financial Incentives*: The state has done a tremendous job attracting companies from all around the country, and the world to relocate. The large grants offered have played a key role in Boeing, VW, and many others relocating to the state – and the low-cost loans have also been a creative approach to funding site-specific projects. On top of that the state offers generous state tax incentives[59] to manufacturers that can greatly improve the viability of large manufacturing operations. Currently the state does not have a semiconductor-specific program to attract manufacturing in this sector, but the scaffolding for one is well-developed.

- *Geographic Clustering*: South Carolina has tremendous potential to become a strong semiconductor cluster due to its geographic centrality in the Southeast. With its extensive network of customers for chips both in the state and nearby, it can greatly reduce supply chain complexity and transportation costs. It also has access to abundant water and energy. One issue, though, is its vulnerability to hurricanes[60] which can incapacitate the state's cluster in one blow, as well as issues with softness of its soil that negatively impacted the VW project.

Texas

Texas boasts a reputation as one of the most business-friendly environments in the United States, offering a slate of incentives that have shaped the state into a leading domestic semiconductor manufacturing hub. In 2021, it beat rival bids by Arizona and New York to secure Samsung's commitment to build a $17 billion semiconductor factory in Taylor, its largest ever investment in the U.S., and another by Texas Instruments to build a $30 billion factory in Sherman. As of 2017, more than 200 of the roughly 730 semiconductor plants in the United States were located in Texas[61] and in 2020, the state led the nation with $17.3 billion in semiconductor exports, more than a quarter of the U.S. total.[62]

- *An Educated Workforce:* Texas boasts the second largest semiconductor manufacturing workforce in the U.S., with just over 40,000 people employed in the industry.[63] Its robust university systems include the University of Texas at Dallas and at Austin, located in key semiconductor manufacturing hubs. In 2022, the University of Texas unveiled its plans for the Texas Institute for Electronics (TIE), a public-private partnership between the State of Texas, private industry, national labs and Texan academic institutions. TIE will leverage a network of

fabs to support technology development and educate industry innovators.[64] Texas also demonstrates the potential of tapping into community college and workforce development program talent. Over the past three years, one-third of technician employees at Samsung Austin Semiconductor have come from the local Austin Community College, which offers a devoted Fab Apprenticeship Program.[65]

- *Regulatory Clarity*: Recently, Texas has taken concrete steps to provide a regulatory environment that protects its standing as a domestic semiconductor manufacturing hub. In 2023, state lawmakers filed bills to create the Texas Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act. Among key provisions in the prospective bills, the creation of a Texas Semiconductor Innovation Fund would provide grants to academic institutions and private industry to spur research and development projects within the State of Texas.[66] In 2021, Governor Greg Abbott bolstered the State's ambition to become the nation's long-term semiconductor manufacturing and innovation hub, forming a task force to secure Texas as the future home of the National Semiconductor Technology Center and National Advanced Packaging Manufacturing Program.

- *Financial Incentives:* Texas succeeds in pairing corporate financial incentives at the state and local levels in its bids for semiconductor manufacturing investment. Most notably, its Chapter 313 tax abatement program has been responsible for billions of dollars in tax savings for companies locating their manufacturing investment in the state. In 2022, Samsung's Taylor fab was approved to receive $4.8 billion in abatements over ten years under the program.[67] Similarly, GlobiTech's $5 billion fab in Sherman was approved to benefit from an 85 percent tax abatement over ten years.[68] However, in 2021, bipartisan debate over the impacts of Chapter 313 on local communities intensified, with an investigation by the Houston Chronicle revealing that dozens of companies receiving Chapter 313 had failed to fulfill their job-creation pledges, without facing any penalties.[69] At the end of 2022, the state Senate allowed the program to expire. Governor Abbott has promised to revive the program in some form, blaming Micron's recent decision to build its $100 billion fab in New York on the expiration of the program.

- *Geographic Clustering:* Speaking on his company's decision to build its $17 billion plant in Texas, Samsung's Vice Chairman Kinam Kim specifically noted the "readiness and stability" of state infrastructure as a decisive factor.[70] Its new plant, only fifteen miles from its existing Austin location, will enable the two sites to share crucial infrastructure and resources. Notably, the state's water collection strategy depends on a collection of nearly 200 open-air reservoirs, a system that is expected to become strained under a rising population and unpredictable drought-flood cycles. Thus, the strategic location of fabs will become increasingly relevant. Sherman, the site of GlobiTech's latest investment, sits close to Lake Texoma and boasts one of the few Texas reservoirs at full capacity.[71]

Appendix I: Blank Rubric for Evaluating States

This rubric is a rough set of criteria that synthesize what industry needs to properly build and run a semiconductor fab in a given state. States should attempt to maximize these categories to attract fabs..

Category	Metric
Access to Talent	University and Workforce Development Capacity
	Economic Environment to Build a Highly Trained Labor Pool *(Availability of housing, taxes, median income, median real estate, etc.)*
Geographic Clustering	Strong Industrial Ecosystem (Including Suppliers and Customers)
	Availability of Water
	Environmental Stability
Corporate Financial Incentives	Tax Burden on Companies
	Corporate Financial Incentives
Regulatory Clarity	Ease of Permitting
	Environmental Standards

Appendix II: Rubric Applied to Studied States

Rubric from Appendix I applied to the states: Arizona, California, Ohio, New York, South Carolina, Texas. Best examples of states attempting to maximize the categories.

Category	Metric	Examples
Access to Talent	University and Workforce Development Capacity	In 2022, the University of Texas unveiled the Texas Institute for Electronics, a public-private partnership that will leverage a network of fabs to support technology development and innovation. Also, Samsung Austin Semiconductor has numerous partnerships in its local community. Programs with the Austin Community College, Skillpoint Alliance, Texas State Technical College and Temple College, each providing training for high-demand positions. The State University of New York Polytechnic's management of the NY Creates R&D Center is an example of a "lab-to-fab" partnership that connects universities with real fabs. Furthermore, Rochester Institute of Technology's Co-Op program presents an example of a program that gives students on-the-job training. Arizona's Skillsbridge partnership enables military members that are within six months of transitioning out of the military to begin paid internships with local industry, often leading to full-time job offers. The University of California Council of Vice Chancellors of Research, which includes ten UC campuses and three UC laboratories, recently established a University of California Institute of Microelectronics to serve as a clearing house to help remove legal barriers to development of fabs in the state. Ohio State University partnered with 11 colleges and universities In Indiana, Ohio, and Michigan to form the Midwest Regional Network to Address National Needs in Semiconductor and Microelectronics. The partnership has allowed the states to join together to draw investment to the region as a whole.

	Economic Environment to Build a Highly Trained Labor Pool *(Availability of housing, taxes, median income, median real estate, etc.)*	When South Carolina built its Boeing 787 plant, the state attracted talent from across the country by advertising a low cost of living and low tax rate to maximize employee salaries and draw in an influx of talent. Arizona features a high livability index, with affordable housing and a low cost of living. Phoenix has begun a city-led initiative to help new immigrants with housing, employment, legal aid and medical case management, creating a friendly environment for foreign labor. In messaging to potential economic development partners, JobsOhio highlights quality of life combined with a low cost of living.
Geographic Clustering	Strong Industrial Ecosystem (Including Suppliers and Customers	New York has coordinated with a number of companies to ensure that its fabs were recycled and expanded between companies, such as the IBM fab transitioning to GlobalFoundries. Furthermore, the NY Creates facility is a meeting point for companies that create semiconductor equipment, enabling companies to form partnerships and synergies between them that enable new innovation and investments. Texas' proximity to Mexico, along with its sizable labor force across many education levels, positions Texas well for a financially competitive packaging and assembly of chips pipelines. Arizona's industry ecosystem has been conducive to semiconductor manufacturing since the 1980's, when manufacturers realized that it could access Silicon Valley's supply chain and market while leveraging lower property taxes. Intel's proximity to suppliers throughout the state allows for quick, in-person machine maintenance assistance conducive to creating more productive fabs. Arizona is also prepared to spend millions in energy, water lines, sewage, roads and traffic lights in an effort to expand existing supply chain infrastructure. For example, Chandler has spent $30 million to improve its local infrastructure to support Intel's expansion in its city limits. California boasts over 64,000 total semiconductor jobs and 643 semiconductor establishments, both the highest levels in the U.S. As the home to AMD, Broadcom and Qualcomm, California is in one of the strongest positions from which to maximize clustering between semiconductor supply chain synergies.

	Availability of Water	Texas' water collection strategy depends on a system of nearly 200 open-air reservoirs. Strategic decision-making in fab location selection will be essential, as the system becomes strained under a rising state population and unpredictable drought-flood cycles. GlobiTech's latest investment in Sherman will benefit from one of the few Texas reservoirs normally at full capacity, next to Lake Texoma. Arizona has developed technology capable of recycling approximately 98% of the water used by fabs. Situated near the Great Lakes and multiple major rivers, Ohio has no shortage of water and fewer restrictions on access. Ohio exhibited through the Intel deal a willingness to invest in water reclamation to draw semiconductor manufacturing while maintaining environmental standards.
	Environmental Stability	South Carolina will provide over $200 million in loans to assist with soil stabilization in relation to Volkwagen's recently-announced Columbia plant. Arizona's seismically stable region and low risk of tornadoes and hurricanes makes it especially attractive to manufacturers.
Corporate Financial Incentives	Tax Burden on Companies	From 2001 to 2022, Texas offered a Chapter 313 program that enabled taxpayers and school districts to negotiate contracts appraising value limitations, or local school district property tax breaks, in exchange for large capital investment and job creation. These breaks often amounted to billions of dollars in savings. Arizona offers pro-business policies and low tax rates. In 2019, Arizona's legislature approved $1 billion tax breaks to stimulate investment in semiconductor production. Arizona also offers tax credits for newly created jobs ($9,000 per job over three years), a job training grants program and a special fun to offset the costs of moving to Arizona. Ohio offers a 30-year economic-development income tax credit. The credit will amount to nearly $700 million for the $20 billion Intel deal.

	Corporate Financial Incentives	Texas features multiple state-level programs that offer grants to companies considering locating in the state. Its Enterprise Fund awards "deal closing" grants in Texas bids and its Texas Enterprise Zone Program provides businesses with refunds on state sales and use taxes for qualified expenditures. Local communities often provide fee waivers and cheap land to businesses within an Enterprise Zone. New York's GreenCHIPS program created over $10 billion in incentives to attract semiconductor companies to the state. This has led to enormous investments from Micron ($100 billion over two decades) amongst others that recoups the cost of the program. The California Competes Act has announced $120 million in grants to bolster semiconductor investment in the state. The state legislature is also considering lowering sales taxes on semiconductor products to stimulate terminal outputs. Ohio's economic development arm, JobsOhio, offers grants to corporations coming to Ohio. Additionally, Ohio offered $2 billion in tax credits, grants, and infrastructure investment for the Intel deal.
Regulatory Clarity	Ease of Permitting	South Carolina's "Business One Stop" is exactly the type of state office necessary to help smaller suppliers that are necessary for large fabs, but might not have the capacity for a large compliance team. The University of California Council of Vice Chancellors of Research, which includes ten UC campuses and three UC laboratories, recently established a University of California Institute of Microelectronics to serve as a clearing house to help remove legal barriers to development of fabs in the state. Also, California offers a customized Employment Training Panel to encourage mid-sized companies to join in funding applications and enhance the capability of Go-Biz to offer all-in-one business solutions. JobsOhio serves as a resource for companies moving to Ohio that helps them navigate permitting and other local regulations.

	Environmental Standards	Arizona offers reasonable environmental standards that strike a balance between environmental protection and economic growth. For example, during periods of severe water shortages the state refrains from limiting access to the water supply fabs while limiting access to communities. In the Intel deal, Ohio decided to invest in infrastructure to mitigate the impact of the fabs rather than lower their environmental standards.

Appendix III: How does the CHIPS Act respond to core needs of industry?

The goal of the CHIPS act is to facilitate industrial "ecosystems" where manufacturers co-locate both research and manufacturing facilities with the United States. Despite having 50%+ market share in the semiconductor design space, the U.S. has little manufacturing capacity.[72] The Commerce Department's strategy is to "have at least two new large-scale clusters of leading-edge logic fabs" that include "a robust supplier ecosystem, R&D facilities to continuously innovate new process technologies, and specialized infrastructure."[73] Despite these plans to distribute funds widely across the country, there is an emphasis on avoiding spreading them too thinly.[74] It will thus likely focus on existing clusters in Arizona, California, New York, Ohio, and Texas. The current goal is to prioritize production of the most advanced types of logic chips, with part of the spending allocated to facilities for mature chips that are still essential for cars, appliances and weapons, as well as suppliers of raw materials for the industry and companies that package the chips into their final products. The remainder will be allocated to supply networks to support the clusters.

The total CHIPS act is $52 billion distributed by the U.S. Department of Commerce. It is divided as follows:

- $39 billion in grants will go to fund the construction of new and existing semiconductor fabs. However, the distribution of funds seems to disproportionately favor large players in the industry —TSMC, Samsung Electronics, Micron Technology, Texas Instruments, and Intel.[75] This choice suggests a desire to reinforce existing clusters rather than supporting emerging players and creating new clusters.
    - $37 billion will be going towards a variety of semiconductors companies, with a primary focus on advanced semiconductors. These incentives are for high-end processors that can power computers, phones, and AI applications.
    - $2 billion is specifically reserved for mature chips, which are heavily used in cars, appliances and military equipment.[76]
- The remaining $13.2 billion will be distributed by the Dept. of Commerce in the form of government grants to support labs and universities all across the country researching new semiconductor technologies. This investment will allow the U.S. to build an R&D and labor advantage that can empower domestic producers.

Policies from the Dept. of Commerce include:

- Offering between 5% to 15% of a company's capital expenditures for a project, with federal funding not expected to exceed 35% of the project's cost.
- 5-year tax credit reimbursing them for 25% of the project's construction cost.

As part of the funding plan, applicants that receive more than $150 million in grants are required to share a portion of unanticipated profits with NIST once they surpass their original projections of profit as per an agreed threshold. This policy is designed to ensure that companies give accurate financial projections in proposals and don't exaggerate costs to get bigger awards. Upside sharing is administered on a case-by-case basis and "only when projects generate cash flows or returns that significantly exceed the projections that were used to determine the CHIPS Direct Funding amount."[77] Companies also need to demonstrate support from the state they are building a fab in to be eligible for federal support.

The Biden Administration is also taking a strong "worker-centered" approach to lower costs of living and to attract more women into the workforce.[78] Every company that receives $150 million or more in funding must provide affordable, high-quality child care to plant construction workers and operators. This policy is not welcomed by everyone. Some in conservative circles are criticizing the addition of this social policy to the CHIPS act as being "expensive and misguided,"[79] while companies such as Samsung are now hesitant to invest in the U.S. citing an increase in business risks with these "unusual conditions."[80]

Applicants must also provide details on their engagement with labor unions, schools and workforce education programs.[81] Other conditions that can assist applicants include using low-emission sources of energy, paying union wages for construction workers, and reinvesting profits into further fab businesses rather than stock buybacks.

Appendix IV: The Secret of Taiwan's Success – the "Science Park" Model

In the 1960s Taiwan's leading export was textiles, today in 2023 they have a dominant 90% market share of the most advanced semiconductor technologies on the planet. How was such a thorough transformation in such a short amount of time, in such a small country, possible? The answer to this question is critical to policy makers of all levels throughout the U.S., and is a story about how smart government policy can successfully turbocharge the semiconductor industry. From the very beginning, due to the large capital involved and mobilization of educational resources, the development of the semiconductor industry fell under the purview of the Taiwanese government's National Science and Technology Council. This ministry directly facilitated the creation and initial investment in UMC (1980) and then TSMC (1987), two of the biggest semiconductor companies on the planet. The secret of how these companies were able to grow so large is a uniquely Taiwanese public-private policy innovation known as the *science park*.[82]

A science park is a large piece of land designated by the government as a special zone for the production of microchips. The government will own the land itself, and then lease it out to tenant companies who will build fabs on it and take advantage of clustering. The science park is a nexus for many companies and their suppliers that make up the semiconductor supply chain. The largest park, Hsinchu Science Park (HSP) is 5.4 square miles and houses more than 548 different tenant companies ranging from fab giants like TSMC, to smaller players in memory or optoelectronics, and even downstream customers like Apple who closely monitor production and rapidly prototype. By having so many businesses clustered together in one location, they can all benefit from shared talent, shorter supply chains, and rapid prototyping. HSP has over 164,000 employees in one park, far dwarfing any similar semiconductor cluster in the U.S. or elsewhere. HSP produced over $48 billion in revenue in 2021, and this single science park was responsible for 6% of Taiwan's entire GDP.[83]

Since the initial founding of HSP in 1980, numerous other science parks have been created in Taiwan with different focuses and industry clusters. Jhunan Park is in a different location in Taiwan, and is focused on the optoelectronic / photovoltaic supply chain (LCD Television displays, Photovoltaics, LED lights, etc.). It has over 13,000 employees and made a revenue of $2 billion in 2021. One of the more recent science parks, Hsinchu Biomedical Science Park, is near HSP and is focused on biomedical devices. It employs over 2,000 people with a revenue of $140 million in 2021, and takes advantage of its proximity to HSP to shorten its supply chain. Due to their tremendous success, we can expect to see Taiwan's science parks continue to expand. So what are the lessons that can be learned from the science parks?

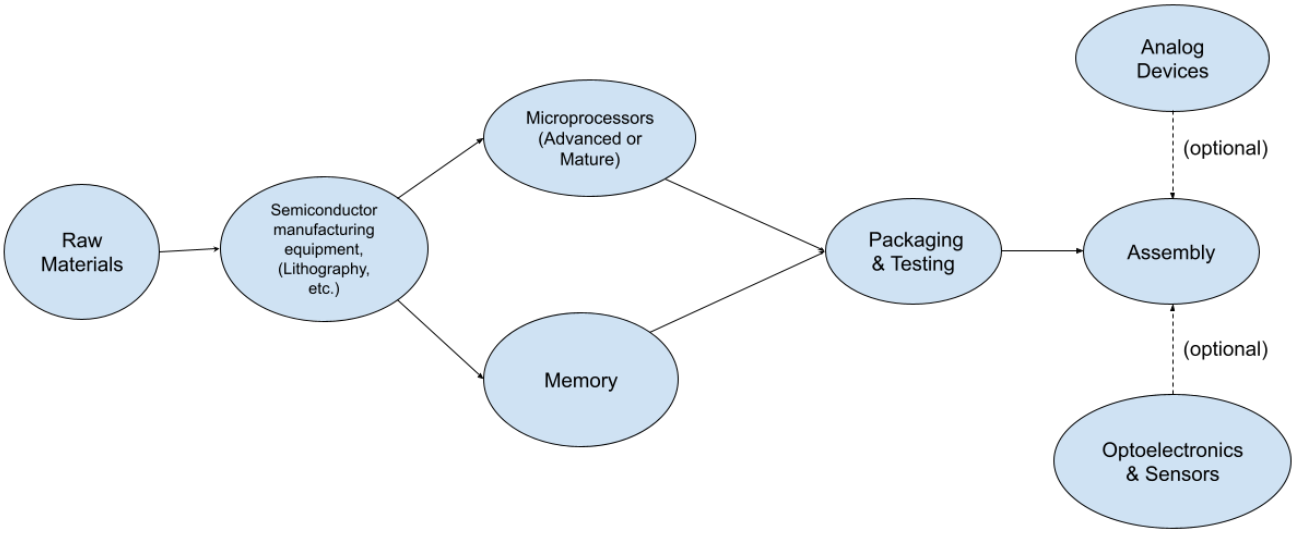
One Stop Government service - All government activity in the park is dealt with by the central park administration. This includes distribution of (1) subsidies / tax incentives (2) environmental regulations (3) safety regulations (4) labor issues. This greatly reduces the confusion fabs have when dealing with multiple agencies and contacts, and allows companies to focus on their business.

Strong industry clusters - There are enormous benefits in terms of supply chain management of having many suppliers in a single place. The science park enables rapid prototyping, easy access to collaborators for inter-company partnerships, and a deep pool of shared knowledge necessary for scaling a fab. This also enables adjacent industries such as healthcare devices, and green tech to set up nearby and benefit from the talent and resources of the semiconductor industry.

Access to University R&D - By bringing in the universities early into the process, HSP is able to ensure a large talent network of well-trained engineers that can operate and scale semiconductor fabs. This close-to-the-fab model also allows academic university labs to pursue projects that can directly benefit from collaboration with private industry.

Sound infrastructure - All of the power, water, waste, and security resources are centrally managed by a park administration who can make sure that they are being distributed fairly and properly to all of the tenants. In 2018 when Taiwan experienced a drought that affected water availability, the park administration worked with tenant companies to develop an effective water recycling and rationing scheme that allowed all of the companies to operate safely and with minimal disruption – a far more efficient solution than having each company fend for itself.

Appendix V: Visualizing the Semiconductor Supply Chain



The figure above is a rough approximation of the different sectors in the industry necessary to create a semiconductor product for a customer. A self-sufficient cluster would ideally include suppliers in all of these areas.

The figure below is a humorous "iceberg meme" illustration of the different tiers of companies required to support advanced fabs like Intel, TSMC or Samsung. For clustering to be successful, the companies in Tier 3, 4, and 5 (chemical companies, machine makers, etc.) need support to service the larger Tier 1 and Tier 2 fabs.

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