DELIVERING ON THE PROMISE OF CHIPS AND SCIENCE

Community Colleges and the Semiconductor Workforce

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This paper series was designed to provide a brief overview of specific issues identified in the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022. These papers are not meant to be exhaustive.

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Delivering on the Promise of CHIPS and Science Report Series

This report is part of a four-part series of research primers produced by the Technology and Public Purpose (TAPP) Project focused on the implementation of the 2022 CHIPS and Science Act.

Report Topics

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2. Community Colleges and the Semiconductor Workforce
3. Standard Setting: Process, Politics, and the CHIPS Program
4. Catalyzing Semiconductor Innovation through a National Semiconductor Technology Center

Each report topic formed the basis of a discussion organized by the Boston Tech Hub Faculty Working Group.

About the Boston Tech Hub Faculty Working Group

The Boston Tech Hub Faculty Working Group (FWG) was founded by former Secretary of Defense and Belfer Center Director Ash Carter and Harvard John A. Paulson School of Engineering and Applied Sciences Dean Frank Doyle. From February to May 2023, the group held monthly discussion-based meetings with senior faculty across Harvard and MIT and practitioners/decision makers across the public and private sectors that sought to explore and answer the questions: "How do we execute on the promise of the CHIPS and Science Act in an effective way?" and "Where do we go from here?"

The report authors would like to thank the Boston Tech Hub Faculty Working Group speakers and attendees for their contributions to each session.

Session Topics

- "Advancing Strategic Translational Science at the newly authorized TIP Directorate."
  Guest Speakers: Erwin Gianchandani, Stacey Dixon, Edlyn Levine, Steven Currall
- "Leveraging America's Potential - Workforce Development for the Semiconductor Industry."
  Guest Speakers: Sujai Shivakumar, Bo Machayo, Anastasia Urtz, Jared Ashcroft, John Katko
- "Standard Setting and CHIPS Legislation Implementation."
  Guest Speakers: Naomi Wilson, Mary Saunders, Andrew Updegrove
- "Catalyzing Semiconductor Innovation through a National Semiconductor Technology Center."
  Guest Speakers: Susie Armstrong, Jim Cable, Dev Shenoy, Gregg Bartlett

Executive Summary

The 2022 CHIPS and Science Act is landmark legislation to advance U.S. global leadership in science and technology, particularly within the semiconductor manufacturing industry. Over the last several decades, the U.S.'s domestic semiconductor manufacturing capacity has declined, creating high dependency on foreign countries for chip manufacturing. The CHIPS Act aims to reverse this trend by investing over $50 billion in direct funding and loan subsidies to expand semiconductor research and development and manufacturing in the U.S.

This primer focuses on the workforce challenges that will be spurred by this microelectronics industry expansion and proposes how community colleges can play a critical role in addressing these challenges. It is estimated that over the next few years an additional 70,000 to 90,000 fab workers will be needed within new CHIPS-funded facilities.[1] If the U.S. were to continue expanding and becoming self-sufficient in chip production, around 300,000 new fab workers would be required.[2] This workforce gap is substantial and demands a large-scale investment in workforce development. Notably, a number of these newly created positions will not require a bachelor's degree; Bureau of Labor Statistics data suggests that 60 percent of semiconductor manufacturing job offerings are available to those with associate degrees or high school diplomas.[3]

Community colleges have a leading role in responding to this coming workforce demand. The workforce shortage is accompanied by a skills gap present across industry positions, including for those without four-year degrees. Technical skills are required to maintain and troubleshoot manufacturing equipment and keep the fab running at maximum capacity.[4] Community colleges can take a leading role in filling the skills gap for these technician positions, providing affordable education and training programs to prepare students for skilled jobs in the workforce.

The CHIPS and Science Act equips the National Science Foundation (NSF) and the National Institute of Standards and Technology (NIST) to support the advancement of robust semiconductor workforce development programs within community colleges. However, while community colleges offer significant potential as partners in national workforce development, many are underfunded and understaffed, leaving opportunities to better utilize their strengths in building the semiconductor workforce.

This primer concludes with seven recommendations to NSF and NIST grant makers and philanthropic organizations who seek to invest and help equip community colleges to leverage their strengths for workforce expansion:

1. Updates to insufficient and outdated facilities, aligned with industry needs, should be prioritized to enhance skill-building and student engagement.
2. Funding should be allocated toward building and/or expanding programs that provide firsthand experience in the semiconductor industry environment to students before graduation.
3. Invest in nationwide programs or in community colleges that are promoting visibility of the semiconductor industry to students and the public.
4. Prioritize outreach and support to community colleges that do not routinely submit federal grant applications.
5. Build training programs and curriculum at community colleges that produce transferable skills for the semiconductor industry and external industries.
6. Invest in strengthening data tracking abilities, enabling community colleges to access comprehensive data that can track progress and student success.
7. Community colleges can enhance resource sharing with other institutions and industry, including four-year universities, and develop joint programs and forums to provide students with practical experience and prepare them for the workforce.

Part 1: Introduction to the CHIPS and Science Act & U.S. Workforce Challenges

What was the impetus for the CHIPS and Science Act?

- **The CHIPS and Science Act is one of the largest federal investments in industry in decades.** With over $50 billion authorized in direct funding and loan subsidies—and billions more appropriated—the U.S. is focusing its resources toward becoming a major competitor in the semiconductor manufacturing industry.[5] Passed in August 2022, the CHIPS Act is in early stages of implementation.
- **The CHIPS Act is embedded in geopolitics, with the ultimate goal of the legislation to boost U.S. national security, competitiveness, and innovation.**
- **Advanced semiconductor manufacturing is a national security issue.** Military applications increasingly demand the use of semiconductors, with advanced sensing and computation widely integrated into military capabilities. This high demand is coupled with a decline in the global share of U.S. domestic semiconductor manufacturing capacity, from 37 percent in 1990 to 12 percent today.[6] Currently, Taiwan and South Korea hold the highest global shares in chip manufacturing, but their posture within geopolitical tensions raise concerns about U.S. dependency. As a result, strengthening the chip supply chain in the U.S. is critical for national security. For more details on the geopolitics of the semiconductor industry, readers can refer to Part 1 of, "Catalyzing Semiconductor Innovation through a National Semiconductor Technology Center."[7]
- **As China seeks to increase its semiconductor manufacturing capabilities, aiming to lead the world by 2049, the U.S. has responded with its own investments in industry and emerging technologies.** China, the U.S.'s primary geopolitical competitor, has prioritized expansion of the semiconductor industry and reduction of its dependence on foreign countries for high-tech. China's past success in capacity building within the technology hardware sector and high investments in research and development suggests their future achievement in this expansion. The CHIPS Act represents the U.S.'s initial response to this competition from China. For more details on U.S. and China competition, readers can refer to Part 1 of, "Lab to Market Translation at NSF's TIP Directorate."[8]
- **A large-scale federal investment in the semiconductor industry is critical to achieve these goals, since the existing infrastructure in the U.S. cannot support a growing chips industry.** The U.S. has provided limited support and attention to the semiconductor industry over the last several decades, particularly in contrast to the strong industrial strategies of other foreign

governments.[9] This disregard has substantially reduced the capacity of the U.S. semiconductor industry and created a crisis that is unlikely to be alleviated without major investment that supports manufacturing, alongside semiconductor research and development.

How has the CHIPS and Science Act spurred a need for U.S. workforce development?

- **The CHIPS Act is a massive U.S. industrial policy that will drive a great need for technical workers in the semiconductor industry.** As per a report by the Semiconductor Industry Association (SIA), the U.S. semiconductor industry is vital to the economy, supporting 1.85 million jobs in 2020, and creating an additional 5.7 jobs in the wider economy for each worker directly employed in the industry.[10] The CHIPS Act aims to expand semiconductor R&D, design, and manufacturing in the United States, which would have positive impacts on the economy. It could add $24.6 billion annually to the U.S. economy and create 185,000 temporary jobs each year from 2021 to 2026. In the long term, this could lead to an additional 280,000 new jobs, with 42,000 of those being directly employed in the domestic semiconductor industry. Consequently, this would raise the employment of the U.S. semiconductor industry to 319,000, and the total jobs impact to 2.13 million by 2027.[11] Workforce development is necessary to support this industry expansion. The occupational profile of the semiconductor industry is vast, including assemblers and fabricators, maintenance and repair workers, software developers, engineers, electricians, management staff, and others.[12] Workforce needs span educational backgrounds—from high school diplomas to PhDs—and industries—from manufacturing to education.
- **The CHIPS Act will create a high number of temporary positions, alongside long-term roles.** Several workforce demands will be temporary, particularly during the build-out period for new fabs. SIA estimates a six-year build-out period during which a fab is constructed, equipment is installed, and the fab reaches full capacity.[13] Positions during this period include construction roles to build the new fab facilities, which may create nearly 120,000 jobs, as well as a number of indirect jobs.[14] Indirect jobs are positions created by supply chain purchases or by semiconductor workers spending their wages on consumer goods and services. The authors attempted a data review to identify challenges in filling these temporary jobs, but data was limited. This may be an important topic for future researchers to analyze. However, long-term roles will also be spurred by CHIPS Act investments, as a workforce will be needed to staff these fabs in perpetuity.
- **Estimates on the future workforce gap are substantial, with a talent shortage estimated to be around 90,000 workers.** Researchers have argued that over the next few years an additional 70,000 to 90,000 fab workers will be needed within new facilities.[15] If the U.S. were to continue expanding and becoming self-sufficient in chip production, around 300,000 new fab workers would be required.[16] For example, over 50 new semiconductor-related projects have already

been announced in the U.S. since the CHIPS Act was introduced in Congress in 2020. As a part of these projects, over 44,000 new industry jobs have been proposed, not including the thousands of indirect positions that will be created across other industries.[17] For a more detailed breakdown on semiconductor supply chain manufacturing investments in the next ten years and their expected job openings, readers can refer to this chart compiled by the SIA.[18]

- **This workforce shortage is accompanied by a skills gap present across industry positions.** Semiconductor manufacturing demands a diversity of specialized skills across roles. Some skills may necessitate an advanced degree, such as PhDs in materials science. Other positions in the semiconductor industry, like factory machine operators or print technicians, do not call for advanced degrees, but still require a technical background.[19] Currently, the demand by industry for talent is greater than the supply: a 'skills gap' present across all job categories.[20] In part, this trend is exasperated by a lack of awareness of the semiconductor industry. Generally, highly trained students with engineering degrees have been attracted to tech firms, with semiconductor firms less on students' radar.[21] A similar awareness challenge is present for students eligible to become entry-level technicians. To address the workforce shortage, the U.S. must first tackle the skills gap and associated awareness challenge.
- **The workforce shortage and skills gap is influenced by a lack of students in related fields.** Educational institutions are not currently prepared with high student enrollment or semiconductor-related curricula to train the staff needed for new fabs. For students seeking four-year and advanced degrees, high-paying and visible jobs in the software industry have lured students away from studying electrical engineering.[22] Additionally, there are limited programs geared specifically for training students for the semiconductor industry, at all levels (from technicians to researchers). Many universities do not have lab space or faculty that can effectively provide students with semiconductor experience. Overall, more students need to be attracted to and trained in science, technology, engineering, math (STEM) and manufacturing.
- **U.S. immigration policies also limit the ability to bolster domestic talent with skilled foreign labor.** Another workforce source includes experienced and educated talent from abroad. However, U.S. immigration policies make it challenging to bring in and keep foreign talent. The U.S. places hard caps on immigrant visas that limit the number of foreign employees, including STEM master's degree and PhD holders that work in critical security industries, like the semiconductor industry.[23] While earlier versions of the CHIPS Act proposed reforms on these policies, they were not passed in the final version.
- **Workforce development may need to expand past local geographies to fill industry needs.** The high estimates for the future workforce gap suggest that local workforce may not be enough to staff fabs long term. As a result, workforce development must take place on a national level, as the U.S. workforce may need to be relocated and/or trained in regions that currently do not have a

semiconductor industry presence. For instance, several CHIPS Act programs explicitly prioritize investments in rural communities, with the hope of promoting rural talent and enabling a wider expanse of people in the United States to participate in the semiconductor industry, among other STEM fields.[24] However, rural employment remains at low levels with poor labor market performance, suggesting challenges for solely utilizing the local workforce to fill these large labor gaps.[25]

- **An interplay of federal, state, local, and private-sector actors will be necessary to support this workforce expansion.** To bolster U.S. workforce across geography, educational levels, and technical skills, actors will need to be effectively coordinated among jurisdictions and industries. For instance, state workforce boards might work in conjunction with regional community colleges and state universities to promote effective skills training aligned with industry needs. CHIPS Act investments should be coordinated alongside existing federal and state efforts in workforce development and tasks should be clearly delineated among actors.

Case Study: Mapping Semiconductor Industry Workforce Needs

Data collected by the Micro Nanotechnology Education Center (MNT-EC) depicts a segment of the workforce needs within the semiconductor industry. The Micro Nanotechnology Education Center, MNT-EC, is a National Science Foundation Advanced Technical Education Center that aims to increase technical education programs in Micro- and Nanotechnology. MNT-EC is conducting a survey to identify national and regional semiconductor industry workforce development needs. MNT-EC has kindly shared their preliminary survey data with the authors of this primer. The survey has received responses from 45 companies working in the semiconductor industry.

The charts below provide some insight into industry's needs within the semiconductor workforce, specifically workers that are community college-trained and without bachelor's degrees.

Figure 1. Where is your company located?

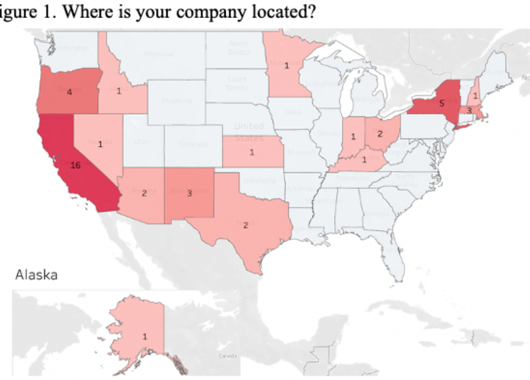


Figure 2. What is the headcount of your company?

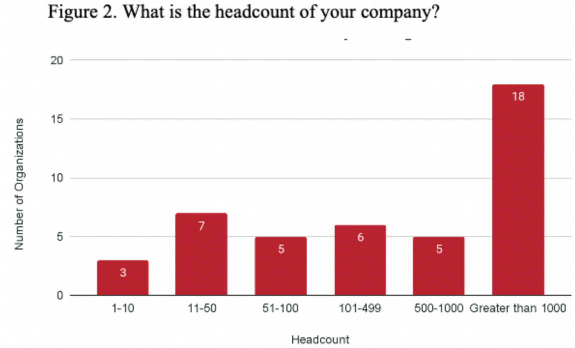


Figure 3. Can you approximate the number of individuals with Associate's or Certificate Degrees that you need to hire on a yearly basis for the next five years?

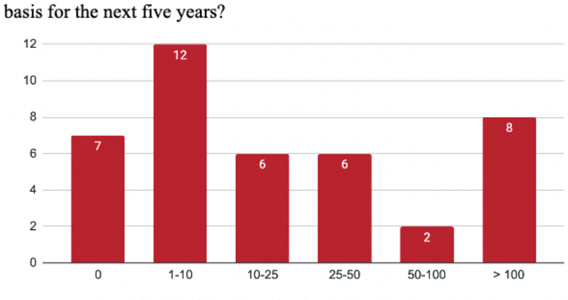
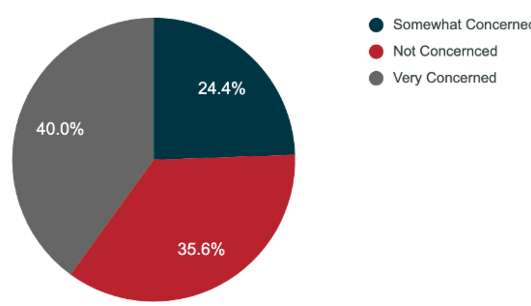


Figure 4. How concerned are you in hiring Associate or Certificate level workers over the next three years?



How might community colleges be utilized to address these workforce challenges?

- **A substantial portion of the workforce are technical workers who will not require a bachelor's degree.** The semiconductor workforce can be divided between engineering and research and development roles, which primarily require advanced and four-year degrees, and technician roles, which often only require associate degrees or certificates (<BA). In Part 2 and Part 3, this primer will focus solely on the <BA technician workforce, which comprises a significant segment of the overall industry workforce. Bureau of Labor Statistics data suggests that two-thirds of semiconductor industry jobs are in the manufacturing workforce and that 60 percent of these manufacturing jobs do not typically require a bachelor's degree for entry.[26] For example, in a new CHIPS-funded Intel fab being constructed in Central Ohio, about 70 percent of the Intel jobs will be technician roles, only requiring an associate degree.[27] Community colleges can take a leading role in filling the skills gap for these positions, providing affordable education and training programs to prepare students for skilled jobs in the workforce.

- **Talent inflows into manufacturing jobs have been significantly lower than in other areas, such as engineering and digital and analytics.** Despite two-thirds of semiconductor industry jobs existing in manufacturing, the change in percentage of employees with desired skills over the past ten years has been lowest in the manufacturing space.[28] Community colleges have the potential to address this manufacturing talent and acquisition challenge, developing effective programs and curricula to promote the semiconductor manufacturing sector within their region.

- **Through construction of an efficient workforce, community colleges can help alleviate the cost differential of labor in the U.S.** One of the major challenges faced by the U.S. semiconductor industry is the high cost of labor. Labor costs in the United States are generally higher than in countries such as Taiwan, which is a major player in the semiconductor industry. According to the Bureau of Labor Statistics, the average hourly wage for semiconductor processors in the United States is around $23.25,[29] compared to approximately $8 in Taiwan.[30] This cost differential makes it difficult for U.S. semiconductor companies to compete with their Asian counterparts. One way to mitigate the cost differential is by developing a more efficient and productive workforce. Community colleges can help by providing training programs that equip the workforce with the skills required for the semiconductor industry. These colleges offer vocational and technical courses at a fraction of the cost of four-year colleges, making it cheaper and more efficient for students to secure high-paying technician-level jobs in the semiconductor industry and helping to boost productivity and innovation in the economy.

- **The CHIPS Act includes programs to support community colleges, investments that can be utilized for workforce development.** As discussed in Part 2, the CHIPS Act offers funding opportunities to help community colleges take on a larger role in addressing this national semiconductor workforce gap. By supporting community colleges, whose actions have historically been limited by underfunding, the CHIPS Act offers a key opportunity to coordinate workforce development for fab technicians.

Part 2: CHIPS and Science Act Workforce Components

Introduction to the CHIPS and Science Act

- **A sweeping piece of legislation, the CHIPS Act makes investments across several sectors, including workforce development.** The CHIPS Act includes investments in science and technology, research and development, clean energy, artificial intelligence, semiconductor manufacturing, supply chains, and education, ultimately centralizing around the goal of promoting U.S. competitiveness and innovative growth.[31] As stated in a press release by the White House, "Workforce development activities are critical to developing skills needed for taking on the highly-skilled jobs of the emerging industries built on technologies of the future."[32] As a result, several key provisions of the CHIPS Act invest in workforce development.
- **CHIPS Act implementers have the responsibility of ensuring that CHIPS investments effectively address the U.S.'s workforce challenge and skills gap.** These CHIPS Act provisions on workforce development are often not well understood, leaving space for implementers to miss the mark on effective allocation of grants and subsidies. This primer seeks to shed light on these workforce provisions and offer recommendations for valuable implementation of the CHIPS Act.

Appropriation versus Authorization

To note, the final appropriated funding for the CHIPS Act is smaller than the amounts authorized. However, there are still multiple relevant programs funded and awaiting implementation.

- When signed into law on August 9, 2022, the CHIPS Act authorized **$280 billion** to boost U.S. semiconductor research, manufacturing, and workforce development, alongside other investments in science and technology. However, only **$54.2 billion** was immediately appropriated.
- In December 2022, Congress appropriated an additional **$1.8 billion** in the federal omnibus bill for the CHIPS Act. Included in this funding was: **$400 million** for NIST, **$700 million** for NSF, and **$335 million** in supplementary funding for NSF CHIPS Act implementation. For a general breakdown, see Computing Research Association (CRA)'s omnibus resource.[33] There is not a clear dollar amount publicly set aside thus far for how the funding will be distributed among all CHIPS programs.

The provisions listed below—focusing on community college workforce development—are primarily grant-focused. However, a few key non-grant provisions have been included for reference. Most of these provisions do not have a clear funding allocation; it is uncertain the dollar amounts of the grants that will be distributed.

Select CHIPS and Science Act Workforce Provisions

Microelectronic Grant Programs. By means of an NSF funding expansion, the CHIPS and Science Act includes provisions to provide grants to community colleges to expand their programming and encourage the development of improved workforce training better connected to industry needs:

Sec. 10318 – Microelectronics Workforce Development Activities
NSF directed to make awards to all education levels related to supporting a diverse and sustainable microelectronic workforce, such as funds to support the development of industry-oriented curriculum or funds for teaching training.

Sec. 10318(a)(5) – Microelectronics Skilled Technical Workforce Programs
NSF directed to make awards specifically to support programs for skilled workforce needs of the microelectronics industry, like hands-on-training, for students receiving associate degrees or certificates.

Industry-Educational Institution Partnerships: The CHIPS and Science Act includes provisions that allocate funding to encourage institutes of higher education to work closer with industry to fill workforce gaps:

Sec. 10318(b) – National Network for Microelectronics Education.
NSF directed to make awards to higher education institutions for the purposes of establishing partnerships with other educational institutions, industry, and labor organizations to foster local workforce pipelines and ensure better connections between industry and academia.

Sec. 102 – Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Fund.
$11 billion appropriated to implement various workforce development programs in the semiconductor industry. This funding specifically aims to promote an inclusive workforce pipeline.

Sec. 10621(f) – Strategy Implementation Grants and Cooperative Agreements.
Grants awarded to regional innovation hubs for the purpose of workforce development activities, like creating partnerships and consortia between industry and educational institutions, procuring facilities and equipment, and updating curriculum.

Sec. 10251 – Establishment of expansion awards pilot program as a part of the Hollings Manufacturing Extension Partnership.
Creates a pilot program that provides worker training and connects individuals or businesses with community services (including community colleges) to support training and job placement in the manufacturing industry.

For a more detailed breakdown of CHIPS and Science Act provisions relevant to community colleges, readers can refer to this fact sheet compiled by the Association of Community College Trustees.[34]

What broad components of the CHIPS and Science Act are focused on workforce development?

- **Workforce development refers to empowering and educating workers to administer advanced technology, while also reducing systemic barriers that currently restrict the labor pool.**[35] Among other activities, workforce development aims to create partnerships between industry and educational institutions, expand STEM education, and increase fellowships and apprenticeships. Ultimately, these activities seek to expand the U.S.'s technological workforce with respect to race, gender, and geographical diversity.[36] Workforce development will also help fill roles in ballooning industries that received increased funding through the CHIPS and Science Act, including semiconductor fabs.

- **Underlying this workforce development is the desire to increase the presence of underrepresented populations in technology and innovation, including investment in rural communities.**[37] Several workforce development provisions of the CHIPS and Science Act provide targeted investment in rural spaces, expanding America's capital and research capacity.[38] Overall, the CHIPS Act acknowledges that equity is a key component in broadening participation in the technology sector and ensuring that America leverages its untapped workforce potential.[39]

- **Instead of building up a single prescribed form of industry in select regions, the U.S. hopes workforce diversity and expansion will stimulate increased global competitiveness.** The CHIPS and Science Act aims to revitalize U.S. leadership in the face of enhanced global competition, especially from China.[40] However, significant and systemic investments are required to shift *from whom* and *where* innovation originates. By expanding its technological capacity and brainpower via new communities and regions, the U.S. hopes to increase its competitiveness on the world stage and ensure long-term growth and sustainability.

- **The CHIPS Act invests in education to facilitate workforce development.**[41] Through funding directed toward NSF and NIST, the CHIPS Act expands STEM education from K-12 through higher education. Operating on the assumption that education reaches new generations before they even enter the workforce, many of the 'workforce development' provisions of the CHIPS and Science Act include training programs for rural teachers, scholarships for low-income students, and studies for stronger and more inclusive STEM education.[42]

- **Workforce training also prioritizes partnerships between industry and educational institutions.** Constructing a more resilient and effective workforce necessitates an alignment of educational programs with industry needs. The CHIPS and Science Act seeks to build networks between academic and industry partners, with the goal of developing local workforce pipelines and ensuring that regions with newly constructed fabs have access to an ample and well-trained workforce.[43]

- **The CHIPS Act emphasizes the augmentation of funding for EPSCoR jurisdictions to**

promote geographic and institutional diversity among federal grantees. The act seeks to expand the Established Program to Stimulate Competitive Research (EPSCoR), which allocates funds to states and territories that have historically received a limited share of federal research funds. This expansion aims to enhance diversity in both the geographic distribution and the recipient institutions of federal research grants. It sets specific targets for increasing the research budget allocated to EPSCoR jurisdictions, aiming for 15.5 percent in fiscal year 2023 and a further increase to 20 percent by fiscal year 2029.[44]

More specifically, what components of the CHIPS and Science Act support community college efforts to train the semiconductor workforce and reduce the technical skills gap?

- **Much of higher education workforce development for individuals with < BA is centered around the microelectronics industry.** The CHIPS and Science Act includes several provisions training workers for positions within semiconductor fabs and the microelectronics industry.[45] Some of these provisions include: NSF awards to develop microelectronic education programs; grants specifically for AA degrees or certificate programs that will create a skilled microelectronic workforce; regional educational partnerships to create a technical workforce trained in microelectronics; and programs to train and foster collaboration for teachers. These programs aim to fill the gap in the current workforce capacity for the microelectronic industry.[46]
- **Through provisions like the 'microelectronics skilled technical workforce programs,' the CHIPS Act promotes hands-on experiences for students in microelectronic studies, which can be facilitated by community colleges.** A majority of students with <BA require training to be employed as technicians in semiconductor fabs. While job titles may vary by company, technicians are primarily responsible for maintaining and troubleshooting manufacturing equipment, preventing chip contamination, and keeping the fab running at maximum capacity.[47] Specific skills are needed to work in these fab clean room facilities. Community colleges can help address this skills gap by providing hands-on opportunities to students.
- **The CHIPS Act aims to bolster the inherent strengths of community colleges through close partnership with industry.** Community colleges are workforce-focused, and their curriculum can be tailored to meet industry needs. By partnering with community colleges, industries can help shape the curriculum and ensure that students receive the skills and training that employers are looking for, increasing their employability, and helping fill skills gaps in the workforce. Collaborative investment in education and training can lead to more productive outcomes for both the industry and community colleges. It can also help take some responsibility for investing in education and training away from the industry alone. Several provisions in the CHIPS Act, such as building a National Network for Microelectronics Education, specifically allocate funding to encourage institutes of higher education to work closer with industry to fill workforce gaps.

PART 3: Opportunities for Investment in Community Colleges

- **In general, community colleges have many strengths that can be advantageous in implementing CHIPS Act workforce development activities.** For instance, community colleges are very workforce oriented.[48] This coursework focus on job placement provides an opportunity for community colleges to tailor their programs closer to industry needs, working with industry partners to identify the skills and knowledge essential for a student's industry success. Other strengths include: the affordability of most community college programs; the often diverse student bodies across class, race, and age; the connectedness between community colleges and the local region; and the flexibility of community college course scheduling.
- **Community colleges can channel these collective strengths toward semiconductor workforce issues.** These include: supporting skill-specific training; serving as hubs to connect state, local, and private-sector actors; and facilitating reaching and training students historically underrepresented in STEM.[49] Community colleges can act as an 'accessible point of entry' for students to gain exposure to the manufacturing and semiconductor industries and generate opportunities for skill development and targeted workforce preparation, particularly through collaborations with local employers.[50] Overall, community colleges have the potential to serve as a critical link between this workforce development and industry development.[51]
- **The CHIPS and Science Act equips NSF and NIST to support the advancement of robust semiconductor workforce development programs within community colleges.** However, unfortunately the majority of community colleges are underfunded and understaffed, leaving opportunities to better utilize their strengths in building the semiconductor workforce.

The recommendations below are designed to identify opportunities where NSF and NIST grant makers and philanthropic organizations can invest and help equip community colleges to leverage their strengths for workforce expansion.

Community colleges offer significant potential as partners in national workforce development; however, investment must be targeted to address specific areas of need. Federal, state, local, and private-sector actors are embedded in these recommendations, given distinct directives to work cooperatively with community colleges. Notably, Diversity, Equity, and Inclusion (DEI) workforce priorities cut across multiple opportunities for investment, as there is capacity to utilize community colleges in expanding diversity and inclusion within the semiconductor workforce.

Acknowledgment of Regional Differences

The recommendations in this section represent challenges and strengths experienced by a number of community colleges across the United States. However, they are generalizations of national trends, not an assumption that every community college carries the same circumstances.

The U.S. community college sector is extremely diverse, with major distinctions between states and within regions. The diverse funding formulas and governance structures of community colleges contribute to these differences, often making one community college's strength another's weakness. National policies and funding opportunities must acknowledge these differences and variations across the community college sector to be successful.

Recommendations

The authors have listed the below recommendations in no particular order. All seven recommendations offer critical opportunities for improving community colleges' abilities to address workforce gaps, with consideration to feasibility, return on investment, and systemic challenges. Refer to "Further Research to Guide CHIPS Implementers" below for suggestions to future researchers on prioritizing these recommendations. The recommendations are as follows:

1. Updates to insufficient and outdated facilities, aligned with industry needs, should be prioritized to enhance skill-building and student engagement.
2. Funding should be allocated toward building and/or expanding programs that provide firsthand experience in the semiconductor industry environment to students before graduation.
3. Invest in nationwide programs or in community colleges that are promoting visibility of the semiconductor industry to students and the general public.
4. Prioritize outreach and support to community colleges that do not routinely submit federal grant applications.
5. Build training programs and curriculum at community colleges that produce transferable skills for the semiconductor industry and external industries.
6. Invest in strengthening data tracking abilities, enabling community colleges to access comprehensive data that can track progress and student success.
7. Community colleges can enhance resource sharing with other institutions and industry, including four-year universities, and develop joint programs and forums to provide students with practical experience and prepare them for the workforce.

1. Opportunity for Investment: Updates to insufficient and outdated facilities, aligned with industry needs, should be prioritized to enhance skill-building and student engagement.

Context: Due to budgetary and capacity constraints, many microelectronic programs at community colleges do not have appropriate facilities to align students with industry needs. Clean rooms, research instruments, software design tools, AR/VR training simulations, and fabrication equipment are limited. While some of these facilities are not as critical for technician training programs, which focus on equipment maintenance and process control, gaining exposure to the facility environment of industry would enhance learning.

In particular, semiconductor manufacturing equipment is costly to build and maintain and suffers the risk of quickly becoming technologically obsolete. As a result, many community colleges do not have the funds to maintain this equipment or the trained personnel to operate it, limiting opportunities for students to receive hands-on training.

Recommendations: Grants should be provided to community colleges who have plans in place to leverage existing fab facilities at other universities, labs, and industry to fill their facility gap and expand access for hands-on training, as developing and maintaining on-site facilities is extremely costly. Since some semiconductor fabs are reluctant to allow non-employees to enter their site, CHIPS funding might also be allocated for separate workforce development spaces within a fab during its greenfield construction stage. This arrangement saves resources for community colleges, enhances exposure of students to industry, and generates a workforce already familiar with the local industry employer.

2. Opportunity for Investment: Funding should be allocated toward building and/or expanding programs that provide firsthand experience in the semiconductor industry environment to students before graduation.

Context: The limited facilities at some community colleges, along with limited internship and apprenticeship opportunities, prevent many students from gaining hands-on experience in the industry environment while enrolled. As a result, several students enter industry without a full understanding of the work environment and day-to-day tasks, leading to dissatisfaction and high attrition within the industry. This dynamic is even more pronounced within short-term semiconductor technician training programs, such as bootcamps, that offer less exposure to industry.

Recommendations: CHIPS funding should support regional and national efforts to expand work-based learning.

Regionally: Grants should support community colleges in forming partnerships with local industry and creating hands-on-experiences in the region. Such experiences might include shadowing programs, local internships, career day visits, and mentorships. Notably, these industry partnerships must also embed DEI efforts, as industries should be cognizant of recruiting a diverse and inclusive talent pool. Overall, these regional efforts can help to upskill the current, local workforce with programs appropriate for the needs of a future-focused workforce.

Nationally: A nationwide work-based learning program will also increase hands-on-training and retain more students to the industry. Notably, this should be a paid program with livable wages, typically those at a higher rate than wages offered in fast food, retail, or hospitality industries. A national program recognizes that workforce needs at new CHIPS-funded fabs may need to be supplemented by talent coming from outside of the region, requiring job mobility. Currently, most community college students working toward semiconductor technician positions focus on employment within their community. However, given the workforce needs outlined in Part 1, industry employers will not be able to fill their needs solely with the available, local workforce. Exposing students to new, well-paid job opportunities and providing resources to temporarily move and gain exposure to a new region, through a nationwide work-based learning program, may help to stimulate this labor movement. Therefore, while this trend of locally based employment may be difficult to shift, eliminating financial constraints on students who may be willing to relocate would encourage some mobility, while also ensuring that more students are familiar firsthand with nuances of the technician job.

3. **Opportunity for Investment:** Invest in nationwide programs or in community colleges that are promoting visibility of the semiconductor industry to students and the public.

Context: While the CHIPS Act has brought the semiconductor industry into the news, its nascent position in the U.S. has meant that the industry is not visible to most students and the public. This lack of awareness inhibits the number of students enrolling in training programs and constrains the growth of electronics infrastructure, creating a shortage of job candidates.[52] Visibility must become a priority to increase enrollment in programs that will fill newly created CHIPS positions and build robust, long-term interest in the semiconductor industry,

Recommendations: While federal funds may not be able to support direct marketing and PR efforts, grant administrators should consider applicants who have plans for outreach activities and dissemination. Outreach activities and campaigns may include dual-credit and bridge programs from high school to community college to help raise visibility and increase recruitment. It might also include outreach campaigns in partnership with industry. For example, Onondaga Community College in Syracuse, NY partnered with Micron to host a free "CHIP Camp" for local middle school students.[53] This camp introduced youth to the semiconductor industry, while also building STEM skills and displaying the industry environment at the Micron facilities. Partnerships like these can serve as important visibility campaigns for the semiconductor industry.

Additionally, the vision and strategy paper for the National Semiconductor Technology Center (NSTC)—established by the CHIPS Act to support U.S. leadership in semiconductor competitiveness—points to visibility as one of their priorities for CHIPS workforce activities. The NSTC Vision Paper suggests that NSTC "create campaigns to increase visibility for careers in the semiconductor industry, highlighting representative role models in a wide range of occupations. The campaigns should be regionally based and include member companies to highlight the unique opportunities available in specific locations."[54] NSTC should consider creating these campaigns in conjunction with community colleges, bolstering existing programs (like Onodaga's CHIP Camp) and utilizing community colleges' unique regional knowledge to promote visibility.

4. Opportunity for Investment: Prioritize outreach and support to community colleges that do not routinely submit federal grant applications.

Context: An absence of grant facilitators reduces the ability of community colleges to apply and receive competitive funding. To be competitive for federal, state, and private grant applications, including CHIPS Act grants, a designated grants manager with insight into the grantmaking process is an asset. However, many under-resourced community colleges do not have a grant writer to facilitate this process, perpetuating a cycle of underfunding. In particular, Historically Black Colleges and Universities (HBCUs) and Hispanic Serving Community Colleges have historically struggled to compete for federal science and technology dollars; 91 percent of recipients of NSF awards are white.[55] There have long been historical biases in the awarding and distribution of federal grant funding, which has limited the competitiveness of HBCUs.[56]

Additionally, the reliance on successful grant writing for funding limits the ability of community colleges to retain a strategic focus, as their strategy is limited by available funding. Notably, many community colleges who do not engage in grantmaking also struggle with underinvestment and have a limited capacity to take on a grant-funded project, even if awarded, which makes addressing this cycle of underfunding challenging.

Recommendations: CHIPS grant implementers should work on scaling successful grant mentorship programs, including shared grantmaking with four-year institutions and mentorships between successful community college grantees and those struggling to apply. For example, NSF's Advanced Technological Education (ATE) program supports several mentoring projects that provides community colleges with a mentor that assists them with developing a grant proposal, submitting it to research.gov or grants.gov, handling negotiation questions, and dealing with other grant administration issues. One such project is Mentor Connect, which helps community colleges develop grant proposals for ATE grants.[57]

NSF should develop and scale successful mentorship programs for CHIPS Act grants. The process of applying for a grant is intensive and it can be discouraging for capacity-limited community colleges to go through the application process and not receive funding. As a result, mentorship programs will aid in promoting high success rates for first-time applicants, a step toward tackling this cycle of underfunding.

NSF should also consider expanding funding for the ATE program, as the current program is oversubscribed and underfunded.[58] Expanding two or four-fold would help meet high demand and increase acceptance rates of deserving proposals. As the ATE program expands, it can house additional grant mentorship for community colleges within its existing program, streamlining grant access and promoting innovative ways to connect with community college consortia that do not typically apply to competitive grant programs—to create robust relationships and encourage applications.

5. **Opportunity for Investment:** Build training programs and curriculum at community colleges that produce transferable skills for the semiconductor industry and external industries.

Context: The semiconductor industry is cyclical within its hiring processes and, notably, a high number of the jobs spurred by the CHIPS Act are likely to be temporary. To support students entering the semiconductor industry—especially for CHIPS and Science created positions—it is important to design programs that will grant students transferable skills. A flexible skill set will allow students to succeed within the semiconductor manufacturing industry, but also, will help students adapt to changing industry needs and remain competitive in the job market long term.

However, this flexibility should be paired with a curriculum aligned to industry, including encouraging industry to be proactive in reviewing curriculum offerings. Curriculum changes might also involve "hands-on" learning opportunities, like lab tours, that industry can guide.

Recommendations: Funding should support community colleges seeking to build new flexible training options for the semiconductor industry. Programs such as bootcamps, certifications, and online courses allow students to acquire new skills quickly and stay up to date with the latest industry trends. However, it is difficult to design a flexible training program that also provides students with enough in-depth training to align with industry needs. As a result, grant allocators must be cognizant to consider the parameters of a community college's program when selecting grant recipients.

Additionally, transferable skills may be supported by investment in a common curriculum that can be adapted and implemented to support various regional industries. For example, the ATE program at NSF funded a project, "Preparing Technicians for the Future of Work," which developed a similar framework for a cross-disciplinary STEM Core.[59] This curriculum was developed in partnership with industry and prioritized the need for people to be up- or re-skilled across related industries, including semiconductors. This combination of industry-validation with flexible implementation offers graduating students the potential for long-term workforce success.

Grant implementers might also look toward Columbus State Community College (CSCC) as an example of a program prioritizing both flexibility and industry-curriculum partnership. Columbus, Ohio is the site of the first new CHIPS Act funded fabrication plant, built by Intel.[60] The construction of this facility demands an expansion of the region's workforce, and, consequently, preparation of non-degree workers for semiconductor manufacturing jobs. Data suggests that "about 70 percent of Intel jobs in Central Ohio will be technician roles, requiring just an associate degree" and that hiring for these technician jobs may begin as early as 2023.[61]

CSCC has emerged as a leader for a statewide strategy to fill these approximately 2,000 non-degreed jobs in Ohio.[62] Two priorities underlie CSCC's statewide strategy: a flexible, short-term certificate program to upskill existing workers and curriculum-enhancement to design programs coordinated with Intel's needs. Both priorities aim to train semiconductor technicians quickly, but with curriculum aligned toward the skills that Intel's jobs require. However, CSCC and the Workforce Development Board of Central Ohio have also prioritized building up this non-degree workforce with skills relevant to other companies in the region, like Honda's electric vehicle battery production plant.[63] CSCC's concern for transferable skills should serve as a model for future CHIPS grants, illustrating that industry-alignment can be successfully prioritized alongside the development of flexible skills.

6. **Opportunity for Investment:** Invest in strengthening data tracking abilities, enabling community colleges to access comprehensive data that can track progress and student success.

Context: Internally, student-level data is critical in implementing programs, including tracking metrics to determine whether students are at-risk of not finishing degrees and informing blueprints to improve student learning.[64] Externally, data on the number of students matriculating in a program, the number of faculty, and other demographic information can inform effective policy making and ensure that current programs can support an expansion of the semiconductor workforce. Data can also help ensure that community college programs are successfully promoting diverse and inclusive workforce placement.

However, institutional data—accessed via the Department of Education and Department of Labor—is lacking.

It is a challenge to track community college student progress, as data does not effectively follow students who go on to four-year institutions or provide wage data for graduates in industry.[65] Additionally, in the semiconductor industry, community colleges offer a variety of certificates and programs with different names and course offerings; for the purposes of data collection, it is challenging to identify which programs are pipelines to the semiconductor industry and to determine the number of students matriculating into these fields. There have been several attempts to track data on federal, state, and community college levels—the majority of which have been unsuccessful. Data tracking has proven to be a challenging issue with no singular solution.

Recommendations: CHIPS funding should support the establishment of state and regional data tracking systems to collect outcome and wage data for non-degree workforce programs at community colleges. Additionally, grants should support training for community college faculty and administrators on how to analyze and implement data, helping community colleges determine the success in filling workforce positions and their reach within communities.

Currently, the federal government and most states do not collect outcomes data for non-degree workforce programs at community colleges. Since many semiconductor technician programs are non-degree, demographic and wage data is not readily available. CHIPS funding should support state/ regional databases that can track employment and earning outcomes for non-degree workforce students, as the state and regional level is most practical for tracking data with a programmatic focus. For example, a similar database was established by the California Community College system, LaunchBoard, to track and report outcomes metrics.[66]

Additionally, CHIPS should include capacity and technical assistance grants to ensure community colleges can utilize the data for student success and are not limited by resource-constraints. Since many community colleges have limited staff, expertise, and technology to analyze the resulting data, CHIPS grants can support this capacity building.[67] The California LaunchBoard program also included capacity-building grants and technical assistance to help college staff grasp how to effectively use outcomes data. However, this capacity building must be expanded to reach more community college administrators effectively.

7. Opportunity for Investment: Community colleges can enhance resource sharing with other institutions and industry, including four-year universities, and develop joint programs and forums to provide students with practical experience and prepare them for the workforce.[68]

Context: Historically, some community colleges have been excluded from partnerships with major industry players and other academic institutions. Many industry partners have sought out the R&D expertise and workforce of four-year institutions and, as a result, created less partnerships with community colleges.[69] However, there is an opportunity for successful partnerships between institutions. With many four-year institutions focused on meeting workforce requirements of larger semiconductor corporations, community colleges can tailor their training offerings to the needs of smaller semiconductor facilities and fill the workforce gap of these regional businesses, acting as a valuable resource for the local economy.

Moreover, partnerships between community colleges and four-year institutions can offer value-adds of facility and faculty sharing, deepening understandings of regional needs, and promoting visibility of the semiconductor industry within a community. For example, a major problem at many community colleges is faculty recruitment, as low community college budgets prevent recruitment and retention of qualified faculty, who are being hired away by private industry that offers higher salaries. Partnering community colleges with four-year institutions may help to alleviate this faculty shortage.

Additionally, even partnerships between regional community colleges offer possibilities to expand programming and enhance capacity building. However, these community college partnerships have often historically been limited, as schools compete for finite funding.

Recommendations: *Forums and Vision Paper:* Funding should be allocated toward building regional and national forums to help foster regional- and national-level conversations that involve all key stakeholders: four-year institutions, community colleges, and small, medium, and large companies. In particular, forums should include Hispanic-serving and historically Black community colleges who are also working in this manufacturing space. Within these forums, best practices and innovative programs could be shared and disseminated to encourage effective partnerships. Currently, there are some examples of individual companies engaging with local community colleges. However, encouraging community colleges and industry to partner at the national level may introduce successful examples of collaboration among institutions and inspire innovation. Additionally, convening a national forum will help to ensure that new federal CHIPS funding is allocated in a coordinated and valuable manner.

Along with a national forum, NSF and/or NIST might consider spearheading a "National Strategy for the Future CHIPS Workforce," releasing a vision paper that lays out how they will encourage nationwide collaboration among industry and educational institutions to create a network of partnerships to grow a domestic semiconductor workforce. NSF and/or NIST can look toward NIST's "Vision and Strategy for a National Semiconductor Technology Center (NSTC)" paper as a model, highlighting high-level goals and action steps for workforce development.[70]

Resource Sharing: Funding should also strengthen partnerships between community colleges and four-year institutions, which may come in the form of facility and faculty sharing. In particular, grantors should consider if there is a way for grants to support creative solutions for fundamental and critical challenges, like lack of qualified faculty at community colleges. For instance, the Support Center for Microsystems Education at the University of New Mexico offers community college faculty and students professional development opportunities within the University's clean room, including hosting several regional community college courses, like "Semiconductor Manufacturing Technologies."[71] Similarly, Penn State University's Center for Nanotechnology Education and Utilization (NACK) runs the Remotely Accessible Instruments for Nanotechnology (RAIN) Network, which is a resource sharing model that focuses on sharing expertise (ex: faculty), materials, and equipment with community colleges.[72] The RAIN network is a unique model for the potential partnerships that could exist between four-year institutions and community college workforce development programs. Instead of replicating resources, sharing faculty and facilities among institutions is an efficient investment, including removing the time and expense of additional recruitment and hiring.

Resource sharing can also be facilitated by cross-personnel appointments between industry and community colleges. In this arrangement, industry personnel are funded for teaching sabbaticals at community colleges, where they can incorporate industry needs into existing, flexible academic curriculum. The NSTC Vision Paper includes a similar recommendation for NSTC to "develop a program for professionals from member companies to guest teach and mentor students at schools, community colleges, or universities in the region."[73] NSTC should proceed with this vision of creating a faculty-sharing program, particularly between industry and community colleges where faculty limitations are high due to underfunding.

Further Research to Guide CHIPS Implementers

The authors conducted interviews and research during the early stages of the CHIPS program through which they gained valuable insights into potential avenues for further research beyond this primer. To streamline the research process for other scholars, this section highlights opportunities for expanding on the authors' work. These insights can serve as a guide for CHIPS implementers in government and in community colleges.

- **Regional/Local Analysis.** At the time the authors wrote this report, the CHIPS Program was still in the early stages and a broad, national analysis of community college needs was most appropriate. The authors recommend that future researchers focus their analyses regionally. As a next step, regional analyses will be most beneficial to CHIPS implementers because community college and industry needs will vary by region, state, and even district. Future research questions could include:
    - Conducting a survey of industry workforce needs for a specific region, similar in concept to the survey MNT-EC survey results highlighted in Part 1.
    - Limiting interviews and surveys of community colleges to a specific region to gauge how the opportunities for investment outlined in Part 3 apply to their specific situation.
    - Mapping the existing training facilities/equipment in a specific region delineated by whether they are owned by/located in an educational institution versus inside a company's facilities and identifying where new training equipment are needed and where training facilities/resources can be shared if incentivized to do so.
    - Analyzing the capacity of a local labor market and determining whether workforce demand will outstrip the local labor market; considering the implications of geography and capacity of statewide labor markets to fill any gaps.
- **Cost Estimates of Investments and Beneficiaries.** To enhance the policy advice provided, it is essential to conduct further research that includes specific cost estimates.
    - Future research could focus on selecting specific recommendations outlined in Part 3 and identifying the projected beneficiaries of such a recommendation and a more detailed outline of the benefits for each recommended investment. This research could take a more in-depth analysis of the interplay of federal, state, local, and private-sector actors.

- Future researchers can identify/debate which recommendations in Part 3 should receive the most priority vs. the least priority and why, with consideration to recommendation cost.
- Future research could also dive deeper into the funding authorizations for each CHIPS Act program and analyze the potential reach of this funding amount, with analysis of existing programmatic guidance.

- **Analysis of Training Investment/Incentives.**
  - In-depth analysis is needed to determine the required training investment in community colleges for semiconductor workforce development, including the number of trainees and expected returns per trainee. Engaging with industry experts and stakeholders will provide valuable insights into their needs and perspectives.
  - Exploring the feasibility of incentivizing states with in-kind training incentives, as allowed by the CHIPS Act, instead of cash incentives, warrants further investigation. This will provide a more comprehensive and data-driven understanding of the costs, benefits, priorities, and potential policy approaches associated with the recommended investments.

About the Technology and Public Purpose (TAPP) Project

The arc of innovative progress has reached an inflection point. It is our responsibility to ensure it bends toward public good.

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1. Technology's advance is inevitable, and it often brings with it much progress for some. Yet, progress for all is not guaranteed. We have an obligation to foresee the dilemmas presented by emerging technology and to generate solutions to them.

2. There is no silver bullet; effective solutions to technology-induced public dilemmas require a mix of government regulation and tech-sector self-governance. The right mix can only result from strong and trusted linkages between the tech sector and government.

3. Ensuring a future where public purpose drives innovation requires the next generation of tech leaders to act; we must train and inspire them to implement sustainable solutions and carry the torch.

For more information, visit: www.belfercenter.org/TAPP

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