Workforce and Talent Management Study

September 2021

NIAC The President's National Infrastructure Advisory Council

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About the NIAC

The President's National Infrastructure Advisory Council (NIAC) is composed of senior executives from industry and state and local government who own and operate the critical infrastructure essential to modern life. The Council was established by executive order in October 2001 to advise the President on practical strategies for industry and government to reduce complex risks to the designated critical infrastructure sectors.

At the President's request, NIAC members conduct in-depth studies on physical and cyber risks to critical infrastructure and recommend solutions that reduce risks and improve security and resilience. Members draw upon their deep experience, engage national experts, and conduct extensive research to discern the key insights that lead to practical federal solutions to complex problems.

For more information on the NIAC and its work, please visit:
https://www.dhs.gov/national-infrastructure-advisory-council

Executive Summary

People are essential to critical infrastructure, but the United States has not given worker readiness the same attention it devotes to protecting critical infrastructure from physical and cyber threats. The consequences of failure, however, are no less severe. The Government Accountability Office (GAO) has identified the U.S. government's own workforce gaps as a "high-risk" area since 2001, and the COVID-19 pandemic has further amplified the range of challenges facing American workers.[1] The Nation is falling short in providing the workers it needs to plan, design, build, operate, maintain, and repair the infrastructure that supports the basic functions of American society.

To address this gap, the National Security Council (NSC) asked the President's National Infrastructure Advisory Council (NIAC) to **examine the challenges facing the critical infrastructure workforce and investigate the potential risks such challenges pose to U.S. national security**.

After conducting substantial research and interviewing dozens of senior leaders and experts, **the NIAC found that the workforce development system in the United States lacks the coordination, data, and strategic human capital management necessary to ensure a skilled workforce for critical infrastructure**. In this report, the NIAC presents its analysis and offers nine recommendations to inform future policy development and keep the critical infrastructure workforce nimble in the face of change and prepared to maintain the stability of American society when disaster strikes.

The NIAC's recommendations are guided by the principle that all workers must have equitable access to the education, training, and resources necessary to begin and advance in critical infrastructure careers.

Jump to the Guiding Principles section in Chapter 1.

Findings

While the NIAC found many challenges impeding the development of the critical infrastructure workforce, three cross-cutting issues stand out for their impact on all critical infrastructure sectors:

Jump to the full Findings in Chapter 3.

[1] Yvonne D. Jones, "Improving Federal Recruiting and Hiring Efforts," (U.S. Government Accountability Office, July 30, 2019), https://www.gao.gov/assets/gao-19-696t.pdf; Susan Lund et al, "The Future of Work After COVID-19," McKinsey Global Institute, February 2021, https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-after-covid-19.

Recommendations

The Nation's infrastructure is key to economic growth, competitiveness, national security, and public health and safety. Rebuilding the Nation's infrastructure is a priority for the Administration and central to bipartisan congressional action. The NIAC believes it is essential that "people-readiness" at all levels be considered a key bipartisan priority for any administration or congressional action plan.

The recommendations outlined here respond to the NSC's tasking to identify near-term actions that require immediate policy intervention and provide two to three mid-term and two to three long-term recommendations to inform future policy development. Taken together, these recommendations provide a strategic workforce planning framework that is fact-based, coordinated, and actionable. The importance of worker readiness in critical infrastructure demands a National Workforce Plan that incorporates strategic planning and human capital management into our Nation's core business processes, backed by the actions and accountability needed to ensure the long-term strength and resilience of the Nation's critical infrastructure workforce. These recommendations also align directly with other national priorities to achieve greater safety, system performance, economic competitiveness, shared prosperity, and diversity.

NEAR-TERM	MID-TERM	LONG-TERM
1 **Track all spending on critical infrastructure, including interagency efforts,** to provide greater visibility on workforce spending and inform future decision-making.	**4** **Develop national standards** for job quality and training.	**7** **Reshape cultural perceptions of technical careers** by reinforcing the importance and public service benefits of critical infrastructure jobs through sustained education and awareness efforts.
2 **Use executive authority to support best practices**, encourage national standards, and incentivize quality training for essential jobs.	**5** **Launch a public awareness and image campaign** to highlight the importance and opportunity of critical infrastructure careers and jobs.	**8** **Develop a National Workforce Plan** to unify and direct national policy and the necessary resources to support the training and skills needed in critical infrastructure sectors.
3 **Establish a critical infrastructure workforce coordinating council** of federal executives and leadership from key stakeholders.	**6** **Provide increased funding and support to state and local governments** to expand and improve opportunities and access to work-based learning programs.	**9** **Build a workforce development system that connects education to career development** and provides lifelong learning opportunities to critical infrastructure workers.

Jump to the detailed Recommendations in Chapter 4.

Next Steps

The overall performance, safety, and resilience of the Nation's critical infrastructure depends on ensuring that important "people-availability" and "people-readiness" considerations (relevant knowledge, skills, and experience) are fully incorporated into decision-making at all levels. Workforce development requires the same level of care and attention afforded to physical and cyber infrastructure protection. Every investment in the systems and assets that comprise critical infrastructure should be paired with investments in the people responsible for safely designing, building, and maintaining the facilities, systems, and services that make critical infrastructure function.

These recommendations require a whole-of-government approach, strong public-private sector leadership, and meaningful collaboration with other critical stakeholders and constituencies. Meaningful improvement of workforce development for critical infrastructure will require an inclusive approach and sustained participation from a range of stakeholders, including:

- Senior public and private sector infrastructure leadership, organized labor, and other critical constituencies representing the infrastructure sectors;
- Education and training organizations; and
- Important community-based organizations, youth, and families.

To that end, the NIAC sees the establishment of a critical infrastructure workforce coordinating council by the White House as an essential first step and mechanism to ensure the coordinated implementation of the recommendations set forth in this report.

1. Introduction

Critical infrastructure plays an essential role in maintaining the stability of American society. Most definitions describe critical infrastructure as the "systems and assets" vital to U.S. national security, public health and safety, and economic prosperity.[2] That definition, however, overlooks the people who make those systems and assets function, as well as the additional supports and services—such as childcare and transportation—those workers rely on to receive the training necessary to do their jobs safely and efficiently.

Any disruption to those "systems and assets" risks imperiling the safety and stability of American society and so, too, does any disruption to the workforce that supports critical infrastructure. Omitting people from the definition of critical infrastructure has multiple direct and indirect consequences, and the omission of people from infrastructure policy results in a more vulnerable Nation.

This report examines the workforce challenges facing the four "lifeline" sectors—energy, transportation, communications, and water and wastewater—to develop recommendations to improve overall workforce development for critical infrastructure.

The stakes could not be higher, and the challenges are growing. The COVID-19 pandemic wrought significant economic damage and fundamentally changed America's workforce and workplaces. That

[2] "Infrastructure Security," U.S. Department of Homeland Security, accessed September 1, 2021, https://www.dhs.gov/topic/critical-infrastructure-security. The current statutory definition is derived from the U.S.A. Patriot Act. See U.S. Congress, Public Law 107-56, U.S.A. Patriot Act (42 U.S.C. 5195c(e)), October 26, 2001.

economic turmoil continues, with millions of workers looking for new careers or leaving the workforce altogether.[3]

Meanwhile, critical infrastructure systems have endured a range of threats in recent years, from wildfires disrupting the power supply in California, to the widespread power outages and water system failures caused by a winter storm in Texas, to repeated cyber attacks on critical infrastructure systems across the Nation. During the pandemic, the shift to remote work exposed a staggering "digital divide" that excludes millions of Americans from the digital economy (with disproportionate impacts on already-vulnerable populations and rural communities) and put new strains on both telecommunication infrastructure and the workforce itself.

Yet in any crisis, there is opportunity. As the economy recovers, the NIAC believes it is imperative to make critical infrastructure workforce development a central focus of the effort to "build back better."

Defining the Critical Infrastructure Workforce

The U.S. government currently recognizes 16 distinct critical infrastructure sectors "considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof."[4] Based on that designation, the Labor Market Institute estimates that more than 104 million U.S. workers—approximately 71 percent of the total workforce—are employed in a critical infrastructure industry.[5]

Efforts to sharpen the definition of the critical infrastructure workforce have accelerated during the COVID-19 pandemic, as U.S. Government agencies—including the Cybersecurity and Infrastructure Security Agency (CISA)—have issued special guidance to designate and protect "essential" and "frontline" workers who perform enabling functions that require them to be on-site.[6]

> **"Public works professionals make normal happen."**
>
> -Mark Ray, City Engineer and Director of Public Works for the City of Crystal, Minn.

While recognizing that certain jobs have increased strategic importance, this report does not take a position on which critical infrastructure jobs should be considered more essential than others. The NIAC does, however, take a strong position on the need for people-readiness and the obligation the Nation has to provide the knowledge base, strategies, guidance, and accountabilities required to prioritize current and future workforce needs—and meaningfully operationalize what it means to say, "Our people are our greatest resource."

[3] Congressional Research Service, "Unemployment Rates During the COVID-19 Pandemic," updated August 20, 2021, https://crsreports.congress.gov/product/pdf/R/R46554/21; "Job Openings and Labor Turnover Survey News Release," U.S. Bureau of Labor Statistics, August 9, 2021, https://www.bls.gov/news.release/jolts.htm.

[4] "Identifying Critical Infrastructure During COVID-19," Cybersecurity and Infrastructure Security Agency, accessed September 1, 2021, https://www.cisa.gov/identifying-critical-infrastructure-during-covid-19.

[5] William Cook, "Many U.S. Workers in Critical Occupations in the Fight Against COVID-19 (Revised)," LMI Institute, March 29, 2020, accessed August 20, 2021, https://www.lmiontheweb.org/more-than-half-of-u-s-workers-in-critical-occupations-in-the-fight-against-covid-19/.

[6] Cybersecurity and Infrastructure Security Agency, "Guidance on the Essential Critical Infrastructure Workforce: Ensuring Community and National Resilience in COVID-19 Response," August 10, 2021, https://www.cisa.gov/publication/guidance-essential-critical-infrastructure-workforce. For state-level guidance on essential workers, see: "Essential Critical Infrastructure Workforce Tracker," U.S. Chamber of Commerce, accessed August 31, 2021, https://www.uschamber.com/tracking-essential-COVID-19-workers.

Guiding Principles

Our people are our greatest resource. The need for significantly increased investment in 21st century infrastructure—physical, cyber, and "people-readiness"—is a well-documented high-risk challenge facing our Nation's critical infrastructure sectors. A holistic approach to people development ("K to Gray") that incorporates a consistent focus and meaningful progress on expanding diversity is required to improve the critical infrastructure workforce. This means providing equitable opportunity and access to all important entry points to education and training, as well as the resources necessary to begin and advance in critical infrastructure careers. Ensuring a consistent focus on diversity, equity, and inclusion—with particular regard for diversity of race, ethnicity, and gender, as well as young adults, low-income communities, veterans, the disabled, and other under-represented groups and under-resourced communities—will be essential to expanding the supply of talent for critical infrastructure.

As the Nation shifts to more sustainable forms of production and physical infrastructure, it will be essential to provide a "just transition" to workers displaced by technological and economic change.[7] Workers in hard-hit, declining industries deserve the opportunity to find fulfilling and gainful employment. The talent pipeline that feeds critical infrastructure jobs must be adjusted to provide those workers the training and support to upskill or reskill into adjacent industries and professions.

Training must be fast, accessible, and affordable. To effectively meet the challenges ahead, the Nation must meet people where they are and eliminate the burdens or barriers faced by workers who seek the additional training and education necessary for careers in critical infrastructure.

The way forward is together. Work in critical infrastructure is vital to the welfare of the Nation, and we cannot maintain the economic, national security, and public health and safety systems the American people rely on without a strong, diverse, and resilient workforce.

Our Task

In April 2020, the NSC asked the NIAC to conduct an in-depth study on the challenges facing the critical infrastructure workforce and the risks to national security posed by barriers to enhance the Nation's talent pipeline. The NSC instructed the NIAC to focus on **the four lifeline sectors—energy, transportation systems, communications, and water and wastewater systems**—where the lack of a skilled workforce could have dire consequences for economic stability, public safety, and national security, but to develop recommendations that apply across all critical infrastructure sectors.

Specifically, the NSC asked the NIAC to develop near-term recommendations related to trends that require immediate policy intervention and two to three mid- and long-term recommendations to guide future policy development, as well as identify examples of policies and programs that have been particularly effective.

For more information on the workforce of the lifeline sectors, see Appendix B.

[7] Brian Palmer, "This Is What Just Transition Looks Like," The Natural Resource Defense Council, March 2, 2020, https://www.nrdc.org/stories/what-just-transition-looks; Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization, *Initial Report to the President on Empowering Workers Through Revitalizing Energy Communities* (2021), p. 4, https://netl.doe.gov/sites/default/files/2021-04/Initial%20Report%20on%20Energy%20Communities_Apr2021.pdf.

Our Approach

Both the NSC and the NIAC have long recognized the importance of workforce issues, but this is the first NIAC report to focus specifically on the challenges facing critical infrastructure workforce development and worker readiness.

To complete this task (full details of which can be found in Appendix A), the NIAC formed a Working Group to conduct in-depth research and interview a variety of experts to better understand the critical infrastructure workforce and challenges in the identified sectors (Appendix B), examine apprenticeship models used in other countries (Appendix C), and provide case studies to highlight successful practices and programs (included in callout boxes throughout the report and in Appendix D).

The Working Group also formed a Study Group composed of leading experts in fields related to workforce development to inform the Working Group's efforts, and the Study Group interviewed additional specialists as part of its research. A full roster of the Working Group and Study Group, and the experts interviewed by each, can be found in Appendix E.

Since 2006, the NIAC has made 28 recommendations in seven reports related to workforce development. Pertinent examples include:

Securing Cyber Assets (2017)

- Implement a public-private sector employee exchange program
- Expand cyber workforce programs

Water Sector Resilience (2016)

- Initiate a national public outreach plan to increase awareness about the importance of water services
- Create job opportunities and inclusion for local communities

Transportation Sector Resilience (2015)

- Assess the current and future transportation sector workforce

Critical Infrastructure Resilience National Research and Development Plan (2014)

- Identify innovative, cost-efficient, and accelerated approaches to "People Readiness" in developing a skilled workforce

2. The Critical Infrastructure Workforce Development System and Its Challenges

Critical infrastructure relies on a lengthy and complicated talent pipeline to build a skilled workforce and contends with many of the same problems that trouble the U.S. workforce development system in general. This section describes some of the challenges that hinder the critical infrastructure workforce: a fragmented and under-resourced workforce development system; a complex and confusing talent pipeline; poor public perception of critical infrastructure work; lack of diversity; and rapid changes in technology that further expand a growing "digital divide."

Any one of these challenges could cause significant harm to the Nation's critical infrastructure; combined, they have the potential to cause severe and lasting economic, safety, and national security issues. The analysis presented here summarizes the most pressing challenges that shaped the Working Group's findings and recommendations.

Fragmented, Under-Resourced Workforce Development

In the United States, **workforce development is largely addressed at the state level or by the private sector**. The last major piece of federal legislation aimed at improving workforce development, the Workforce Innovation and Opportunity Act (WIOA), was passed in 2014. Although WIOA helped consolidate funding streams and created new performance metrics, it failed to provide the coordination, accountability, and data needed to set the United States on par with other industrial nations.[8]

To help fill the gaps left by the private sector, policymakers need to understand how much training is provided and funded by private employers. The Federal Government has significant blind spots that make it difficult to track progress or coordinate funding and support. Congress stopped funding the Bureau of Labor Statistics' Survey of Employer Provided Training (SEPT) in 1995, which means that policymakers, training providers, and governments can no longer quantify how much job training is provided by the private sector. This data will be essential to assessing and meeting the current and future skills and workforce needs of critical infrastructure.

Incentivizing greater private-sector participation in workforce development is crucial to meeting current and future workforce needs. Small and mid-size businesses need support to create and maintain workforce development and training programs, while all employers need further incentives to support local workers in historically underrepresented communities.

Human Capital and Enterprise Risk Management

Poor management of human capital is the number one challenge facing the critical infrastructure workforce. The U.S. Government Accountability Office (GAO) first designated strategic human capital management as a governmentwide, high-risk area in 2001—and it remains at the top of the GAO's High-Risk List today.[9]

[8] U.S. Department of Labor, *The Workforce Innovation and Opportunity Act Factsheet: Final Rules* (June 2016), https://www.dol.gov/sites/dolgov/files/ETA/wioa/pdfs/WIOA_Factsheets.pdf.
[9] Office of Management and Budget, *Memorandum to the heads of executive departments and agencies,* July 15, 2016, https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2016/m-16-17.pdf; "Strategic Human Capital Management," Office of Management and Budget, accessed August 25, 2021, https://www.gao.gov/highrisk/strategic-human-capital-management.

Human capital refers to the collective "skills, knowledge, and qualifications of a person, group, or workforce" that create value for an organization.[10] Successful management of human capital means ensuring that an organization has the trained personnel necessary to achieve its mission.

Neglecting the strategic importance of good human capital management impedes enterprise risk management, whether in the federal workforce or in critical infrastructure. In broad terms, enterprise risk management refers to the practice of anticipating threats or vulnerabilities that could impair an organization's ability to achieve its goals.[11] In practice, however, many organizations tend to overlook the risks associated with critical skills gaps or poor management of human capital.

As a result, **human capital is often omitted from enterprise risk analyses, just as people are omitted from the definition of critical infrastructure**. The NIAC Working Group's research indicates that people must be an essential part of enterprise risk planning for critical infrastructure owners and operators and the federal agencies with which they partner.

Funding Challenges

Federal funding for workforce development has declined significantly over the last few decades, and the vast majority of funding now comes from the private sector. Private companies contribute as much as 10 times more to training than the federal and state governments combined.[12] With little federal direction, the U.S. workforce development system remains fragmented and often fails to serve either employers or the populations that would benefit the most.

At the federal level, 96 percent of funding comes from four agencies: the U.S. Departments of Labor (45 percent), Education, (30 percent), Health and Human Services (13 percent), and Veterans Affairs (8 percent).[13] The funds from these agencies include those allocated through WIOA.

The distribution of funds from the federal to state level is typically done via block grants, and the process is highly complicated, uncoordinated, and inconsistent. Federal funds typically pass through an array of agencies and institutions before reaching workers or frontline training providers, and the way those funds are spent varies substantially from state to state, as does the information state governments report back to federal agencies.[14]

Private companies contribute as much as 10 TIMES MORE to training than the federal and state governments combined.

Pell Grants—directed primarily to low-income students pursuing two- and four-year degrees or approved professional

[10] "Definition of *human capital*," Merriam-Webster, accessed July 22, 2021, https://www.merriam-webster.com/dictionary/human%20capital.

[11] For more on federal enterprise risk management practices, see: U.S. Government Accountability Office, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk* (December 1, 2016), https://www.gao.gov/assets/gao-17-63.pdf.

[12] Anthony P. Carnevale, Jeff Strohl, and Artem Gulish, *College Is Just the Beginning: Employers' Role in the $1.1 Trillion Postsecondary Education and Training System* (Washington, D.C.: Georgetown University McCourt School of Public Policy, 2015), https://files.eric.ed.gov/fulltext/ED558166.pdf.

[13] Demetra Smith Nightingale and Lauren Eyster, "Results and Returns from Public Investments in Employment and Training," *Investing in America's Workforce* (Kalamazoo, Michigan: W.E. Upjohn Institute for Employment Research, 2018), https://www.investinwork.org/-/media/Project/Atlanta/IAW/Files/volume-three/Results-and-Returns-from-Public-Investments-in-Employment-and-Training.pdf.

[14] "Federal Sources of Workforce Funding," Urban Institute: Local Workforce System Guide, accessed September 1, 2021, https://workforce.urban.org/strategy/federal-sources-workforce-funding.

certifications—also provide significant (though indirect) funding for workforce development, contributing more than $8 billion to workforce education and development each year.[15]

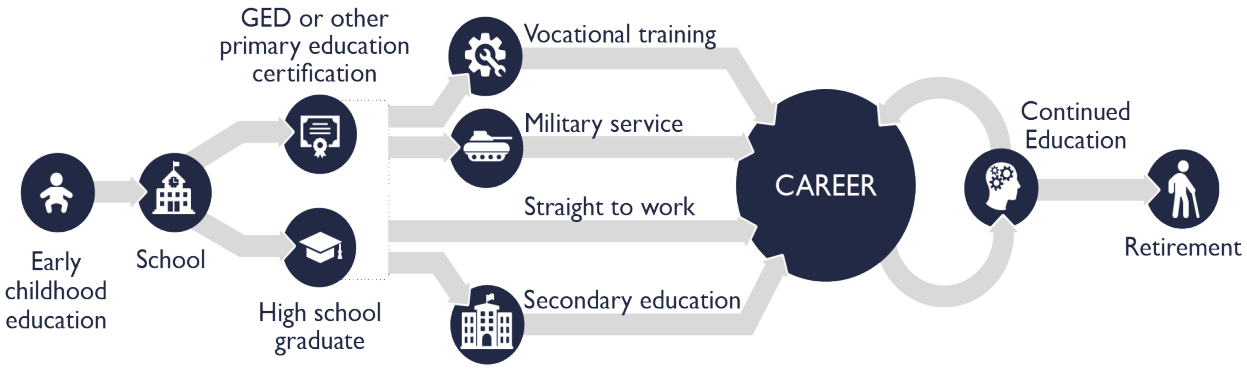
Community and family development grants are also vital to improving workforce development by providing workers with the general support they need to thrive. Programs like the Supplemental Nutrition Assistance Program (SNAP) Employment and Training (E&T) helps recipients of SNAP gain job training to help them get back on their feet, while Temporary Assistance for Needy Families (TANF) funds can help provide cash to low-income families struggling to make ends meet. These programs provide low-income individuals with access to the resources they need to be able to attend and complete job training or certification and help lower the barriers that prevent diverse and low-income individuals from entering the critical infrastructure workforce.

The Talent Pipeline

Economists debate whether the U.S. education system should be considered part of the larger workforce development system. In practical terms, the two systems are only loosely connected and are designed to serve different ends and support individuals at different stages of life. As a 2017 National Academies of Sciences, Engineering, and Medicine report observed, "There is no single, formal system for training workers, and Americans are responsible for finding their own path, based on their preferences, capacities, and means."[16]

An Educational Continuum

The education needed for a job in any of the critical infrastructure sectors is a never-ending continuum that requires lifetime investment and involves all levels of instruction, from early childhood to secondary or post-secondary education, as well as continuing on-the-job professional development. This is best described as a "K to Gray" system.



THE EDUCATION/CAREER-READINESS CONTINUUM

The pathway to a career in critical infrastructure is part of a lifelong educational continuum, with necessary skills for the work attained at all stops along the pipeline no matter which specific path a person takes.

[15] Demetra Smith Nightingale and Lauren Eyster, "Results and Returns from Public Investments in Employment and Training," *Investing in America's Workforce* (Kalamazoo, Michigan: W.E. Upjohn Institute for Employment Research, 2018), p. 101, https://www.investinwork.org/-/media/Project/Atlanta/IAW/Files/volume-three/Results-and-Returns-from-Public-Investments-in-Employment-and-Training.pdf.

[16] National Academies of Sciences, Engineering, and Medicine, *Building America's Skilled Technical Workforce* (Washington, D.C.: The National Academies Press, 2017), p. 63, https://www.nap.edu/read/23472/chapter/6.

A "K to Gray" education encompasses all the learning a person does over the course of their lifetime, not just an individual's formal academic education. Critical infrastructure workers need to learn the hard and soft skills taught in the traditional K–12 system, but they also need continual upskilling to maintain the agility and adaptability demanded by a constantly changing technological landscape. The talent pipeline should be accessible to potential workers no matter where they fall on the continuum.

The typical education-to-career path in the United States often has a narrow emphasis on a traditional four-year degree. We need a system that creates multiple entry points for potential workers and takes full advantage of the diversity of experience within the U.S. workforce, with a particular emphasis on creating better linkage to specialized experiences like career and technical training or military service, which can often take the place of a four-year degree.

Apprenticeships are an especially valuable component of the educational continuum. Traditionally, apprenticeships are a common form of training for infrastructure occupations and often take the place of four-year degrees and formal secondary education.

The North America's Building Trades Unions' (NABTU) Multi-Craft Core Curriculum

Pre-apprenticeship programs provide entry-level workers with the opportunity to acquire some of the industry-recognized skills necessary to enter and succeed in a Registered Apprenticeship Program. Utilizing the Multi-Craft Core Curriculum, NABTU has developed one of the most successful industry-recognized training systems in the world. They also regularly work to streamline the secondary school-to-career pathway in support of underserved and underrepresented communities.

Read the full case study in Appendix D.

Many industrialized nations use apprenticeships to identify and train their workforce at an early age. Apprenticeships in other nations are frequently tied to secondary schools and are closely coordinated with works councils, employers, and governments. In both Germany and Switzerland, for example, over half of the population participates in dual academic and vocational training programs that allow students to acquire-on-the-job training and certifications while pursuing educational degrees.[17]

In the United States, apprenticeships are a growing but underutilized method of workforce development in the 21st century. The two most common types are Registered Apprenticeship Programs (RAPs) and Industry-Recognized Apprenticeship Programs (IRAPs).

RAPs are validated by the U.S. Department of Labor (DOL) or a State Apprenticeship Agency and grant the employer funding opportunities and tax credits to help improve the program. IRAPs are recognized by a Standards Recognition Entity (SRE) pursuant to the DOL's standards. In addition to providing progressively advancing skills, they typically include a paid-work and an educational component and result in an industry-recognized credential.

RAPs and IRAPs are differentiated further by their utility, with RAPs offering more broadly transferrable skills, while IRAPs tend to focus more narrowly on skills that are pertinent to specific roles within specific industries. Unfortunately, relatively few RAPs and IRAPS produce portable or universally recognized

[17] "Apprenticeship System," Apprenticeship Toolbox, accessed September 1, 2021, https://www.apprenticeship-toolbox.eu/germany/apprenticeship-system-in-germany; "Economic Context," Apprenticeship Toolbox, accessed September 1, 2021, https://www.apprenticeship-toolbox.eu/switzerland/economic-context-in-switzerland.

credentials, which restricts worker mobility across and within sectors, industries, or states.[18] Intermediaries, like Jobs for the Future and the National Skills Coalition, have succeeded in helping communities and industries set up RAPs.

For more information on global apprenticeships, see Appendix C.

Barriers to the Pipeline

Even in an educationally inclusive pipeline, there are barriers between potential employees and their chosen professions. **Credentialing** is one of the biggest challenges. Many jobs in critical infrastructure require special training, resulting in job- or industry-specific credentials. Unfortunately, the United States lacks a unified set of standards and processes for obtaining credentials. This hinders the mobility of labor and often presents an undue financial burden for young or prospective workers. Cyber credentials in particular are difficult to maintain given how quickly technologies evolve and how drastically the requirements can change.

Credential Engine: State Policy Partnership

The Credential Engine offers a centralized, searchable database to bring greater transparency to credentialing and ensure a more streamlined pipeline of skilled workers. Since 2016, 19 states have joined the Credential Registry and used the provided data to better meet the needs of employers and job seekers and improve educational access and equity.

Read the full case study in Appendix D.

In addition to credentialing, the requirement of state licenses for occupations is a burden to entering the workforce. Requirements vary by state and are often used to raise revenue rather than provide quality-control mechanisms.

Short training courses targeted toward a specific skill—sometimes referred to as "micro-credentials"—have emerged as one way to quickly train workers.[19] By focusing on specific skills, the certifications received through these programs are more portable and allow employees to attain more senior positions and better demonstrate how their skills translate to different occupations and companies.

Many systems across sectors are similar, so it is essential to workforce readiness that stackable, transferable credentials are utilized whenever applicable. Moveable credentials not only allow owners and operators to bring new employees into the critical infrastructure workforce, but they allow existing employees to grow and advance in their careers, whether they choose to stay in one sector or opt to switch sectors as opportunities arise.

Given the sensitive nature of the work, many critical infrastructure employers—including those operating solely at the local level—also require **federal security clearances**. But clearance processes are often lengthy and pose significant challenges. Examining the Federal Government's clearance process for its own employees, a 2019 GAO report found that "97 percent of the executive branch agencies GAO

[18] Sarah Ayres Steinberg, "National Standards for Strong Apprenticeships," Center for American Progress, August 27, 2014, https://www.americanprogress.org/issues/economy/reports/2014/08/27/96088/national-standards-for-strong-apprenticeships/.
[19] Jordan Friedman, "What Employers Think of Badges, Nanodegrees from Online Programs," *U.S. News & World Report*, January 22, 2016, https://www.usnews.com/education/online-education/articles/2016-01-22/what-employers-think-of-badges-nanodegrees-from-online-programs.

reviewed did not meet the timeliness objectives for initial secret clearance investigations in fiscal year 2018."[20] The wait times for private sector employees can often be longer.

Following the transfer of responsibility for background investigations from the Office of Personnel Management (OPM) to the U.S. Department of Defense (DOD), however, the process has improved substantially.[21] **In 2021, the clearance backlog remained steady at about 200,000 cases, down from nearly 1 million in 2019**.[22] The improvement cannot be considered final, however, and the clearance backlog must be regularly monitored to ensure an expeditious process.

Public Perception of Critical Infrastructure Jobs

The public's overall lack of awareness of the job opportunities in critical infrastructure is a particularly challenging and deep-rooted problem. This is due partly to the U.S. education system's overwhelming focus on a four-year degree track, which discourages students from pursuing technical training. In 2017, the United States spent nearly $2 trillion on education and workforce training across the public and private sectors, with $1.325 trillion going to educational activities and only $516 billion going to workforce training. As a result, **trade jobs have a lingering stigma in American society**.[23]

AT&T's Nanodegree Program

In partnership with Udacity, AT&T offers 23 "nanodegree" programs to help employees learn new skills and stay up to date with the Communications Sector's constantly evolving needs. Programs like this not only help critical infrastructure companies maintain a skilled workforce, but also allow workers financial mobility, as the certifications from such programs are often widely portable between companies. Since launching in 2014, more than 4,000 AT&T employees have graduated from one or more nanodegree programs.

Read the full case study in Appendix D.

In the increasingly interconnected digital world of 21st century infrastructure, however, **the line between "blue collar" and "white collar" jobs is blurring and antiquated**. Although many traditional trade jobs do not require a college degree, most critical infrastructure jobs do require constant on-the-job training and need highly specialized technical knowledge for steady professional growth. Many critical infrastructure jobs are increasingly on the cutting edge of emerging technologies, and nearly all require a high degree of digital literacy, data analytics, and critical thinking.

Improving public understanding of the importance of critical infrastructure—and advertising the rewards of work in these sectors—is essential to building a more diverse and resilient workforce. The Nation's four critical "lifeline" sectors—energy, transportation, communications, and water—offer high-skill, high-wage jobs, ample opportunity for growth, and a chance to serve the serve the community.

[20] U.S. Government Accountability Office, *High-Risk Series: Substantial Efforts Needed to Achieve Greater Progress on High-Risk Areas* (March 2019), https://www.gao.gov/assets/gao-19-157sp.pdf.

[21] Nicole Ogrysko, "Progress on security clearance backlog is real, but federal contractors still seeking end-to-end solutions," *Federal News Network*, February 24, 2020, https://federalnewsnetwork.com/contractsawards/2020/02/progress-on-security-clearance-backlog-is-real-but-federal-contractors-still-seeking-end-to-end-solutions/; Nicole Ogrysko, "Industry urges DCSA to accelerate security clearance transformation efforts," *Federal News Network*, May 27, 2021, https://federalnewsnetwork.com/defense-main/2021/05/industry-urges-dcsa-to-accelerate-security-clearance-transformation-efforts/.

[22] Nicole Ogrysko, "Industry urges DCSA to accelerate security clearance transformation efforts," *Federal News Network*, May 27, 2021, https://federalnewsnetwork.com/defense-main/2021/05/industry-urges-dcsa-to-accelerate-security-clearance-transformation-efforts/.

[23] Credential Engine, *Education and Training Expenditures in the U.S.,* February 2021, http://credentialengine.org/wp-content/uploads/2021/02/Education-and-Training-Expenditures-in-the-US.pdf.

Revamping the image of work in infrastructure as a public service opportunity is important as we work to enhance the public perception of the critical infrastructure workforce. The critical infrastructure workforce "makes normal happen."[24] By promoting the essential nature of the work in critical infrastructure, the workforce can attract potential employees looking for meaningful, community service-oriented jobs, including military veterans.

Lack of Diversity, Equity, and Inclusion

Lack of diversity is a major component of the public perception challenge, as those who can't see themselves in the workforce are unlikely to pursue careers there. Unfortunately, many critical infrastructure sectors do not reflect the communities they serve. This can create disconnects that threaten the provision of services as well as diminish the likelihood that those communities will see critical infrastructure as a viable career path.

According to 2019 U.S. Census Bureau estimates, the Nation is currently 60 percent non-Hispanic white and 50 percent male. However, 58 percent of the civilian labor force is women. And the demographics of the Nation continue to evolve. By 2060, it is expected that people who identify as non-Hispanic white will make up only 44 percent of the population, while women will continue to outnumber men, especially in aging populations.[25] In terms of race and gender, critical infrastructure falls short.[26] In the Transportation Sector, 72 percent of the workforce is white, and only 24 percent women. The electric power generation industry, to cite another example, is 32 percent female and 69 percent white.[27]

Pacific Gas & Electric's (PG&E) PowerPathway Program

PG&E's highly selective, nationally recognized workforce development model helps the utility company enlarge the talent pool for high-skill industry jobs. Students can participate in the program independently or through the curriculum of local community colleges or trade schools. Students of the program receive 320 hours of professional training and education to help them obtain the skills needed for a career in the critical infrastructure workforce. Following completion of the program, participants have the opportunity to meet with trade unions and community groups to find a job. Of those that successfully completed the program, 25 percent have been women, and more than 50 percent have been veterans.

Read the full case study in Appendix D.

An Aging Workforce

The critical infrastructure workforce is also aging, leaving gaps that are difficult to fill as people retire, a trend that has accelerated during the pandemic. High retirement rates, particularly in skilled leadership and senior roles, mean that many industries will face knowledge losses unless they implement sustainable policies to ensure the transfer of industry best practices and information to new and

[24] Cat Zakrzewski, "The Senate's $1 trillion infrastructure bill includes funding to secure Americans' water systems and power grids from cyberattacks," *The Washington Post*, August 14, 2021, accessed August 31, 2021, https://www.washingtonpost.com/technology/2021/08/14/cybersecurity-infrastructure-senate-legislation/.

[25] Jonathan Vespa, Lauren Medina, and David M. Armstrong, *Demographic Turning Points for the United States: Population Projections for 2020 to 2060* (Washington, D.C.: U.S. Census Bureau, February 2020), https://www.census.gov/content/dam/Census/library/publications/2020/demo/p25-1144.pdf.

[26] "Quick Facts," U.S. Census Bureau, July 1, 2019, accessed August 4, 2021, https://www.census.gov/quickfacts/fact/table/US/PST045219.

[27] "Labor Force Statistics from the Current Population Survey, Employed Persons by Detailed Industry, Sex, Race, and Hispanic or Latino Ethnicity," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/cps/cpsaat18.htm; National Association of State Energy Officials, *2020 U.S. Energy & Employment Report* (2020), p. 55, https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5ee78423c6fcc20e01b83896/1592230956175/USEER+2020+0615.pdf.

remaining employees.[28] Critical infrastructure sectors face a particularly unique challenge attempting to replace retirees with new, high-skilled workers who must be familiar with both new technology as well as aging legacy equipment.[29]

The Transportation Systems Sector is particularly impacted by the increasing age of the workforce, with the sector expecting to see high retirement rates over the next six years. In 2020, roughly one quarter of all Transportation workers were over the age of 55, with more than 40 percent of workers in the Mass Transit and Passenger Rail subsector falling in that range.[30] In Freight Rail, retirements are disproportionately taking place in senior positions, representing significant knowledge loss.[31] At the same time, many subsectors have difficulty attracting new employees, as their industries are often viewed as old-fashioned, inflexible, and financially non-competitive. Targeting marketing and outreach initiatives—particularly through new and social media—to youth groups, veterans, nontraditional workers, and employees of diverse backgrounds is one of many steps key stakeholders can take to strengthen the sector's workforce for many years to come.

The need to maintain a strong knowledge base and workforce is particularly vital given the stringent compliance standards set for many infrastructure industries. Anecdotally, the GAO found that multiple water and wastewater utilities had "experienced compliance problems with the Safe Drinking Water and Clean Water acts and some difficulties in hiring certified water operators and other skilled workers." The Bureau of Labor Statistics (BLS) projects that 8.2 percent of existing water operators will need to be replaced annually between 2016 and 2026.[32] In an effort to combat the high turnover, water utilities and operators have created new training programs for employees.

The Impact of the Digital Divide & Advancing Technologies

Training for critical infrastructure jobs often depends on broadband internet access and the digital skills needed to utilize online platforms and resources. Major disparities in both access and adoption, however, have created a digital divide that risks slowing the development of a well-trained workforce.

The digital divide disproportionately affects people living in rural areas and tribal lands, with 30 percent of the rural population having no access to high-speed internet. The divide is greater for low-

[28] "Fabio Bento and Luciano Garotti, "Resilience beyond Formal Structures: A Network Perspective towards the Challenges of an Aging Workforce in the Oil and Gas Industry," *Journal of Open Innovation: Technology, Market, and Complexity* 5, no. 1 (2019): 15, https://www.mdpi.com/2199-8531/5/1/15; "Aging Infrastructure, Aging Workforce Deepen Challenges for the Water Industry," Empowering Pumps & Equipment, July 10, 2020, http://empoweringpumps.com/black-veatch-aging-infrastructure-aging-workforce-deepen-challenges-for-the-water-industry/.

[29] "Labor Force Statistics from the Current Population Survey," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/cps/cpsaat11b.htm.

[30] "Employment in Transportation: Employment in Transportation and Related Industries," Bureau of Transportation Statistics, Department of Transportation, accessed August 31, 2021, https://data.bts.gov/stories/s/caxh-t8jd.

[31] Transportation Research Board, *A Guide to Building and Retaining Workforce Capacity for the Railroad Industry* (Washington, DC: National Academy Press, 2015), https://www.nap.edu/catalog/21904/a-guide-to-building-and-retaining-workforce-capacity-for-the-railroad-industry.

[32] U.S. Government Accountability Office, *Water and Wastewater Workforce: Recruiting Approaches Helped Industry Hire Operators, but Additional EPA Guidance Could Help Identify Future Needs* (2018), https://www.gao.gov/products/gao-18-102.

income families; according to the Pew Charitable Trusts, 44 percent of households with annual incomes below $30,000 have no access to high-speed internet.[33]

Connected Nation

Many U.S. communities lack adequate access to broadband internet and other digital tools viewed as essential in the 21st century, leaving large swathes of the population disadvantaged in education and the workforce. Connected Nation works with federal and state government agencies to provide an array of resources to help local communities bridge this digital divide. Expanded broadband access has been shown to have numerous benefits, including improved civic engagement and accelerated economic development.

Read the full case study in Appendix D.

This divide has severe economic consequences. A 2021 study by Deloitte found that "a 10-percentage-point increase of broadband access in 2014 would have resulted in more than 875,000 additional U.S. jobs and $186B more in economic output in 2019."[34]

Meanwhile, in the 2017 *Report to the President on Emerging Technologies Strategic Vision*, the President's National Security Telecommunications Advisory Committee (NSTAC) assessed the potential effect of advanced technologies, including the implications for the U.S. workforce. In short, advanced technologies will have an impact on operations within every critical infrastructure sector, which is where many new technologies will first be deployed.

The NSTAC identified a range of closely interconnected emerging technologies (e.g., artificial intelligence [AI], quantum computing, the ubiquity of devices, the Internet of Things [IoT]) that enable each other and will impact the Nation's workforce. The continued evolution of advanced technology relies on a strong talent pipeline. Training programs must be adaptable to transition the workforce from old to new and emerging technologies. These programs can take several forms, including scholarship programs, apprenticeships, certification programs, and bootcamps—demonstrating that four-year degree programs are not the only way to advance careers or build skillsets. Another alternative is the expansion of existing programs at high schools, universities, and community colleges.

The workforce must adapt alongside these new technologies to ensure critical infrastructure continues to operate in a safe, efficient, and resilient manner. Providing affordable, accessible, safe, and secure broadband access to rural populations, people of color, and low-income communities must be a priority for developing the workforce.

For detailed information on the workforce of the "lifeline sectors," see Appendix B.

[33] Joyce Winslow, "America's Digital Divide," Pew Charitable Trusts, July 26, 2019, https://www.pewtrusts.org/en/trust/archive/summer-2019/americas-digital-divide.

[34] Jack Fritz and Dan Littmann, *Broadband for all: charting a path to economic growth* (Deloitte, April 2021), p. 1, https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-charting-a-path-to-economic-growth.pdf.

3. Findings

Based on the research, interviews, and input from experts, the NIAC Working Group found that the absence of a strong, unifying national workforce policy has created a range of barriers for critical infrastructure workers. These findings highlight the most significant challenges and opportunities.

FINDING 1

Worker readiness is disconnected from the traditional education system.

The absence of a strong, unifying national workforce policy leaves the Nation without clear goals and metrics to connect education with career development. **At the national level, educational attainment varies substantially, and the United States is deficient in many of the core competencies needed for critical infrastructure occupations.**[35] Meaningful change to STEM (science, technology, engineering, and math) education must come from the bottom up, but reform must also be directed from the top by strong national policy and strategy.

The future resiliency of the critical infrastructure workforce depends on a multi-part "K to Gray" system that includes both a K–12 system that reliably provides students with core skills and proficiencies and a nimble technical training system that provides workers with new skills quickly and efficiently.

The traditional emphasis on primary and secondary instruction, and on college and university degrees at the post-secondary level, coupled with the imbalance between career technical education (CTE) and college-bound training, all effectively work to *de facto* promote the four-year degree as the automatic default. This stymies young adults and others who simply do not want to pursue a college degree, and results in a lack of career awareness. **As a result, adult learners and workers seeking additional training receive little support.** Community colleges meet some of this need but are often chronically under resourced. Much of the training necessary to meet the current and future needs of critical infrastructure will happen outside of the traditional education system, making it imperative to develop new mechanisms to meet those needs and a clear national strategy to close the gap between education and workforce readiness.

The Virtual Apprenticeship Network by the AACC

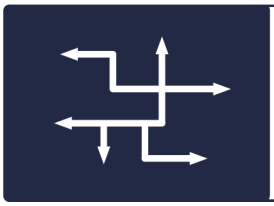
Community colleges play an essential role in U.S. workforce development. With a current membership of nearly 1,200 degree-granting institutions enrolling over 12 million students, the American Association of Community Colleges (AACC) is the "voice of America's community colleges." The Virtual Apprenticeship Network connects businesses and AACC partners to find qualified workers. Between May 2019 and April 2021, the program successfully trained 11,082 new apprentices in 454 different occupations.

Read the full case study in Appendix D.

[35] National Science Foundation, "Science & Engineering Indicators 2020: State of U.S. STEM Education," September 5, 2019, https://nsf.gov/nsb/news/news_summ.jsp?cntn_id=299150; U.S. Department of Defense, *Fiscal Year 2020: Industrial Capabilities, Report to Congress* (January 2021), p. 12, https://media.defense.gov/2021/Jan/14/2002565311/-1/-1/0/FY20-INDUSTRIAL-CAPABILITIES-REPORT.PDF.

Many jobs in the critical infrastructure sectors require only a high-school diploma or the equivalent; few require more than a bachelor's degree. According to a recent report from Georgetown University, more than 50 percent of infrastructure jobs require only a high-school diploma or less. Only 11 percent of jobs require a bachelor's degree, while a mere 4 percent require a graduate degree.[36]

Critical infrastructure makes normal happen, but for many Americans, the systems and assets that make everyday life possible fade into the background—and so, too, do the men and women who maintain them. Owners and operators must work cooperatively and deliberately with policymakers and educators to elevate the public image of critical infrastructure jobs and promote the training and skills necessary to maintain the safety, stability, and health of American life.



FINDING 2

Lack of coordination between the public and private sectors and across all levels of government hampers critical infrastructure workforce development.

Different sectors and industries often use different standards, certifications, and licensing, even for similar skill sets and occupations. Without consistent standards or universally recognized and transferrable credentials, workers face a variety of challenges as they seek to advance in their careers or move between industries or regions.

Poor national coordination also creates inefficiencies in workforce funding. At the national level, DOL provides significant—but not sufficient—funding for job training and placement services, mostly in the form of block grants to states. However, the Federal Government provides little oversight or coordination between agencies or with state governments to ensure that national workforce policy is aligned to the current and future needs of critical infrastructure.

Without strong national policy, **policymakers and owners and operators alike lack the data or direction necessary to ensure resources are allocated to need**. As a result, decisions are often made without complete information and without the perspective of other essential stakeholders, such as educators, training providers, and organized labor leaders, who will have significant influence over the equity of any policy implementation.

The "Children's Cabinets" Model

Collaborative-action bodies that bring the public and private sectors together at the community level are an effective mechanism to compensate for fragmented funding systems and policy areas. In the realm of childhood development and education, the "Children's Cabinet" model plays an important role in building connections for a more coordinated approach at the municipal and county level. The Children's Cabinet pinpoints resources and builds connections for a more coordinated approach at the local and municipal level.

Read the full case study in Appendix D.

[36] Anthony P. Carnevale and Nicole Smith, *15 Million Infrastructure Jobs: An Economic Shot in the Arm to the COVID-19 Recession* (Georgetown University Center on Education and the Workforce, 2021), https://1gyhoq479ufd3yna29x7ubjn-wpengine.netdna-ssl.com/wp-content/uploads/cew-15_million_infrastructure_jobs-full_report.pdf. See also "Skills Mismatch: Lack of Access to Skills Training Hurts Workers and Business," National Skills Coalition, accessed August 27, 2021, https://www.nationalskillscoalition.org/wp-content/uploads/2020/12/US-Skills-Mismatch-Fact-Sheet-2020.pdf.

FINDING 3

Lack of diversity presents significant and persistent challenges for recruitment and retention.

The national workforce is in the midst of a broad demographic transformation.[37] However, many critical infrastructure industries and professions remain largely white and male, and **many infrastructure service providers fail to reflect the communities they serve**.[38]

At the executive level, the absence of diverse voices within corporate leadership makes critical infrastructure less knowledgeable and responsive to the needs of the community.

At the community level, applicants who do not see themselves reflected in the critical infrastructure workforce are unlikely to pursue careers in those industries, limiting the pool of potential and future workers. Applicants from minority or underserved populations also face additional cultural, economic, and practical challenges when seeking employment in critical infrastructure professions.

BAYWORK

BAYWORK stakeholders are dedicated to recruiting and training the next generation of water and wastewater industry professionals. The partnership is made up of 39 signatories that promote workforce development through various outreach activities. The organization increases the visibility of viable careers in water, facilitates relationships between underserved and disadvantaged communities and trade professionals, and helps remove barriers to entry in water and wastewater careers.

Read the full case study in Appendix D.

A variety of programs have successfully improved diversity, equity, and inclusion. Second chance programs are important vehicles for economic opportunity and social justice, and federal agencies can improve hiring in occupations of critical need by easing restrictions on hiring individuals previously involved with the justice system for non-violent offenses. Employers can also partner with training providers to ensure that workers have the support they need to seek training.

Veterans transitioning to civilian life also offer a valuable opportunity to quickly expand the supply of skilled labor and improve diversity. Roughly 31 percent of active military service members identify as part of a racial minority group, while women make up 10 percent of the overall veteran population.[39] Approximately 200,000 veterans transition to civilian life every year, and the U.S. Armed Forces invest significant resources into training military personnel, including in many jobs that translate directly or with minimal upskilling into critical infrastructure professions.[40]

[37] "Generations: Demographic Trends in Population and Workforce (Quick Take)," Catalyst, March 2, 2021, https://www.catalyst.org/research/generations-demographic-trends-in-population-and-workforce/.

[38] "Labor Force Statistics from the Current Population Survey, Employed Persons by Detailed Industry, Sex, Race, and Hispanic or Latino Ethnicity," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/cps/cpsaat18.htm.

[39] "Veterans' Employment and Training Service: Demographics," U.S. Department of Labor, accessed August 2, 2021, https://www.dol.gov/agencies/vets/womenveterans/womenveterans-demographics.

[40] Department of Defense, Office of the Deputy Assistant Secretary of Defense for Military Community and Family Policy, *2019 Demographics: Profile of the Military Community*, accessed September 1, 2021, https://download.militaryonesource.mil/12038/MOS/Reports/2019-demographics-report.pdf; "Your VA Transition Assistance Program (TAP)," Department of Veterans Affairs, last updated June 9, 2021, https://www.benefits.va.gov/transition/tap.asp.

4. Recommendations

The Nation's critical infrastructure workforce challenges require a whole-of-nation approach focused on stronger coordination, development of national standards, and a larger cultural shift in how we talk about, resource, and perceive the technical jobs necessary to plan, design, build, maintain, operate, and restore the infrastructure essential to our survival.

For each recommendation, the NIAC has identified a lead organization or agency responsible for implementation, as well as primary support roles for agencies or partners that will need to provide significant input, expertise, and assistance.

In keeping with the NSC's guidance, the NIAC has identified a series of near-, mid-, and long-term recommendations—but all require immediate action. The timing reflected here is intended to provide a sense of sequence and an acknowledgment that some of the recommendations outlined here will take time to develop, implement, and mature.

Near-Term Recommendations

The challenges before the Nation are significant, but much can be accomplished under the existing authorities of the White House and federal agencies. The recommendations outlined below represent a first step, and the NIAC urges that they be implemented within 12 months of the issuance of this report.

RECOMMENDATION 1

Track all spending on critical infrastructure, including interagency efforts, to provide greater visibility on workforce spending and inform future decision-making.

The White House's Office of Management and Budget (OMB) is the most important accounting and resource management office in the Federal Government. Closely tracking federal commitments to and spending on critical infrastructure projects will provide greater visibility on the flow of funding and the amount specifically allocated to workforce development, allowing greater insight into training as a percentage of overall infrastructure investment.

This improved visibility will provide some of the data necessary to identify resources eligible for workforce development purposes, track actual expenditures, identify significant gaps, and pinpoint opportunities to better align funding, improving the overall efficiency of critical infrastructure spending. This spending analysis should track and analyze projects and workforce development programs across federal agencies, including information on performance measures and outcomes.

Lead: Office of Management and Budget
Support: U.S. Department of Labor, U.S. Department of Education, U.S. Department of Homeland Security, and Sector Risk Management Agencies

RECOMMENDATION 2

Use executive authority to support best practices, encourage national standards, and incentivize quality training for essential jobs.

Many of the changes necessary to improve critical infrastructure workforce development will take time to mature, but the Federal Government has significant leverage and authority to begin making those changes now and ensure they are implemented on a national basis by making relatively minor adjustments to procurement practices, grant criteria, and government benefits.

Specific actions include:

A. Adjust Workforce Innovation and Opportunity Act (WIOA) grant criteria to prioritize applications that provide training for in-demand critical infrastructure occupations.

- **i.** WIOA grant applications are judged based on criteria scores that target communities, sectors, and job quality. In the future, adjust the criteria to include evaluation factors that align with identified national high-risk workforce priorities and specialized needs. Award additional points to those applications that provide training for specific sectors or occupations of urgent need.

B. Set federal procurement targets to promote national standards and best practices.

- **i.** Require all private companies bidding on federally funded infrastructure projects or grants to meet specific benchmarks, such as providing a documented corporate and project-based workforce development plan and partnering with knowledgeable community-based practitioners and stakeholders, wrap-around service providers, disability employment practitioners, and second chance and youth opportunity programs.
- **ii.** Reward efforts to improve job quality and provide universal skills (i.e., work safety certification, digital literacy/proficiency, or basic practical math and literacy).
- **iii.** Set standards for good jobs and wages, hiring from the local community, and employing workers across levels of education and credentials as part of the eligibility criteria to promote diversity, equity, and inclusion.
- **iv.** Consider removing or revising hiring restrictions and other barriers to employment to increase opportunities for equity and inclusion initiatives such as second chance and work-release programs, with a focus on non-violent offenders, including the implementation of pilot programs.

C. Redefine or amend the statutory definition of critical infrastructure to include workforce.

- **i.** The current definition of critical infrastructure is derived from the U.S.A. Patriot Act, section 5195c(e). The White House should investigate whether redefining critical infrastructure using other templates in U.S. statute will require legislative action or could be accomplished via executive order.
- **ii.** Strengthen Federal Enterprise Risk Management practices to explicitly incorporate Human Capital Risk (HCR) more fully into the overall risk-management structures of the Nation's critical infrastructure sectors (i.e., safety plans, asset management plans, capital plans).

Include critical infrastructure sector grantees, owners and operators, and contractors providing or performing essential services.

Lead: White House, U.S. Department of Labor, Office of Management and Budget
Support: U.S. Department of Labor, U.S. Department of Education, Department of Veterans Affairs, and other relevant federal agencies

RECOMMENDATION 3

Establish a critical infrastructure workforce coordinating council of federal executives and leadership from key stakeholders.

Workforce development policy for critical infrastructure needs stronger nationwide coordination across the Federal Government; among state, local, tribal, and territorial (SLTT) governments; and between the public and private sectors. The emphasis must be on working cooperatively, building connections, and involving a wide range of stakeholders to build lasting consensus and ensure the breadth of perspective necessary to ensure that recommendations are fact-based, inclusive, and centered on equity. The council must avoid perpetuating the status quo or favoring one industry or region over another.

The initial focus for the council will be to provide a forum for exchanging information, identifying gaps, and providing the cross-sector and interagency coordination that is currently lacking at the national level, and at the same time provide a meaningful opportunity for input from important nongovernmental stakeholders and constituencies.

A. Identify a lead within the White House and select senior executive stakeholders from government and critical infrastructure sectors to form the council.

i. Sustained executive-level engagement is essential for improving coordination. A single individual within the Executive Office of the White House should lead the creation of the council and be able to pull together a successful team of executive-level representatives from the relevant federal agencies—such as the Departments of Labor and Education—and the private sector.

ii. The council should comprise diverse leaders across the public and private sectors, including: relevant federal agencies; critical infrastructure owners and operators; SLTT governments; regional groups; local workforce development boards (WDBs); organized labor; youth groups; relevant nonprofit and community-based organizations; and private sector and other relevant stakeholders and constituencies.

iii. The White House lead will report directly to the Executive Office and will develop an annual work plan to help guide implementation of the council's recommendations by working with the White House, relevant government agencies, and other federal councils with charters focused on the Nation's critical infrastructure sectors.

B. Establish governance structure and guidelines to ensure the council is sustainable and successful.

i. The White House will define the governance structure, roles, responsibilities, and authority of the council, as well as the resources necessary to successfully execute its mission in a charter.

ii. The initial charter should establish the council for two years, with the option for the White House to extend or amend the goals and responsibilities based on the council's progress and success.
iii. The objective of this team is to define a set of enforceable responsibilities including synchronizing local, regional, and national efforts; developing national standards; and aligning funding streams. The council's initial task will be to advise on implementation of the recommendations captured in this report.
    a. The council will lead development of national workforce standards based on the enhanced data collection called for in Recommendation 4.
iv. The White House will set clear milestones for the council to ensure it is meeting its goals and objectives.
    a. The council will have 90 days to get set up and must submit their first report to the White House six months after establishment.
    b. Following the initial six-month status update, the council should submit quarterly reports to the White House on progress made toward achieving the defined goals and objectives.

C. Conduct outreach to key partners to gather perspectives and needs.

i. Engagement with public-private partnerships, industry associations, workers' rights groups, and other stakeholders is necessary to ensure the council's work is inclusive and captures perspectives and needs beyond the group's membership.

Lead: White House
Support: U.S. Department of Labor, U.S. Department of Education, U.S. Department of Homeland Security (as critical infrastructure convener), and Sector Coordinating Councils

Mid-Term Recommendations

The near-term recommendations described above focus on making immediate changes and establishing better mechanisms for coordination. The mid-term recommendations below focus on maturing those mechanisms, developing greater cohesion and consensus, and moving the country toward a more robust and resilient workforce development system for critical infrastructure. The NIAC estimates these recommendations will take two to three years to implement.

RECOMMENDATION 4

Develop national standards for job quality and training.

The development of national standards is a critical first step toward a shared understanding of core competencies and skills. The establishment of clear national standards, in turn, will drive greater portability of credentials (between industries, sectors, occupations, and geographic regions) and more consistent training. Articulating those standards, however, will require better data from the Federal Government to identify gaps, measure success, and achieve better coordination between state governments and private sector partners.

Policy must be fact-driven, and a coordinated national approach will require substantial dialogue and engagement from private sector partners and critical infrastructure owners and operators.

A. Provide the funding and access for enhanced data collection needed to develop national standards for job quality and training.

i. Provide the Bureau of Labor Statistics (BLS) with better access to state-level labor and employment data. To assist with better access to state and local data, active stakeholder engagement is required to encourage buy-in from state governments.

ii. Fund the BLS's Survey of Employer-Provided Training (SEPT). In 1993 and 1995, the SEPT provided detailed information on training by industry and company. SEPT data was used by government, private industry, and the academic community to determine the major types of training that American workers receive from their employers.[41] With renewed funding, the survey should be conducted on an ongoing basis (i.e., every two to five years) to fill an important strategic gap in current economic analysis.

iii. Add new questions to the Quarterly Census of Employment and Wages (QCEW) to incorporate data points such as hours, job title, work location, and demographics. The QCEW is a federal/state cooperative program that publishes reports of employment and wages filed by employers each quarter covering more than 95 percent of U.S. jobs, available at the city, county, state, and national levels by industry.[42] The BLS uses the QCEW data as the benchmark source for employment, and it serves as a central input for other federal and state programs.

B. Convene relevant federal agencies to develop national standards.

i. The critical infrastructure workforce coordinating council should convene the federal agencies, critical infrastructure owners and operators, workforce development experts, and other key stakeholders to take part in a transparent process.

ii. Advisory and oversight groups, like the National Academies of Sciences, Engineering, and Medicine and the National Transportation Safety Board, should be tapped to provide a cross-sectoral look at existing and proposed standards.

Lead: White House, Critical infrastructure workforce coordinating council
Support: Secretaries of the relevant Sector Risk Management Agencies (Primary) and other federal agencies as appropriate

RECOMMENDATION 5

Launch a national public awareness and image campaign to highlight the importance and opportunity of critical infrastructure careers and jobs.

One of the greatest hurdles to building a sustainable pipeline of critical infrastructure workers—including leaders, inventors, entrepreneurs, and the skilled workforce—is that people are not aware of the skills needed or the wealth of career opportunities available in the sectors. Affecting this kind of cultural change will require a whole-of-nation approach that addresses a range of interconnected preferences and assumptions to communicate that critical infrastructure jobs are a form of public

[41] "Survey of Employer-Provided Training," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/ept/eptover.htm.
[42] "Quarterly Census of Employment Wages," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/cew/.

service, and that trade jobs and technical careers are honorable and invaluable professions that ensure the stability of American life.

A targeted public awareness effort by the White House will draw attention to the abundant, well-paid career opportunities that exist within critical infrastructure industries across experience, training, and education levels. Increasing the knowledge and awareness of critical infrastructure as a career path is intended to support more interest in these crucial jobs. Public education campaigns will require sustained funding to affect social and cultural change, and any resources put into expanding training resources and opportunities will be more effective when backed by a robust messaging campaign.

A. Develop a multi-pronged approach that engages workforce stakeholders across the Nation.

i. Develop a task force that includes workforce development experts, critical infrastructure employers, education experts, state, local, tribal, and territorial (SLTT) governments, federal agencies, and others to help assess the existing messaging around critical infrastructure work and to identify key messages and share information within their networks.
ii. Support all communications efforts with best-in-class marketing efforts to ensure the "brand" of critical infrastructure is well-defined.
iii. Encourage critical infrastructure owners and operators to publicly pledge support to the effort. This could also help call attention to the need to share information and highlight innovative practices.
iv. Deploy formal and informal national advertising campaigns.
v. Engage younger potential workers through innovative, youth-focused programming and new and social media campaigns. Reaching new generations of workers where they are will help ensure a strong, vital critical infrastructure workforce for years to come.
vi. Ensure conversations about the critical infrastructure workforce are occurring outside of the workplace by developing outreach to parents, educators, guidance and career counselors, and other community leaders that will meaningfully supplement youth outreach programs.

B. Educate employers about available government-sponsored training programs.

i. WIOA provides grants for businesses, training partners, and governments to set up data and information exchanges and regional/sectoral partnerships. Employers can engage in these partnerships to provide input on the skills necessary for economic development in their region.
ii. The Department of Labor (DOL) provides wage subsidies to bring in and support workers while they train for full-time jobs and has extensive Registered Apprenticeship Program grants to develop training models that are effective and sustainable.

C. Include a focus on veterans transitioning to civilian life.[43]

i. Owners and operators should work with the Department of Veterans Affairs (VA) to develop guides that help utilities and other infrastructure service providers match skills to military occupational specialties and recruit veterans returning to civilian life.

D. Develop K–12 curricula on the basics of critical infrastructure.

i. A federal program that connects K–12 and college education to the workforce must be developed to guide students at all levels to improve cyber skills and understanding of critical infrastructure.

ii. Curricula should include a focus on cyber hygiene to help students develop the skills necessary for an increasingly digital world. An early education in cyber literacy will provide students with the foundation needed for lifelong cyber education and foster early understanding of the need for and options available in critical infrastructure jobs.

iii. Owners and operators must improve early exposure and awareness of opportunities in critical infrastructure by working with educational providers to develop curricula on the basics of critical infrastructure and its role in supporting everyday life.

Lead: White House, critical infrastructure workforce coordinating council
Support: U.S. Department of Labor, U.S. Department of Education, Sector Risk Management Agencies, and other relevant federal agencies; critical infrastructure owners and operators; SLTT governments, workforce development and education experts, and other stakeholders

RECOMMENDATION 6

Provide increased funding and support to state and local governments to expand and improve opportunities and access to work-based learning programs.

Work-based learning (WBL) programs provide young people with opportunities to gain valuable hands-on work experience and develop the skills needed to compete in the labor market while in high school. A 2021 state-by-state analysis conducted by American Student Assistance and Bellwether Education Partners identified four key components of successful state WBL programs: broad eligibility, state funding, quality and accountability standards, and infrastructure to support WBL programs.[44]

The importance of funded work-based learning stood out clearly in the NIAC's research and conversations as one of the most important mechanisms to expose young people to the opportunities in critical infrastructure and get them interested in the systems that make modern life possible. WBL programs can be more inclusive by providing different styles of instruction and can foster greater awareness of the different kinds of training and work that can lead to fulfilling careers.

[43] U.S. Environmental Protection Agency, *From M.O.S. to J-O-B: A Guide for Applying Military Occupational Specialties (M.O.S.) to Civilian Drinking Water and Wastewater Operations* (April 2014), https://nepis.epa.gov/Exe/ZyPDF.cgi/P100NGJS.PDF?Dockey=P100NGJS.PDF.
[44] Kelly Robson, Jennifer O'Neal Schiess, and Julie Lammers, *Working to Learn and Learning to Work: A state-by-state analysis of high school work-based learning policies* (Washington, D.C.: American Student Assistance and Bellwether Education Partners, March 2021), p. 3, https://file.asa.org/uploads/Learning-to-Work-and-Working-to-Learn.pdf.

A. Incentivize school systems to offer more work-based learning opportunities through Department of Education grants with matching federal funds for state initiatives.

i. Call for states to offer WBL opportunities and incorporate the programs into high school graduation requirements.
ii. Develop a sustained educational program to ensure teachers, counselors, parents, and students are aware of opportunities.

B. Engage critical infrastructure owners and operators in developing formal training curricula to meet new standards of job quality and training and create more educational work opportunities in the private sector.

i. At the regional level, owners and operators can become more involved with their local school systems to create more opportunities for work-based learning, and the expansion of such programs will help increase the connections between educators and employers at the local level.
ii. Critical infrastructure owners and operators should work with a range of education partners to develop specialized formal curricula to encourage skill development consistent with national job training standards.
iii. Owners and operators should work to expand the opportunities for hands-on training through mentorships and paid internships and externships, particularly focused on potential workers not otherwise engaged through a credit-bearing education program, including minorities, veterans, the disabled, and other underrepresented and disadvantaged groups.
iv. The Federal Government must incentivize the private sector, including small and mid-size businesses, to maintain and expand their workforce development programs.

Lead: U.S. Department of Education, U.S. Department of Labor
Support: Critical infrastructure workforce coordinating council, critical infrastructure owners and operators

Long-Term Recommendations

The near- and mid-term recommendations described above are largely tactical in nature; the long-term recommendations described below are strategic and intended to shape systemic change. They center on creating a system that treats education and career development as a single spectrum, rather than two largely distinct systems, while also addressing the challenges that are unique to critical infrastructure. The work below is rooted in the recommendations described above, and the NIAC believes these actions will take four to five years to implement.

RECOMMENDATION 7

Reshape cultural perceptions of technical careers by reinforcing the importance and public service benefits of critical infrastructure jobs through sustained education and awareness efforts.

Critical infrastructure work requires a wide range of skills and occupations, many of which are high-tech and on the cutting edge of their respective fields. However, the public does not fully understand the nature of this work and the opportunities available. Building on the national public awareness campaign

(Recommendation #5), a sustained whole-of-nation approach will reframe how we think and talk about critical infrastructure careers to ensure we have workers prepared to meet the challenges of tomorrow.

Engagement at the community level is essential. We need to encourage a bottom-up approach to communicate to the public that critical infrastructure jobs provide opportunities to build lucrative careers and serve the public. Encouraging broader public awareness of critical infrastructure careers will reduce hesitation, but it will require deliberate effort to overcome the history of dual-tracking (when minority students are encouraged to pursue trade skills while white students are encouraged to get four-year degrees) and explain the breadth of opportunities available in critical infrastructure fields.

A. Build additional public-private partnerships to create sustained education and awareness campaigns at the regional, state, and local levels to highlight the nature of critical infrastructure jobs.

- **i.** Partner with community groups (e.g., religious entities, social clubs, youth organizations, professional associations) and school districts (including Historically Black Colleges and Universities and other minority-serving institutions, as well as community colleges) to help connect people to programs.
- **ii.** Recruit ambassadors, such as young or advancing critical infrastructure workers, and highlight prominent voices from within the community, with an emphasis on women and minorities.
- **iii.** Partner with existing organizations working in the community on workforce development, social justice, economic empowerment, or environmental justice.

Lead: Critical infrastructure workforce coordinating council
Support: SLTT government partners, nonprofits, workforce development organizations, educational experts, and other stakeholders

RECOMMENDATION 8

Develop a National Workforce Plan to unify and direct national policy and the necessary resources to support the training and skills needed in critical infrastructure sectors.

We need deliberate, thoughtful policy at the national level to unite critical infrastructure workforce development in common purpose and direction. A national plan would provide the framework and guidance needed to direct efforts at the federal, state, and local levels and be based on analysis of enhanced data collection (see Recommendation #4). It should develop a common view and shared vision of critical infrastructure jobs and training; identify needs across sectors, industries, and regions; and outline policy solutions and programs needed to address the identified needs.

A. Conduct regular audits of workforce policy to assess and reassess the state of critical infrastructure jobs and training, akin to military force readiness.

B. Assess workforce policy to ensure the necessary skills are developed to continue to meet the challenges in the future.

Lead: Critical infrastructure workforce coordinating council
Support: U.S. Department of Labor, critical infrastructure owners and operators, workforce development and education experts, SLTT governments, and relevant federal agencies

RECOMMENDATION 9

Build a workforce development system that connects education to career development and provides lifelong learning opportunities to critical infrastructure workers.

We need to recognize that the traditional education path of K–12 and on to a four-year degree program at a college or university does not serve all Americans equally well and provides relatively few paths into the talent pipeline necessary to sustain critical infrastructure. This system needs to be reconsidered and modernized. We also must recognize that any effort to quickly provide the U.S. workforce with new skills will take place largely outside of the traditional education system.

We need a more comprehensive, inclusive system capable of keeping the workforce nimble and resilient in the face of change to ensure the continued integrity of critical infrastructure, and one framed through the needs and eyes of the trainees and frontline training providers. The NIAC believes there is a great opportunity here to join with other leading voices to modernize our traditional 20th century education and workforce system in the direction of a "K to Gray" system that quickly provides training to workers in a variety of different life stages and closes the gap between education and career development, making it more relevant and effective in the 21st century.

As the country reckons with the legacy of historic economic injustice, there is also an opportunity to create a workforce development system that goes beyond mere job training to one that invests in both jobs and communities by providing universal skills and clear paths to hiring, career development, and economic mobility, and the NIAC urges critical infrastructure owners and operators to help lead the way.

A. Build a system that connects K–12 education to career development that better serves people who choose not to immediately pursue a four-year degree following completion of their primary education, provides career development services early, and fosters lifelong learning opportunities.

B. Partner with businesses and employers to promote earlier career exposure during the primary and middle grades and expand mentoring and internship opportunities.

C. Partner with unions, trade organizations, and industry associations to build out pre-apprenticeship programs and connect them to local school districts.

D. Support access to pre-apprenticeship programs and affordable childcare, as well as other wrap-around services such as transportation, to help women, parents, and underrepresented populations succeed.

E. Ensure 100 percent accessible, affordable, safe, and secure broadband access to the entire Nation so no communities are left behind.

Lead: Critical infrastructure workforce coordinating council
Support: Department of Labor, Department of Education, and other appropriate federal agencies and stakeholders

5. Call to Action and Opportunity

Workforce development is a well-documented high-risk challenge facing our Nation's critical infrastructure sectors, and the problem has been further exacerbated by the COVID-19 pandemic. The Nation needs significant investments in 21st century infrastructure—in terms of physical, cyber, and people-readiness. Urgent action is needed to rebuild a strong 21st century workforce capable of facing all current and future challenges. Failure to act poses an existential threat to our national security.

Looking to the future, the Nation needs a strong, unifying national policy that connects education to career development to provide *all American workers* with lifelong learning opportunities and support. We must work to create the systemic, institutional, and cultural changes necessary to develop the deep partnerships needed to support our workers. We must also provide the necessary resources and accountabilities to drive best-in-class results.

Rebuilding the Nation's infrastructure has become the centerpiece of an inclusive economic recovery plan. As millions of Americans seek new careers and employment possibilities, we have a singularly unique opportunity to develop the policies and practices necessary to help every American achieve their potential. Leaders and policymakers across the political spectrum have the chance to invest in a future that benefits every American.

The NIAC's recommendations stress the necessity of executive leadership, meaningful public-private partnerships, fact-informed decision-making, and more rigorous business processes that allow the workforce to continue to "make normal happen." The path forward requires that we join forces to modernize and expand our overall workforce development system to include a revitalized "K to Gray" approach to education.

The world is changing, and we must act now to keep our critical infrastructure workforce agile, nimble, and ready to adapt to new challenges. We not only need to improve our education system, but our lifelong education expectations and opportunities to ensure that *all Americans share in the prosperity of our Nation*.

Work is already underway in both the public and private sectors, and the case studies identified throughout this report point the way forward. But we must be intentional, we must be inclusive, and we must start today.

Appendix A: Study Methodology

The United States depends on a secure and resilient critical infrastructure, which underpins all aspects of modern life. These critical infrastructure systems rely on a skilled workforce to operate effectively and reliably with continued operations, regardless of the threats the Nation may face. The 2020 *National Counterintelligence Strategy* aptly states, "a disruption of U.S. critical infrastructure could undermine our Nation's security, economy, public health and safety in a variety of ways."[45]

The National Security Council (NSC) asked the President's National Infrastructure Advisory Council (NIAC) to examine the challenges facing the critical infrastructure workforce and investigate the potential risks such challenges pose to U.S. national security. This appendix outlines the NIAC's approach to this tasking.

Charge to the NIAC

On April 27, 2020, the White House, through the NSC, tasked the NIAC with conducting an in-depth study on the challenges facing the critical infrastructure workforce and the risks to national security posed by a lack of skilled workers. The NIAC was asked to focus on a limited set of sectors but developed recommendations across all sectors. Additionally, the NSC directed the NIAC to develop near-term and long-term recommendations to improve worker readiness to ensure the continuity of the Nation's critical infrastructure sectors.

The NIAC was charged with examining whether critical infrastructure workers have the skills needed to operate, repair, or restore infrastructure in an emergency and in steady state; identifying training needed; and determining how to shape the workforce and education systems to meet demand for certain skillsets to operate critical infrastructure.

On December 3, 2020, the NSC further refined the scope of the study to focus on:

- Focus on the four lifeline sectors: energy, transportation systems, communications, and water and wastewater systems.
- Provide examples of policies that have been effective or counterproductive for workforce resilience. Recommended areas of consideration included:
    - Cybersecurity education, training, and workforce development, particularly at the operator level.
    - Machine learning/artificial intelligence (AI) and other automation tools.
    - Progress toward identifying, creating, or enhancing credentials needed for critical infrastructure occupations.
- Identify mid- to long-term trends regarding the resilience of the Nation's critical infrastructure workforce and highlight trends that may require near-term policy intervention.
- Provide 2–3 mid-term and 2–3 long-term recommendations that can inform future policy development.

[45] National Counterintelligence and Security Center, *National Counterintelligence Strategy of the United States of America 2020-2022* (Washington, D.C.: National Counterintelligence and Security Center, 2020), https://www.dni.gov/files/NCSC/documents/features/20200205-National_CI_Strategy_2020_2022.pdf.

Study Approach

The NIAC formed a Working Group of members to complete this task. To do this, the Working Group:

- **Held a panel discussion at the May 2020 Quarterly Business Meeting** with representatives from the energy, transportation systems, and water and wastewater systems sectors to better understand the workforce challenges facing critical infrastructure and to help inform the study approach.
- **Reviewed previous NIAC studies touching on workforce issues** to identify any relevant prior recommendations or efforts.
    - The NIAC made 28 recommendations addressing workforce development issues across seven previous studies starting with the 2006 report *Workforce Preparation, Education, and Research*.
    - The analysis found that the NIAC had not previously focused solely on the concept of worker readiness; prior recommendations had instead focused primarily on cyber or a single sector. The issues of apprenticeships and credentials were highlighted as key factors in developing and supporting critical infrastructure workforce.
- **Conducted 24 separate interview sessions with more than 60 individual leading experts** from across the fields of education, human capital, workforce training, and critical infrastructure.
- **Conducted in-depth research** and consulted more than 300 sources on a variety of subjects to better understand the makeup of the workforce and challenges in the identified sectors (Appendix B), examine apprenticeship models used in other countries (Appendix C), and provide case studies highlighting successful practices (Appendix D).
- **Formed a Study Group composed of industry and workforce experts** to provide insights and analysis on key topics to the Working Group on a rolling basis by engaging with other experts, conducting in-depth research, and examining critical infrastructure workforce challenges consistent with NSC guidance. As part of this tasking, the Study Group was asked to share any national or international best practices and case studies it identified as part of this effort.
    - **Met more than 20 times** to share their insights and expertise with each other and the Working Group, including four joint sessions with Working Group.
    - **Interviewed 9 other experts**.
    - **Provided direction and input on interim research products,** including the analysis of U.S. and international apprenticeship models (Appendix C) and the sector workforce profiles (Appendix B).
    - **Developed a report** to help inform the Working Group's efforts.
    - **Remained engaged with the Working Group** throughout the study effort.

A full roster of the NIAC Working Group and Study Group, and the additional experts interviewed by each can be found in Appendix E.

Appendix B: Overview of the Lifeline Sectors Workforce

The NIAC was asked to focus on the lifeline sectors of energy, transportation systems, communications, and water and wastewater systems as it examined how the lack of a skilled workforce could have negative economic and national security consequences. These sectors are among the 16 critical infrastructure sectors identified in Presidential Policy Directive 21 (PPD-21), issued in February 2013. PPD-21 also characterizes the energy and communications sectors as being "uniquely critical due to the enabling functions they provide across all critical infrastructure sectors."[46]

Drawing on open-source research and the insights of the Study Group, this appendix provides a general overview of each sector, its risks, and specific workforce challenges. This overview is not intended to be a comprehensive description of each sector, but rather is intended to help inform the study effort.

Energy Sector

A stable energy supply—including electricity, oil, and natural gas—is essential to the health, welfare, and economic well-being of the Nation. All sectors are, to some degree, reliant on the energy sector, making it a backbone of the U.S. economy and national security. The sector is delineated into two subsectors: Electricity and Oil and Natural Gas (ONG).[47]

The sector faces evolving changes, threats, risks, and workforce challenges, including technology shifts, climate change, natural disasters, cyber and physical security breaches, aging infrastructure, and potential mismatch of jobs and skills. Major challenges to the energy workforce include anticipated retirements, mismatches in skills (particularly in STEM), attracting a more inclusive workforce, and the lingering effects of the COVID-19 pandemic.

As the sector continues to grow, there will be incentives to diversify the workforce. Education and training should be aligned with evolving technical skills needed to alleviate hiring difficulties. Expanded investments in workforce training and greater collaboration between educational institutions and employers will help ensure a resilient energy sector.

Sector Stakeholders

The U.S. Department of Energy (DOE) serves as the Sector Risk Management Agency (SRMA) for the energy sector.[48] Other key federal agencies include the Department of the Interior (DOI), the U.S. Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). A variety of coordinating councils help to manage public-private collaboration across the industry. The Electricity

[46] "Presidential Policy Directive—Critical Infrastructure Security and Resilience," Office of the Press Secretary, The White House, February 12, 2013, https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil.
[47] "Energy Sector," Cybersecurity and Infrastructure Security Agency, accessed September 1, 2021, https://www.cisa.gov/energy-sector.
[48] Sector Risk Management Agency (SRMA) replaces the terminology that was previously known as Sector Specific Agencies (SSA). The National Defense Authorization Act 2021 assigns the new term to evaluate the current framework for security critical infrastructure and revise the current list of critical infrastructure sectors designated pursuant to Presidential Policy Directive 21. H.R.6395 - National Defense Authorization Act for Fiscal Year 2021, 116th Congress, 2nd Session, accessed August 31, 2021, https://www.congress.gov/bill/116th-congress/house-bill/6395/text.

and Oil and Natural Gas Subsector Coordinating Councils (ESCC and ONG SCC, respectively), for example, operate under the Critical Infrastructure Partnership Advisory Council (CIPAC) framework.[49]

Federal Stakeholders

As the SRMA for energy, DOE is responsible for providing federal guidance, knowledge, and expertise regarding energy's impact on critical infrastructure.[50]

The DOI oversees oil and natural gas production on federal lands and waters. Oversight of offshore production is provided by DOI's Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE).

The FERC is the principal federal regulator of electricity markets and is responsible for: encouraging the development of independent transmission operators such as regional transmission organizations (RTOs); approving plans for the creation of independently operated, centralized markets; and monitoring the competitiveness of those markets.[51]

State Energy Offices (SEOs)

SEOs—located in all 50 U.S. states and six territories—help to advance energy policies, inform regulatory processes, and support energy technology research, demonstration, and deployment. SEOs coordinate closely with state emergency management and homeland security officials as well as state fusion centers.

Public Utility Commissions (PUCs)

PUCs set rates, approve utility infrastructure investment, determine whether utilities meet energy efficiency mandates and other regulations, and help facilitate the advancement of new energy technologies and services. While roles may differ from state to state, all PUCs have broad regulatory authority over investor-owned electric and natural gas utilities.

Information Sharing and Analysis Centers (ISACs)

ISACs parse information on behalf of operators, providing analytics and assessment. Though private, many ISACs receive some federal funding and operate at the national level. Particularly relevant ISACs are Electricity (E-ISAC), Multi-State (MS-ISAC), Oil and Natural Gas (ONG-ISAC), and Downstream Natural Gas (DNG-ISAC).

Trade Associations

Trade associations participate in public relations activities and help facilitate collaboration in the energy sector. Key energy trade associations, among many others, include:

- American Gas Association (AGA)
- American Petroleum Institute (API)
- American Public Power Association (APPA)
- Center for Energy Workforce Development (CEWD)
- Edison Electric Institute (EEI)
- Independent Petroleum Association of America (IPAA)
- National Rural Electric Cooperative Association (NRECA)
- Natural Gas Supply Association (NGSA)

[49] The U.S. Department of Homeland Security established the Critical Infrastructure Partnership Advisory Council (CIPAC) to facilitate interaction and provide a forum for Government Coordinating Councils (GCCs) and Sector Coordinating Councils (SCCs).
[50] "Federal Authorities: Office of Cybersecurity, Energy Security, and Emergency Response," U.S. Department of Energy, accessed August 31, 2021, https://www.energy.gov/ceser/activities/energy-security/emergency-preparedness/federal-authorities.
[51] "Electric Power Markets," Federal Energy Regulatory Commission, last updated July 20, 2021, https://www.ferc.gov/electric-power-markets.

- Solar Energy Industries Association (SEIA)
- U.S. Energy Association (USEA)
- U.S. Oil and Gas Association (USOGA)

Working Groups and Unions

Working groups bring together experts to guide programs and projects across the energy sector. Unions represent workers' interests through collective bargaining.

Energy sector working groups include:

- Control Systems Working Group
- Cybersecurity Capability Maturity Model (C2M2) Working Group
- DOE, Electricity and Oil and Natural Gas Sector Coordinating Councils CATT 2.0 Coordination
- State, Local, Tribal, Territorial Energy Assurance Joint Policy Committee (EAJPC)
- Electricity Subsector
- Oil and Natural Gas Subsector

Unions include:

- International Brotherhood of Electrical Workers (IBEW)
- Utility Workers Union of America (UWUA)[52]

Sector Coordinating Councils (SCCs)

SCCs are self-governing, private sector councils composed of owners and operators and their representatives. They are the principal entity for owners and operators to coordinate with the government on security and resilience.[53] Each SCC has a Government Coordinating Council (GCC) counterpart, consisting of federal agencies and state, local, tribal, and territorial (SLTT) representatives. The CIPAC structure also includes four cross-sector councils.

Sector Workforce

The National Association of State Energy Officials (NASEO) 2020 U.S. Energy and Employment Report found that 6.8 million Americans work in the energy sector, representing 4.6 percent of the U.S. workforce. Employment in the energy sector increased 1.8 percent in 2019 over the previous year, adding 120,300 jobs—more than 7 percent of all new jobs nationwide. Changes in technology continue to drive labor markets across the sector; coal-fired generation jobs decreased by almost 7,700 positions in 2019, while natural gas added 9,100 jobs and renewable technologies added 10,900.[54] While the energy industry was impacted by the COVID-19 pandemic, the sector lost fewer jobs compared to other areas of the economy, such as Tourism, Hospitality and Recreation, Information and Communications, Retail, and Building Design.[55] The table below, derived from the NASEO report, summarizes the report's approximate high-level employment findings.

[52] "Energy Sector Working Groups," Cybersecurity and Infrastructure Security Agency, accessed September 1, 2021, https://www.cisa.gov/energy-working-groups.
[53] U.S. Department of Homeland Security, *2010 Critical Infrastructure Partnership Advisory Council Annual* (2010), p. 2, https://www.dhs.gov/xlibrary/assets/cipac/cipac-annual-2010.pdf.
[54] National Association of State Energy Officials & Energy Futures Initiative, *2020 U.S. Energy and Employment Report: Executive Summary* (2020), USEnergyJobs.org, p. xii, https://www.usenergyjobs.org/s/2020-USEER-EXEC-0615.pdf.
[55] National Association of State Energy Officials & Energy Futures Initiative, *Wages, Benefits, and Change: A Supplemental Report to the Annual U.S. Energy and Employment Report* (2020), https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/606b8901bf00740418c36d33/1617660161554/Fact+Sheet+-+The+Wage+Report.pdf.

Subsector	Jobs	Percent Increased in 2019
Fuels	1.1 million	1.9
Electric Power Generation	897 thousand	2.5
Transmission, Distribution, and Storage	2.4 million	1.3
Energy Efficiency	2.4 million	3.4
Motor Vehicles	2.6 million	1
Total	6.8 million	1.8

The American Petroleum Institute reports that Millennials (those born between 1981 and 2000) accounted for 34 percent of the ONG workforce in 2015 (comparable to Millennials' 35 percent share in the American workforce).[56]

Renewables represent one of the fastest growing segments of the industry. The business group Advanced Energy Economy (AEE) reported 3.6 million advanced energy jobs in renewables and electrified transportation (for comparison, coal and oil industries employ 1 million) and an expected five percent growth in advanced energy jobs in 2020—prior to the pandemic.[57]

Clean energy jobs are one of the fastest-growing sectors in the U.S. economy and long-term prospects remain strong, but the industry was significantly affected by the pandemic, with over half a million clean energy workers out of work at the end of July 2020.[58] However, at the end of May 2020, clean energy jobs grew by more than 11 percent compared to about 9 percent across the U.S. economy overall.[59]

Fastest Growing Energy Occupations by Rate

According to the U.S. Bureau of Labor Statistics, the following occupations are among the twenty projected fastest growing occupations for 2019–2029.[60]

Occupation	Jobs (2019)	Job Outlook, 2019–29	2020 Median Pay	Entry-Level Education
Wind turbine service technician	7,000	+61%	$56,230	Postsecondary nondegree award
Solar photovoltaic installers	12,000	+51%	$46,470	High school diploma or equivalent
Derrick operators, oil and gas	12,000	+31%	$47,920	On-the-job training
Rotary drill operators, oil and gas	20,900	+27%	$53,820	On-the-job training

[56] Richard Fullenbaum and Rebecca Winkel, *Millennials in the Oil & Natural Gas and Petrochemical Industries* (Washington, D.C.: American Petroleum Institute, January 2018), https://www.api.org/-/media/Files/Policy/Jobs/IHS-Millennials-Report-January-2018.pdf.
[57] "2020 Advanced Energy Employment Fact Sheet," Advanced Energy Economy, 2020, https://info.aee.net/2020-national-jobs-fact-sheet.
[58] Philip Jordan, "Clean Energy Employment Initial Impacts from the COVID-19 Economic Crisis, July 2020," BW Research Partnership, August 12, 2020, https://e2.org/wp-content/uploads/2020/08/Clean-Energy-Jobs-July-COVID-19-Memo-Final.pdf.
[59] Environmental Entrepreneurs, *Clean Jobs America 2021* (April 2021), https://e2.org/wp-content/uploads/2021/04/E2-2021-Clean-Jobs-America-Report-04-19-2021.pdf.
[60] "Occupational Outlook Handbook: Architecture and Engineering Occupations," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/architecture-and-engineering/home.htm; "Occupational Outlook Handbook: Construction and Extraction Occupations," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/construction-and-extraction/home.htm; "Occupational Outlook Handbook: Installation, Maintenance, and Repair Occupations," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/installation-maintenance-and-repair/home.htm; "Occupational Outlook Handbook: Data for Occupations Not Covered in Detail," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/about/data-for-occupations-not-covered-in-detail.htm.

Roustabouts, oil and gas	58,500	+25%	$39,420	On-the-job training
Industrial machinery mechanics, machinery maintenance workers, and millwrights	521,300	+13%	$54,920	High school diploma or equivalent
Industrial engineers	295,800	+10%	$88,950	Bachelor's degree
Electricians	739,200	+8%	$56,900	High school diploma or equivalent

Sector Workforce Programs and Initiatives

The public and private sectors support an array of initiatives to promote workforce development in the energy sector at the national, regional, and state levels. New technologies, diversified energy resources, and evolving consumer preferences all create opportunities to align programs and initiatives with a diverse, highly skilled, and trained workforce.

The Federal Government administers several relevant workforce development initiatives, mostly through DOE.

- DOE's Bioenergy Technologies Office offers informational tools, such as a Bioenergy Career Map, to map occupations and career paths in the sector.[61]
- DOE's Energy Workforce Division in the Office of Minority Programs provides tools, resources, and assistance to increase participation for underrepresented communities to support "entrepreneurship, innovation, and job creation for diverse communities" in the energy sector.[62]
- At the regional level, DOE is working with the City of Pittsburgh, the Allegheny Conference, and member companies to revamp workforce development and create a "veterans employment pipeline" to meet local needs in the energy and manufacturing sector.[63]

Many trade associations sponsor their own, industry-specific initiatives.

- In April 2018, the American Petroleum Institute (API) announced the creation of a Pipeline Construction Safety Training Program in partnership with the North America's Building Trades Unions (NABTU) to "marry the best practices of both the building trades unions and the natural gas and oil industry" and expand economic opportunities for workers to enhance skills development.[64]

[61] "Workforce Development," Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, accessed September 1, 2021, https://www.energy.gov/eere/bioenergy/workforce-development.
[62] "Energy Workforce Division," Office of Economic Impact and Diversity, U.S. Department of Energy, accessed September 1, 2021, https://www.energy.gov/diversity/services/minority-business.
[63] U.S. Department of Energy, "Veterans Day Message From DOE Secretary And Deputy Secretary," Berkeley Lab, November 11, 2015, accessed September 2, 2021, https://diversity.lbl.gov/2015/11/11/veterans-day-message-from-doe-secretary-and-deputy-secretary/.
[64] "American Petroleum Institute Teams Up with North America's Building Trades Unions to Enhance Safety Training for Tomorrow's Energy Workforce," American Petroleum Institute, April 18, 2018, https://www.api.org/news-policy-and-issues/news/2018/04/18/api-and-nabtu-team-up-to-enhance-safety-training.

Several strategic partnerships dedicated to meeting the future workforce needs of the energy sector also help to coordinate between individual companies, educational institutions, government agencies, and other interested parties. Examples of such consortia include:

- The Center for Energy Workforce Development (CEWD), a consortium of electric, natural gas and nuclear utilities and their associations, hosts an annual summit and regional meetings on workforce development initiatives.[65] Career awareness activities specifically target youth, low-income young adults, women, veterans, and transitioning workers.
- The Energy Sector Security Consortium (EnergySec) partners with academia to promote internships and apprenticeships and was recently co-awarded a DOL grant for the development of cybersecurity apprenticeships.[66]

Workforce development initiatives can also be found at the individual corporate level.

- GridEd is a collaborative educational initiative by the Electric Power Research Institute (EPRI), seven partner universities, and utility and industry sponsors to train the next generation of power engineers and adapt to a changing electrical industry by providing educational products, training programs, and student-oriented activities for K–12 and universities.[67]
- In June 2020, the Duke Energy Foundation awarded more than $240k in grants to five South Carolina education organizations and programs to build and enhance strategic engineering initiatives, such as a STEM club for middle school girls and high school engineering courses to grow the energy industry's "workforce of tomorrow."[68]

Workforce Challenges or Issues

Workforce challenges in the energy sector primarily emerge from demographic and economic changes in the labor market as a whole and the evolution of the industry as it responds to changing energy demands.

Anticipated Wave of Retirements

- The ONG industry anticipates a wave of retirements after the pandemic subsides, leading to a potential "knowledge-loss crisis."[69]

Skills Mismatch

- STEM skills are increasingly in demand in the workforce. However, women and racial or ethnic minorities are less likely to earn STEM degrees and enter STEM employment. This limits the sector's ability to sustain growth, nurture innovation, and improve diversity.[70]

[65] "About CEWD," Center for Energy Workforce Development, accessed September 1, 2021, https://cewd.org/resources/.
[66] Emily Weeks, "News Release: U.S. Department of Labor Announces Nearly $100 Million In Apprenticeship Grants to Close the Skills Gap," U.S. Department of Labor, February 18, 2020, https://www.dol.gov/newsroom/releases/eta/eta20200218.
[67] Electric Power Research Institute, *Leveraging Industry Research to Educate a Future Electric Grid Workforce* (August 2019), https://grided.epri.com/tpl/docs/3002017113.pdf.
[68] "Duke Energy Invests More than $240,000 in Programs to Build Energy Industry Workforce in South Carolina," *PRNewswire*, June 11, 2020, https://www.prnewswire.com/news-releases/duke-energy-invests-more-than-240-000-in-programs-to-build-energy-industry-workforce-in-south-carolina-301074653.html.
[69] Fabio Bento and Luciano Garotti, "Resilience Beyond Formal Structures: A Network Perspective towards the Challenges of an Aging Workforce in the Oil and Gas Industry," *Journal of Open Innovation: Technology, Market, and Complexity* 5, no. 1 (2019): 15, https://www.mdpi.com/2199-8531/5/1/15.
[70] Matthew D. Baird, Robert Bozick, and Mark Harris, *Postsecondary Education and STEM Employment in the United States: An Analysis of National Trends with a Focus on the Natural Gas and Oil Industry* (Santa Monica, CA: RAND Corporation, 2017), p. 54, https://www.rand.org/pubs/research_reports/RR2115.html.

- Employers in some regions struggle with a skills mismatch and have difficulty filling middle-skill jobs (those requiring more than a high school diploma but less than a four-year degree) that require interpersonal and managerial skills.[71]
- Education programs and employer needs do not align.
    - A 2017 RAND report on developing a skilled workforce in the ONG industry of the upper Appalachians found that the necessary skills were not sufficiently emphasized in the local education system in the primary, secondary, or postsecondary levels.[72]
- New technologies will require new skills from the workforce.
    - Information and communication technologies in the electricity sector such as distributed generation, smart home devices, power electronic, direct current, renewables, and electric battery storage will require upskilling as well as new safety and security practices.

Diversity Gap

- While the sector tends to be more racially diverse than the national workforce, specific racial categories are "frequently underrepresented."
- Women are underrepresented in the energy workforce (23–32 percent compared to 47 percent of the entire workforce).[73]

Pandemic Complications

- During the COVID-19 pandemic, energy companies had the dual challenge of protecting the health and safety of their employees and customers while also continuing to produce reliable electricity and natural gas.[74]

Transportation Systems Sector

The Transportation Systems Sector is responsible for the security and resilience of the nation's transportation systems, ensuring the ability to move people and goods quickly, safely, and securely throughout the country and overseas. It is made up of seven subsectors: Aviation, Highway and Motor Carrier, Maritime Transportation System, Mass Transit and Passenger Rail, Pipeline Systems, Freight Rail, and Postal and Shipping.[75]

A strong workforce is critical to the safe and efficient continued operations of the Transportation Systems Sector. However, the sector faces several key challenges, including a rapidly aging workforce—a problem compounded by many subsectors' difficulties in hiring and retaining talented employees. This has created a shortage of skilled workers across the sector even as advancements in technology upend future job markets and force employers to adopt new training and education methods. The COVID-19

[71] Harry J. Holzer, Robert I. Lerman, *America's Forgotten Middle-Skill Jobs: Education and Training Requirements in the Next Decade and Beyond* (Washington, D.C.: The Urban Institute, November 2007), https://www.urban.org/sites/default/files/publication/31566/411633-America-s-Forgotten-Middle-Skill-Jobs.PDF.
[72] Robert Bozick, Gabriella C. Gonzalez, Cordaye Ogletree, and Diana Gehlhaus Carew, *Developing a Skilled Workforce for the Oil and Natural Gas Industry: An Analysis of Employers and Colleges in Ohio, Pennsylvania, and West Virginia* (Santa Monica, CA: RAND Corporation, 2017).
[73] National Association of State Energy Officials & Energy Futures Initiative, *2020 U.S. Energy and Employment Report: Executive Summary* (2020), p. xix, https://www.usenergyjobs.org/s/2020-USEER-EXEC-0615.pdf.
[74] "Ensuring Energy Reliability Throughout the COVID-19 Pandemic: Testing and Protecting Mission-Essential Control Center and Generation Facility Personnel is Fundamental," Electricity Subsector Coordinating Council, April 2020, https://www.electricitysubsector.org/-/media/Files/ESCC/Documents/ESCC_Mission_Essential_Workforce_2020.ashx.
[75] "Transportation Systems Sector," Cybersecurity and Infrastructure Security Agency, accessed September 1, 2021, https://www.cisa.gov/transportation-systems-sector.

pandemic accelerated the decline in the Transportation Systems workforce and sharpened many of the challenges faced by the sector.

The Transportation Systems Sector has taken numerous steps to counter these challenges, including new training initiatives and outreach programs promoted by industry, sector partners, and government. Targeting marketing and outreach initiatives to youth groups, veterans, nontraditional workers, and employees of diverse backgrounds to attract and retain a skilled, younger, and more diverse workforce is one of many steps that industry, government agencies, and sector partners alike can take to strengthen the sector's workforce for many years to come.

Sector Stakeholders

The Departments of Transportation (DOT) and Homeland Security (DHS) are the co-SRMAs for the Transportation Systems Sector. DHS's SRMA responsibilities are delegated to the Transportation Security Administration (TSA) and the U.S. Coast Guard.[76]

Most of the subsectors are largely publicly owned and operated. Every level of government is involved in managing Transportation Systems in some way, including municipal, county, special district, regional, state, and federal agencies. In addition, thousands of special authorities fund many of the waterways, ports, airports, and public transit functions across the country.

Because so many levels of government are involved in the management of the Transportation Systems Sector, jurisdictional boundaries and funding streams are often complicated, limiting the overall efficiency of top-down structural reforms. Additionally, due to declining federal funding, state and local governments are taking on larger roles in the management of interstate waterways, commerce, and airspaces.[77]

There are dozens of national trade associations, worker groups, and private organizations across the sector. Some of the most prominent are listed below by subsector.

Aviation Subsector

- Aircraft Owners and Pilots Association
- Airlines for America
- Airport Council International – North America
- American Association of Airport Executives
- Cargo Airline Association

Highway and Motor Carrier Subsector

- American Association of State Highway and Transportation Officials
- American Transportation Research Institute
- American Trucking Association

Maritime Transportation Subsector

- American Maritime Officers
- American Maritime Officers Service
- American Maritime Partnership
- American Waterways Operators
- Dredging Contractors of America

Pipeline Subsector

- Association of Oil Pipelines
- American Petroleum Institute
- American Pipeline Contractors Association

Freight Rail Subsector

- Association of American Railroads

[76] U.S. Department of Homeland Security and U.S. Department of Transportation, *Transportation Systems Sector-Specific Plan* (2015), https://www.cisa.gov/sites/default/files/publications/nipp-ssp-transportation-systems-2015-508.pdf.
[77] Transportation Research Board, *Critical Issues in Transportation 2019* (Washington, DC: National Academy Press, 2019), https://www.nap.edu/catalog/25314/critical-issues-in-transportation-2019.

- National Association of Pupil Transportation
- National Association of Small Trucking Companies

Mass Transit and Passenger Rail Subsector

- American Public Transportation Association
- American Bus Association
- American Short Line and Regional Railroad Association
- Intermodal Association of North America

Postal and Shipping Subsector

- Association for Postal Commerce
- National Association of Letter Carriers
- National Association of Postal Supervisors

Sector Workforce

In 2020, transportation and warehousing sector and related industries employed 14.2 million people, or 10 percent of the U.S. workforce.[78] This amounts to a 4.1 percent decline in the industry from 2019. Although the industry was hard hit during the pandemic, the Bureau of Labor Statistics (BLS) projects that jobs in transportation and warehousing industries will increase by about 5.8 percent, or 326,000 employees, over the next ten years.[79]

Fastest Growing Transportation System Occupations by Rate

The table below includes occupational data on the Transportation Systems Sector from the Bureau of Labor Statistics.[80]

Occupation	Jobs (2019)	Job Outlook, 2019–29	2020 Median Pay	Entry-Level Education
Flight attendants	121,900	+17%	$59,050	High school diploma or equivalent
Passenger vehicle drivers	1,076,700	+11%	$34,670	High school diploma or equivalent
Delivery truck drivers and driver/sales workers	1,506,000	+5%	$34,340	High school diploma or equivalent
Airline and commercial pilots	127,100	+5%	$130,440	Bachelor's degree, commercial pilot's license, certificate from the Federal Aviation Administration (FAA)
Hand laborers and material movers	4,231,600	+3%	$30,490	No formal educational credential
Material moving machine operators	761,400	+2%	$37,790	No formal educational credential

[78] "Employment in Transportation: Employment in Transportation and Related Industries," Bureau of Transportation Statistics, U.S. Department of Transportation, accessed August 31, 2021, https://data.transportation.gov/stories/s/caxh-t8jd.
[79] "News Release: Employment Projections 2019–2029," U.S. Bureau of Labor Statistics, September 1, 2020, https://www.bls.gov/news.release/pdf/ecopro.pdf; "Industries at a Glance: Transportation and Warehousing NAICS 48-49," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/iag/tgs/iag48-49.htm#workforce.
[80] "Transportation and Material Moving Occupations," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/transportation-and-material-moving/home.htm.

Heavy and tractor-trailer truck drivers	2,029,900	+2%	$47,130	Postsecondary nondegree award
Air traffic controllers	24,300	+1%	$130,420	Associate's degree

Aviation Subsector

As of September 2020, an estimated 409,500 people worked in aviation transportation—a decline of 96,800 workers from the previous year.[81] The jobs impacted include a range of professions and skills, including aircraft mechanics and service technicians; airline pilots, copilots, and flight engineers; cargo and freight agents; and reservation and transportation ticket agents and travel clerks.

Although the industry faces continued turmoil and potential layoffs during the COVID-19 pandemic, BLS projects that the number of aircraft and avionics equipment mechanics and technicians, as well as airline and commercial pilots, will both increase by 5 percent between 2019 and 2029.[82]

Highway and Motor Carrier Subsector

An estimated 1.45 million people were employed across various truck transportation jobs as of September 2020, representing a decline of about 73,000 jobs from the previous year. These occupations include mechanics and engine specialists, first-line supervisors, vehicle operators, laborers and material movers, and truck drivers (including delivery service drivers and heavy truck and tractor-trailer drivers).[83]

BLS projects a 2 percent growth rate for heavy-duty truck driving between 2019 and 2029.[84] Notably, Securing America's Future Energy (SAFE), a non-profit dedicated to improving energy security, reports that the trucking industry could face peak worker displacement in 2045, with over 200,000 unemployed workers.[85]

Maritime Transportation System Subsector

58,900 people were employed in maritime occupations in the United States in September 2020, in occupations including captains, mates, and pilots of water vessels; general and operations managers; laborers and freight, stock, and material movers; sailors and marine oilers; and engineers.[86] The industry has declined by an estimated 8,000 jobs from September 2019 and is expected to undergo little or no growth from 2019 to 2029.[87]

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[81] "Air Transportation: Databases, Tables & Calculators by Subject," U.S. Bureau of Labor Statistics, accessed September 3, 2021, https://data.bls.gov/timeseries/CES4348100001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true.
[82] "Occupational Outlook Handbook: Airline and Commercial Pilots," U.S. Bureau of Labor Statistics, accessed August 31, 2021, https://www.bls.gov/ooh/transportation-and-material-moving/airline-and-commercial-pilots.htm; "Occupational Outlook Handbook: Aircraft and Avionics Equipment Mechanics and Technicians," U.S. Bureau of Labor Statistics, accessed August 31, 2021, https://www.bls.gov/ooh/installation-maintenance-and-repair/aircraft-and-avionics-equipment-mechanics-and-technicians.htm.
[83] "Truck Transportation: NAICS 484," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/iag/tgs/iag484.htm.
[84] "Occupational Outlook Handbook: Heavy and Tractor-Trailer Truck Drivers," U.S. Bureau of Labor Statistics, accessed August 31, 2021, https://www.bls.gov/ooh/transportation-and-material-moving/heavy-and-tractor-trailer-truck-drivers.htm.
[85] Erica L. Groshen, Susan Helper, John Paul MacDuffie, and Charles Carson, *Preparing U.S. Workers and Employers for an Autonomous Vehicle Future*(Securing America's Future Energy, June 2018), https://avworkforce.secureenergy.org/wp-content/uploads/2018/06/Groshen-et-al-Report-June-2018-1.pdf.
[86] "Water Transportation: Databases, Tables & Calculators by Subject," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://data.bls.gov/timeseries/CES4348300001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true.
[87] "Occupational Outlook Handbook: Water Transportation Workers," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/transportation-and-material-moving/water-transportation-occupations.htm.

Mass Transit and Public Rail Subsector

As of September 2020, 343,400 people were employed across this subsector, including bus and truck mechanics and engine specialists; school, charter, transit, and intercity bus drivers; dispatchers (excluding police, fire, and ambulance drivers); and taxi drivers, chauffeurs, and ride-share drivers.[88] This subsector has declined by an estimated 149,400 employees since September 2019. Although the subsector is showing signs of recovery, the loss of revenues due to the pandemic could have a catastrophic effect.[89] BLS anticipates the number of passenger vehicle drivers will increase by 11 percent from 2019 to 2029.[90]

Pipeline Systems Subsector

As of September 2020, 50,200 workers were employed in pipeline transportation jobs. Common occupations include control and valve installers and repairers; gas compressor and gas pumping station operators; gas plant operators; industrial machinery mechanics; and petroleum pump system and refinery operators.[91] Between 1990 and 2017, jobs in the pipeline industry declined by 19.2 percent.[92]

Freight Rail Subsector

Approximately 145,400 employees worked across this subsector as of September 2020, a number that has declined by 24,500 workers since September 2019.[93] Rail transportation occupations include locomotive engineers; rail car repairers; rail-track laying and maintenance equipment operators; railroad brake, signal, and switch operators; and railroad conductors and yardmasters. The number of railroad workers is expected to decline by about 3 percent from 2019 to 2029.[94]

Postal and Shipping Subsector

In 2019, approximately 503,100 people were employed in postal occupations. The subsector is expected to decline by about 14 percent, or 70,434 workers, between 2019 and 2029.[95] Jobs include first-line supervisors and managers of transportation and vehicle operators; postal service clerks; mail carriers; mail sorters, processors, and processing machine operators; and postmasters and superintendents.[96]

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[88] "Transit and Ground Passenger Transportation: NAICS 485," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/iag/tgs/iag485.htm.
[89] "Table B-1. Employees on nonfarm payrolls by industry sector and selected industry detail," U.S. Bureau of Labor Statistics, last updated October 5, 2020, https://www.bls.gov/news.release/empsit.t17.htm.
[90] "Passenger Vehicle Drivers," Occupational Outlook Handbook, U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/transportation-and-material-moving/passenger-vehicle-drivers.htm.
[91] "Pipeline Transportation: Databases, Tables & Calculators by Subject," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://data.bls.gov/timeseries/CES4348600001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true.
[92] U.S. Bureau of Transportation Statistics, *Transportation Economic Trends Chapter 4: Transportation Employment* (2018), https://www.bts.dot.gov/sites/bts.dot.gov/files/u796/TET%202018%20Chapter%204.pdf.
[93] "Rail Transportation: Databases, Tables & Calculators by Subject," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://data.bls.gov/timeseries/CES4348200001?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true; "Table B-1. Employees on nonfarm payrolls by industry sector and selected industry detail," U.S. Bureau of Labor Statistics, last updated October 5, 2020, https://www.bls.gov/news.release/empsit.t17.htm.
[94] "Occupational Outlook Handbook: Railroad Workers," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/transportation-and-material-moving/railroad-occupations.htm.
[95] "Occupational Outlook Handbook: Postal Workers," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/office-and-administrative-support/postal-service-workers.htm.
[96] "Postal Service: NAICS 491," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/iag/tgs/iag491.htm.

Sector Workforce Programs and Initiatives

Across the Transportation Systems Sector, trade associations, industry, and all levels of government are undertaking initiatives to improve the sector's training programs, hiring and outreach methods, and other workforce practices.

Since 2011, the Federal Transit Administration (FTA) has provided funding for the sector through the Innovative Public Transportation Workforce Development Program, which "assists in developing innovative programs and activities in public transportation that address the human resource needs of public transportation operators and build pathways to long-term careers in the public transportation industry."[97] The program awarded $3 million to 12 workforce development projects in 2011 and $7 million to 16 projects in 2012; the program provided an additional $9.5 million to 19 more projects across the country in 2015.[98] FTA funding supported the development of a shared leadership learning program in Charlotte, North Carolina, to train less-experienced employees, emphasize networking and mentorships, and scale from the larger Charlotte metro area to smaller, more rural communities.[99]

After declining involvement in workforce issues in recent years, the FAA has taken on a greater role following the passage of the FAA Reauthorization Act of 2018. Part of this legislation provides for the development of an unmanned aircraft system (UAS) collegiate training initiative, which is still underway. The FAA is currently modernizing the regulations for FAA-certified Aviation Maintenance Technician Schools to move toward a performance-based standard and attract new and high-performing employees.[100]

Many transportation industries recruit veterans to the workforce through targeted outreach to the military, as well as partnerships between transportation agencies and military organizations.[101] Examples include the U.S. Army Partnership for Youth Success (PaYS), which has partnered with agencies in the Freight Rail Subsector to recruit veterans.

Partnerships with colleges and trade schools help create internship opportunities, specialized programs and panels, and other student initiatives. The Greater Cleveland Regional Transit Authority (RTA) has partnered with various academic and trade schools under a $400,000 grant from the Department of Labor (DOL).[102]

Industry organizations and associations in several subsectors conduct recruitment initiatives for students of all ages. The American Public Transportation Association (APTA) organizes annual career

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[97] National Transit Institute, Small Urban and Rural Transit Center, Upper Great Plains Transportation Institute, and North Dakota State University, *Workforce Development Summit: Implementing, Disseminating, and Modeling Ladders of Opportunity; Proceedings*, FTA Report No. 0096 (Federal Transit Administration, October 2016), p. iv, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Report_No._0096.pdf.
[98] National Transit Institute, Small Urban and Rural Transit Center, Upper Great Plains Transportation Institute, and North Dakota State University, *Workforce Development Summit: Implementing, Disseminating, and Modeling Ladders of Opportunity; Proceedings*, FTA Report No. 0096 (Federal Transit Administration, October 2016), p. 7, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA_Report_No._0096.pdf.
[99] Del Peterson and Ted Rieck, *Workforce Development and Succession Planning to Prepare the Rural Transit Industry for the Future* (National Center for Transit Research, July 2016), p. 6, https://www.nctr.usf.edu/wp-content/uploads/2016/09/NCTR-77060-07-Workforce-Development-508.pdf.
[100] U.S. Department of Transportation, *Looking Forward: The Future of America's Aviation Maintenance and Manufacturing Workforce*, U.S. House of Representatives, Committee on Transportation, Subcommittee on Aviation 116th Congress, February 11, 2020, https://www.transportation.gov/testimony/looking-forward-future-america%E2%80%99s-aviation-maintenance-and-manufacturing-workforce.
[101] Transportation Research Board, *A Guide to Building and Retaining Workforce Capacity for the Railroad Industry* (Washington, DC: National Academy Press, 2015), https://www.nap.edu/catalog/21904/a-guide-to-building-and-retaining-workforce-capacity-for-the-railroad-industry.
[102] "Federal officials praise RTA for job training and workforce development," Greater Cleveland Regional Transit Authority, November 2, 2015, http://www.riderta.com/news/federal-officials-praise-rta-job-training-and-workforce-development.

days for K–12 students with age-appropriate activities, from interactive demos to on-site job shadowing.[103]

Several airlines, including JetBlue and American Airlines, have begun to offer *ab initio* ("from the beginning") training programs, which include free flight training in exchange for several years of service to the airline offering the program.[104] While this training has drawn new pilots to the industry, particularly from outside the traditional backgrounds of wealthy families or military aviators, a 2016 report by the Transportation Research Board observed that these programs have not resolved the workforce gaps across the subsector.[105]

Workforce Challenges or Issues

The Transportation Systems Sector faces various challenges, including an aging workforce, underrepresentation of women and minorities, difficulty attracting new workers, and gaps in education and training due to factors such as changing skill requirements as technology evolves.

Aging Workforce

- An aging workforce is one of the biggest challenges facing the sector.
    - According to the Bureau of Transportation Statistics, "roughly one-quarter of all transportation workers in 2020 are over the age of 55—slightly more than the percent employed in all industries."[106]
    - The sector is experiencing high rates of retirement. In the Freight Rail Subsector, retirements are disproportionately taking place in senior positions, necessitating both a steady stream of new talent entering the industry and well-developed paths of advancement for existing workers.[107]
    - Certain professions are experiencing industry-wide shortages due to large-scale retirements and difficulty attracting new employees.
        - The Aviation Subsector is struggling to hire enough maintenance technicians and commercial and airline pilots to meet industry demand; long training periods and high cost of attracting new workers compound the problem.[108]

Diversity Gap

- Women and people of color are underrepresented across the sector, particularly in leadership roles.

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[103] Transportation Research Board, *Building a Sustainable Workforce in the Public Transportation Industry—A Systems Approach* (Washington, DC: National Academy Press, 2013), https://community-wealth.org/sites/clone.community-wealth.org/files/downloads/report-cronin-et-al.pdf; "APTA National Public Transportation Career Day," American Public Transportation Association, September 1, 2021, https://www.apta.com/research-technical-resources/aptau/industry-resources/national-workforce-programs/educational-youth-and-student-programs/apta-national-public-transportation-career-day/.

[104] Christine Negroni, "Airlines Try New Ways to Build Pilot Ranks," *New York Times,* June 17, 2019, https://www.nytimes.com/2019/06/17/business/pilot-training-airlines.html#:~:text=Recently%2C%20American%20Airlines%20and%20JetBlue,and%20teach%20them%20everything%20else.

[105] David A. Byers, "The Aviation Workforce of Tomorrow," *TR News* 304 (July-August 2016), http://onlinepubs.trb.org/Onlinepubs/trnews/trnews304feature.pdf.

[106] "Employment in Transportation: Employment in Transportation and Related Industries," Bureau of Transportation Statistics, U.S. Department of Transportation, accessed August 31, 2021, https://data.transportation.gov/stories/s/caxh-t8jd.

[107] Transportation Research Board, *A Guide to Building and Retaining Workforce Capacity for the Railroad Industry* (Washington, DC: National Academy Press, 2015), https://www.nap.edu/catalog/21904/a-guide-to-building-and-retaining-workforce-capacity-for-the-railroad-industry.

[108] David A. Byers, "The Aviation Workforce of Tomorrow," *TR News* 304 (July-August 2016), p. 8, http://onlinepubs.trb.org/Onlinepubs/trnews/trnews304feature.pdf; J. David VanderVeen et al, "Pilot Shortage Task Group Report," Michigan Aeronautics Commission, January 22, 2019, https://www.michigan.gov/documents/mdot/PilotShortageTaskGroupFinalReport_645000_7.pdf.

- A 2020 Global Maritime Forum Diversity Study Group study determined that 95 percent of senior managers in the global shipping industry are male.[109] Women and minorities are often restricted to professions such as customer service or manual labor. For instance, 94 percent of women in the shipping industry were employed on cruise ships or passenger ferries in 2017.[110]

Difficulty Attracting New Workers

- Many subsectors face outreach challenges when attempting to recruit and retain employees in industries viewed as old-fashioned, inflexible, or financially non-competitive.[111]
  - Many companies have struggled to rebrand their images for a younger and broader audience.[112] This effort is vital to addressing hiring challenges; in 2017, 77 percent of young professionals working in aerospace jobs were drawn to the industry due to outreach events and industry exposure between grades K–12.[113]
- Limited funding has led to increased competition among sectors for a shrinking talent pool.[114] The Transportation Systems Sector is often unable to match other industries' salaries and flexibility, particularly among private sector jobs.

Education and Training Gaps

- Advancements in technology impact all subsectors of the transportation industry, requiring new training and education requirements for incoming employees and retraining for existing workers.[115]
  - Freight rail and mass transit industries face many new technologies, including the introduction of high-speed rail, increasing automation, the use of artificial intelligence (AI), and the development of micro-transit and mobility on demand services.[116]
- Due to the localized nature of many transportation subsectors, there are few standardized workforce practices between agencies or companies, leaving gaps in training, hiring practices, job requirements, and best practices.[117]

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[109] Heidi Heseltine, "Why the maritime industry needs to improve diversity in the workplace," *Global Maritime Forum,* June 23, 2020, https://www.globalmaritimeforum.org/news/why-the-maritime-industry-needs-to-improve-diversity-in-the-workplace.
[110] "Women in shipping: pushing for gender diversity," Ship Technology, August 23, 2017, https://www.ship-technology.com/features/featurewomen-in-shipping-pushing-for-gender-diversity-5907538/.
[111] Lesley Hirsch, Pamela Hoberman, and Ronnie Kauder, *Final Report: Major Workforce Challenges Confronting New York City Transit* (University Transportation Research Center, May 2017), http://www.utrc2.org/sites/default/files/Final-Report-Major-Workforce-Challenges.pdf.
[112] Julio Monroy, Cheryl Riddick, Carissa Nichols, and Joseph Calhoun, *The Aging Transit Workforce: Investing in Human Capital* (American Public Transportation Association, 2018), https://www.apta.com/wp-content/uploads/Resources/members/memberprogramsandservices/Emerging-Leaders-Program/Documents/APTA%20ELP%20Group%202%20Handout%20(PDF).pdf.
[113] Carole Richard Hedden, "A&D Leaders Work to Manage Multiple Generations; Survey Responses Call for Rebranding of Industry," *Aviation Week Special Report*, September 12, 2017, https://www.aia-aerospace.org/report/2017-aviation-week-workforce-report/.
[114] Lesley Hirsch, Pamela Hoberman, and Ronnie Kauder, *Final Report: Major Workforce Challenges Confronting New York City Transit* (University Transportation Research Center, May 2017), http://www.utrc2.org/sites/default/files/Final-Report-Major-Workforce-Challenges.pdf.
[115] "People Make the Hardware Work: Transit Experts Call for Labor-Management Training Partnerships," Transit Cooperative Research Program, October 1, 2020, http://www.transportcenter.org/images/uploads/publications/People_Make_the_Hardware_Work-Final.pdf.
[116] Transportation Research Board, *Managing the Transit Scheduling Workforce* (Washington, DC: National Academy Press, 2019), https://www.nap.edu/catalog/25457/managing-the-transit-scheduling-workforce; Peter J. Hass, Paul D. Hernandez, and Katherine Estrada, *Estimating Workforce Development Needs for High-Speed Rail in California* (San Jose, CA: Mineta Transportation Institute, 2012), https://transweb.sjsu.edu/sites/default/files/1027-california-high-speed-rail-workforce-needs.pdf.
[117] Federal Transit Administration, *FTA Annual Report on Technical Assistance and Workforce Development for FY 2018*, FTA Report No. 0132 (Washington, D.C.: Federal Transit Administration, February 2019), https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/132006/fta-annual-report-technical-assistnce-and-workforce-development-fy-2018-ftareportno0132_0.pdf.

- Some industries, such as the railroad industry, lack consistent data collection practices and have sparse, outdated workforce statistics, making it difficult to identify and address workforce challenges.[118]

Communications Sector

Regular, rapid access to information has become a defining feature of life in the 21st century. The Communications Sector plays an essential role in the basic function of all other critical infrastructure sectors.

The Communications Sector includes five major subsectors, which include both physical (e.g., buildings, switches, towers, antennas) and digital infrastructure (e.g., routing and switching software, operational support systems, user applications).[119] These are: Broadcast, Cable, Satellite, Wireless, and Wireline.

Most of the Communications Sector is privately owned, necessitating close cooperation between public and private sector to identify risks to infrastructure, develop protective programs, and measure program effectiveness.[120]

In 2014, information and communication technology companies accounted for 3.5 million jobs and contributed $1 trillion to the U.S. gross domestic product (GDP), accounting for 7 percent of the total U.S. economy.[121] The sector faces a growing demand for services and skilled workers, particularly related to developing broadband access and 5G infrastructure. Government agencies, industry associations, and private companies can continue to encourage and incentivize workers to seek training and professional development, particularly in regions where telecommunications access is limited, and develop industry-wide timelines to achieve the intended objectives.

Sector Stakeholders

DHS serves as the SRMA for the Communications Sector.

Elements of the Communications Sector are overseen by several other federal agencies, such as the Cybersecurity and Infrastructure Security Agency (CISA, part of DHS), the Department of Commerce, the Department of Energy, and the Department of Defense. Other public sector agencies involved in various aspects of Information Communication Technology (ICT) policy, protection, and implementation include the Federal Communications Commission, the National Telecommunications and Information Administration, and the President's National Security Telecommunications Advisory Committee (NSTAC).

In addition, over 40 private operators, trade associations, and other stakeholders support the Communications Sector by serving on the Communications SCC hosted by CISA. Each SCC has a GCC counterpart, consisting of federal agencies and SLTT representatives.

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[118] Transportation Research Board, *A Guide to Building and Retaining Workforce Capacity for the Railroad Industry* (Washington, DC: National Academy Press, 2015), https://www.nap.edu/catalog/21904/a-guide-to-building-and-retaining-workforce-capacity-for-the-railroad-industry.
[119] "Home," U.S. Communications Sector Coordinating Council, accessed September 1, 2021, https://www.comms-scc.org/; U.S. Department of Homeland Security, *Communications Sector-Specific Plan: An Annex to the NIPP 2013* (2015), p. 3, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf.
[120] U.S. Department of Homeland Security, *National Infrastructure Protection Plan: Communications Sector*, p. 2, accessed August 31, 2021, https://www.dhs.gov/xlibrary/assets/nipp_commun.pdf.
[121] U.S. Department of Homeland Security, *Communications Sector-Specific Plan: An Annex to the NIPP 2013* (2015), p. 3, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-communications-2015-508.pdf.

The Communications Sector GCC[122]

- Federal Communications Commission
- Federal Reserve Board of Governors
- National Aeronautics and Space Administration
- National Security Council
- Nuclear Regulatory Commission
- U.S. Department of Commerce
  - National Institute of Standards and Technology
  - National Telecommunications and Information Administration
- U.S. Department of Defense
  - Defense Information Systems Agency
  - National Security Agency
- U.S. Department of Energy
- U.S. Department of Homeland Security
  - Cybersecurity and Infrastructure Security Agency
- U.S. Department of the Interior
- U.S. Department of Justice
  - Federal Bureau of Investigation
- U.S. Department of State
- U.S. Department of Transportation
- U.S. Department of Treasury
- U.S. General Services Administration
- U.S. Office of the Director of National Intelligence

The Communications SCC[123]

- 3U Technologies
- American Cable Association
- Alliance for Telecommunications Industry Solutions
- Association for International Broadcasting
- AT&T
- CableLabs
- Cellular Telecommunications Industry Association
- Century Link
- Charter Communications
- Cincinnati Bell
- Comcast
- Consolidated Communications
- Cox Communications
- CSRA
- Fairpoint Communications, Inc.
- Frontier
- Harris Corporation
- Hubbard Radio
- Hughes Network Systems
- Iconectiv
- Independent Telephone and Telecommunications Alliance
- Internet Security Alliance
- Iridium
- Juniper Networks
- Level 3 Communications
- NABA
- National Association of Broadcasters
- National Cable & Telecommunications Association
- National Telephone Cooperative Associations
- NeuStar
- Nsight Technologies
- NTT Communications Corporation
- Satellite Industry Association
- Sprint
- T-Mobile
- Telecommunications Industry Association (TIA)
- Telephone and Data Systems, Inc.
- U.S. Cellular
- US Telecom - The Broadband Association
- Utilities Technology Council
- Verizon
- Viasat
- Windstream

[122] "Communications Sector: Charters and Membership," Cybersecurity and Infrastructure Security Agency, last revised June 24, 2020, https://www.cisa.gov/communications-sector-council-charters-and-membership.
[123] "Communications Sector: Charters and Membership."

Sector Workforce

According to BLS, the wired and wireless telecommunications industries are both standout performers in labor productivity over the past 31 years. Wireless telecommunications ranked second highest in labor productivity growth between 1987 and 2018. Wired telecommunications ranked twentieth.[124] Communications equipment manufacturing ranked thirteenth in productivity growth between 1987 and 2018.[125]

Fastest Growing Communications Occupations by Rate

According to BLS, the following occupations are the projected fastest growing communications occupations for 2019–2029.[126]

Occupation	Jobs (2019)	Job Outlook, 2019–29	2020 Median Pay	Entry-Level Education
Information security analysts	131,000	+31%	$103,590	Bachelor's degree
Software developers	1,469,200	+22%	$110,140	Bachelor's degree
Film and video editors and camera operators	67,900	+18%	$61,900	Bachelor's degree
Computer and information research scientists	32,700	+15%	$126,830	Master's degree
Database administrators	132,500	+10%	$98,860	Bachelor's degree
Broadcast, sound, and video technicians	140,300	+9%	$47,420	High school diploma, bachelor's degree, or associate's degree
Web developers and digital designers	174,300	+8%	$77,200	Associate's degree
Computer support specialists	882,300	+8%	$55,510	Bachelor's degree or associate's degree

[124] Nathan F. Modica and Brian Chansky, "Productivity trends in the wired and wireless communications industries," *Beyond the Numbers* 8, No. 8 (May 2019), https://www.bls.gov/opub/btn/volume-8/productivity-trends-in-the-wired-and-wireless-telecommunications-industries.htm#_edn1.

[125] Modica and Chansky, "Productivity trends in the wired and wireless communications industries."

[126] "Computer and Information Technology Occupations," Occupational Outlook Handbook, U.S. Bureau of Labor Statistics, U.S. Department of Labor, accessed August 26, 2021, https://www.bls.gov/ooh/computer-and-information-technology/home.htm; "Occupational Outlook Handbook: Media and Communication Occupations," U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/media-and-communication/home.htm.

Sector Workforce Programs and Initiatives

The Communications Sector is supported by a variety of programs to foster workforce development at the national and regional level.

The Federal Government has initiated several programs in the last four years to develop a foundation for the workforce in the fields of science, technology, engineering, and math (STEM). For instance, the Department of Education prioritized STEM workforce education and training in their fiscal year 2020 budget requests.[127]

In 2017, the White House issued an executive order to expand apprenticeships and improve job-training programs.[128] In 2018, President Trump signed the Strengthening Career and Technical Education for the 21st Century Act into law, increasing student access to high-quality technical education and credentialing at the secondary and postsecondary levels.[129]

Notable telecommunication industry association programs have focused on funding and expanding workforce development programs. The Telecommunications Industry Registered Apprenticeship Program (TIRAP), will deliver America's 5G Apprenticeship Initiative, sponsored by the Wireless Infrastructure Association (WIA), to engage public and private partners and 33 small and mid-sized employers to create more than 5,500 new apprentices for the development and acceleration of 5G networks.[130] Additionally, the Consumer Technology Association's (CTA) Apprenticeship Coalition is a collaborative effort by CTA member companies to create and expand apprenticeship opportunities nationwide and prepare American workers for careers in software engineering, data analytics, and hardware design.[131]

Nonprofit efforts, some of which are supported by DOL funds, help to develop the telecommunications workforce. The National Urban League provides hands-on support to underserved populations by providing well-paid jobs and training in the adjacent Information Technology Sector for middle-skill occupations through the Urban Tech Jobs program with a 73 percent completion rate.[132]

Individual companies offer a variety of internal training programs and initiatives. Amazon will spend more than $700 million to train 100,000 employees for higher-skilled jobs in the IT sector over the next six years.[133] Likewise, in 2020, AT&T invested about $166 million in direct employee training and professional development programs and delivered 16 million hours of training.[134]

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[127] "Memorandum for the Heads of Executive Departments and Agencies," Executive Office of the President, July 31, 2018, https://www.whitehouse.gov/wp-content/uploads/2018/07/M-18-22.pdf.

[128] "U.S. Department of Labor Announces Apprenticeship.gov to Connect Job Seekers and Employers," Department of Labor, June 15, 2018, https://www.dol.gov/newsroom/releases/eta/eta20180615#:~:text=The%20initial%20launch%20of%20Apprenticeship,Americans%20secure%20family%2Dsustaining%20jobs.

[129] "Fact Sheet: President Donald J. Trump is Committed to Preparing America's Workers for the Jobs of Today and Tomorrow," White House, issued on July 31, 2018, https://trumpwhitehouse.archives.gov/briefings-statements/president-donald-j-trump-committed-preparing-americas-workers-jobs-today-tomorrow/?utm_source=twitter&utm_medium=social&utm_campaign=wh.

[130] "WIA Awarded $6 Million DOL Grant to Train 5G Workforce," Telecommunications Industry Registered Apprenticeship Program, February 19, 2020, https://www.tirap.org/wia-awarded-6-million-dol-grant-to-train-5g-workforce/.

[131] "Who We Are: The Future of Work," Consumer Technology Association, accessed September 1, 2021, https://www.cta.tech/who-we-are/future-of-work.

[132] "Urban Tech Jobs Program," National Urban League, accessed September 1, 2021, https://nul.org/program/urban-tech-jobs-program.

[133] Amy Scott, "From the Warehouse to IT: Amazon Offering 100,000 Workers Tech Training," *NPR News*, July 11, 2019, https://www.npr.org/2019/07/11/740660070/from-the-warehouse-to-it-amazon-offering-100-000-workers-tech-training.

[134] A full list of programs can be found at "Building Digital Skills," AT&T, accessed September 2, 2021, https://about.att.com/csr/home/reporting/issue-brief/digital-skills.html.

Workforce Challenges or Issues

The Communications Sector workforce faces a variety of challenges. The most pressing difficulty is an aging workforce combined with rapid technological change and relatively few training and apprenticeship opportunities to develop a younger workforce.

Lack of Appropriate Skills and Training

- A mismatch of skills is an increasing concern in the Communications Sector.
- Workforce challenges are particularly acute for 5G wireless infrastructure.
    - 5G infrastructure is growing, but the country lacks the skilled technicians and workforce needed to build, manage, and sustain the infrastructure and perform tasks such as climbing cell towers, laying fiber, and installing wireless transmitters.
- The sector needs more educational opportunities, including apprenticeships, internships, and training schools to meet the demand for workers.
    - Only a handful of programs exist nationwide at colleges and technical institutes to train the wireless workforce.[135]

Aging Workforce

- The aging workforce is not being adequately backfilled to support growth and competition for talent from China and other countries.[136]
    - In a 2019 report, the NSTAC observed that "the number of American university students graduating with degrees in computer science, electrical engineering, and material science and going into the semiconductor industry is not nearly enough to support the current demand of U.S. companies." [137]
- The Communications Sector workforce faces recruitment and retainment challenges.
    - The same 2019 NSTAC report found that U.S. immigration policy further hinders the communications industry by "discouraging or prohibiting graduate students in these disciplines, who are primarily foreign nationals, from remaining in the United States."[138]

Inequities in Access

- Not all individuals in the Nation have access to broadband.
    - Access to broadband affects an individual's ability to conduct and participate in online certification programs, which in turn, allows them to participate in a technologically advanced workforce.

Shifting Skill Requirements

- The continued development of AI and other technologies will reshape demands for certain skilled labor.
    - Mike Mansuetti, president of Bosch North America, stated that "rapid advancements in areas like artificial intelligence and machine learning have the potential to create 60

[135] Sam Sabin, "5G Worker Shortages Could Provide many Americans with Chance to Return to Work," *Morning Consult*, May 6, 2020, https://morningconsult.com/2020/05/06/5g-wireless-workforce-shortage-coronavirus/.
[136] National Security Telecommunications Advisory Committee, *NSTAC Report to the President on Advancing Resiliency and Fostering Innovation in the Information and Communications Technology Ecosystem* (2019) p. B-1, https://www.cisa.gov/sites/default/files/publications/nstac_letter_to_the_president_on_advancing_resiliency_and_fostering_innovation_in_the_ict_ecosystem_2.pdf.
[137] NSTAC, *NSTAC Report to the President on Advancing Resiliency and Fostering Innovation in the Information and Communications Technology Ecosystem*, p. B-1.
[138] NSTAC, *NSTAC Report to the President on Advancing Resiliency and Fostering Innovation in the Information and Communications Technology Ecosystem*, p. B-1.

million new jobs by 2022, but those jobs will go unfilled unless business leaders help shoulder the responsibility of educating and upskilling our existing workforce. These types of training programs, complemented by apprenticeships, STEM education in K–12 and more, are critical for the industry and future of America's economic success." [139]

Pandemic Complications

- COVID-19 has brought new challenges to the Communications Sector workforce.
    - The pandemic highlighted the necessity of stable internet connections amid social distancing guidelines, with a sharp increase in remote working, telemedicine, online learning, and streaming in-home entertainment.[140]

Water and Wastewater Systems Sector

The Water and Wastewater Systems Sector is responsible for ensuring the nation's supply of drinking water and wastewater treatment and services. The sector constitutes 153,000 public drinking water systems and over 16,500 publicly owned wastewater treatment systems across the country. These systems provide potable water to over 80 percent of the U.S. population and sanitary sewerage treatment to about 75 percent of the population.[141]

Wastewater treatment systems provide services to over 227 million people across the country. Most facilities are designed for domestic sewage treatment, but some publicly owned treatment works (POTWs) receive and treat wastewater from industrial plants. Wastewater treatment systems are engaged in many activities, including waste collection, storage, treatment (physical and chemical), disinfection, monitoring, and discharge (into a body of water, groundwater, or back into the water system for reuse, depending on water quality and local legislation).[142]

A thriving, skilled Water and Wastewater Systems Sector workforce is vital to the nation's environmental protection, public health, and general day-to-day activity. A deteriorating physical infrastructure, rapidly changing technology, an aging workforce, and a lack of funding for training and education results in an understaffed, insufficiently skilled workforce. The Water and Wastewater Systems Sector is undertaking many hiring, outreach, and training initiatives to combat these challenges, including focusing more effort on hiring and outreach programs, particularly for potential workers from nontraditional backgrounds.

Sector Stakeholders

The Environmental Protection Agency (EPA) is the SRMA for the Water and Wastewater Systems Sector.[143] The sector is supported by an SCC and GCC. The sector is almost entirely publicly owned and operated and consists of a decentralized system of water and wastewater treatment operations across the country, with different levels of government control water treatment.

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[139] Jennifer Taylor, "The Future of Work Hits a High Note at CES 2020," *Consumer Technology Association*, April 6, 2020, https://www.cta.tech/Resources/i3-Magazine/i3-Issues/2020/March-April/The-Future-of-Work-Hits-a-High-Note-at-CES-2020.
[140] "COVID-19 Outlook on the US Telecom Industry," Deloitte, accessed August 31, 2021, https://www2.deloitte.com/us/en/pages/technology-media-and-telecommunications/articles/covid-19-outlook-on-telecommunications-industry.html.
[141] "Water and Wastewater Systems Sector," Cybersecurity and Infrastructure Security Agency, accessed August 26, 2021, https://www.cisa.gov/water-and-wastewater-systems-sector.
[142] Cybersecurity and Infrastructure Security Agency, *Water and Wastewater Systems Sector-Specific Plan,* 2015, https://www.cisa.gov/sites/default/files/publications/nipp-ssp-water-2015-508.pdf.
[143] Cybersecurity and Infrastructure Security Agency, *Water and Wastewater Systems Sector-Specific Plan,* 2015.

Under the Safe Drinking Water Act (SDWA), states may request primacy over their drinking water systems (i.e., authority to oversee their own water programs); state agencies that administer these programs are known as primary agencies. For locations that do not have primacy, EPA regional offices administer drinking water programs instead, as is the case for Wyoming, the District of Columbia, most sovereign tribal nations (excluding the Navajo Nation, which has primacy), and several U.S. territories.[144]

Wastewater treatment is primarily conducted by public utilities across the country, though some private facilities, such as industrial plants, operate within the sector as well. Public or private, all facilities that discharge treated wastewater into U.S. water systems are subject to the Clean Water Act (CWA) National Pollutant Discharge Elimination System (NPDES) program.

In addition to federal and state authorities, the Water and Wastewater Systems Sector has partnerships among public and private drinking water and wastewater utilities, national and state associations, and research foundations.

The Water and Wastewater Systems Sector GCC

The Water Sector GCC is chaired by the EPA and includes the following members.[145]

- Association of State Drinking Water Administrators
- Environmental Council of the States
- Montana Department of Environmental Quality
- National Association of County & City Health Officials
- National Association of Regulatory Utility Commissioners
- New Hampshire Department of Environmental Services
- State of New Hampshire/Department of Environmental Services
- U.S. Department of Agriculture
- U.S. Department of Defense
- U.S. Department of Health and Human Services
- U.S. Department of Homeland Security
- U.S. Department of the Interior
- U.S. Department of Justice
- U.S. Department of State
- U.S. Environmental Protection Agency

The Water and Wastewater Systems Sector SCC

The SCC is made up of the following organizations.

- Alexandria Renew Enterprises
- American Water
- American Water Works Association
- Association of Metropolitan Water Agencies
- Boston Water and Sewer Commission
- Breezy Hill Water and Sewer Company
- Catalyst Partners L.L.C
- Conway County Regional W.D.D.
- Davidson Water, Inc.
- National Association of Water Companies
- National Rural Water Association
- New York City Department of Environmental Protection
- Onondaga County Water Authority
- Orlando Utilities Commission
- Prince William County Service Authority
- San Jose Water Company
- Spartanburg Water
- Water Environment Federation
- Water Environment Research Foundation

[144] Cybersecurity and Infrastructure Security Agency, *Water and Wastewater Systems Sector-Specific Plan,* 2015.
[145] "Water and Wastewater Systems Sector: Council Charters and Membership," Cybersecurity and Infrastructure Security Agency, accessed August 31, 2021, https://www.cisa.gov/water-sector-council-charters-and-membership.

- District of Columbia Water and Sewer Authority
- LA Sanitation City of Los Angles (California)
- National Association of Clean Water Agencies
- Water Information Sharing and Analysis Center
- Water Research Foundation

Sector Workforce

According to BLS, nearly 1.7 million people worked within the sector in designing, constructing, operating, and managing water and wastewater treatment systems as of 2016.[146]

The Water and Wastewater Systems Sector encompasses more than 200 distinct occupations, from skilled trade positions like electricians and technicians to financial, administrative, and management jobs.[147] Water operators, for instance, ensure federal, state, and/or local water quality standards, test water samples, and monitor facility conditions. These facilities also require diverse groups of mechanics, machinists, electricians, and instrument technicians to install, repair, and oversee utility equipment.

BLS projects that water occupations will grow 9.9 percent per year between 2016 and 2026 (compared to the national average of 7.4 percent growth in other industries).[148] Software and app developers in the water industry are projected to grow the fastest during this period, at over 30 percent. However, operators of water and wastewater treatment plant systems are expected to decline between 2019 and 2029 by about 4 percent.

Fastest Growing Water and Wastewater Occupations by Rate

The table below provides Water Sector occupations outlined by BLS, including description, entry-level education, and 2019 median pay.[149]

Occupation	Jobs (2019)	Job Outlook, 2019–29	2020 Median Pay	Entry-Level Education
Electricians	739,200	+8%	$56,900	High school diploma or equivalent
Environmental engineering technicians	18,500	+7%	$51,630	Associate's degree
Plumbers, pipefitters, and steamfitters	490,200	+4%	$56,330	High school diploma or equivalent

[146] "May 2017 National Industry-Specific Occupational Employment and Wage Estimates: NAICS 562200 - Waste Treatment and Disposal," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/oes/2017/may/naics4_562200.htm; "May 2017 National Industry-Specific Occupational Employment and Wage Estimates: NAICS 221300 - Water, Sewage and Other Systems," U.S. Bureau of Labor Statistics, accessed September 1, 2021, https://www.bls.gov/oes/2017/may/naics4_221300.htm.

[147] Joseph Kane and Adie Tomer, *Renewing the Water Workforce: Improving Water Infrastructure and Creating a Pipeline of Opportunity* (Washington, D.C.: Brookings Institution, June 2018), https://www.brookings.edu/wp-content/uploads/2018/06/Brookings-Metro-Renewing-the-Water-Workforce-June-2018.pdf.

[148] Kane and Tomer, *Renewing the Water Workforce*.

[149] "Architecture and Engineering Occupations," Occupational Outlook Handbook, U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/architecture-and-engineering/home.htm; "Construction and Extraction Occupations," Occupational Outlook Handbook, U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/construction-and-extraction/home.htm; "Production Occupations," Occupational Outlook Handbook, U.S. Bureau of Labor Statistics, accessed August 26, 2021, https://www.bls.gov/ooh/production/home.htm.

Chemical engineers	32,600	+4%	$108,540	Bachelor's degree
Civil engineering technicians	70,900	+3%	$54,080	Associate's degree
Environmental engineers	55,800	+3%	$92,120	Bachelor's degree
Civil engineers	329,200	+2%	$88,570	Bachelor's degree
Stationary engineers and boiler operators	34,400	+2%	$64,680	High school diploma or equivalent

Sector Workforce Programs and Initiatives

Governments from the federal to local levels, as well as national industry associations, maintain a variety of initiatives to improve the Water Sector's training programs and hiring, rebranding, and outreach. However, there are currently few industry-wide metrics to measure the success of these workforce development programs.

At the federal level, the EPA has undertaken many outreach programs and initiatives for the Water and Wastewater Systems Sector.[150] One of its most recent efforts is a 2020 Water Workforce Initiative to help cities and communities of all sizes combat critical staffing shortages in water and wastewater positions.[151] This initiative will focus on strong federal leadership, sector collaboration with diverse partners, and an increase in education and awareness of Water Sector careers.

In February 2020, the EPA, alongside the U.S. Department of Agriculture, announced a Memorandum of Agreement (MOA) to help rural water systems address their aging workforces, employment shortages, increasing costs, and other challenges.[152] This MOA will provide rural utilities with training and education resources and support partnerships between the Water Sector and other community organizations.

The EPA's recruitment campaigns include a guide for water operators to recruit veterans and match their military skills with similar skills in the Water Sector.[153] These corresponding skills include basic skills such as installing, operating, and maintaining water equipment and water quality analysis tests; and advanced skills, including supervising other soldiers, overseeing larger projects, and familiarizing themselves with more complex water equipment.

Many regional and local jurisdictions also support workforce initiatives. For instance, in 2015 the Baltimore Public Works Department redeveloped and rebranded its training program, Y-H20, to appeal

[150] National Academy of Public Administration, *Enhancing Water Delivery and Waste Water Systems in the United States: An Agenda for 2021* (Washington, D.C.: National Academy of Public Administration, 2020), https://www.napawash.org/uploads/Create_Modern_Water_Systems.pdf.
[151] "EPA Announces Water Workforce Initiative to Help Recruit and Prepare the Next Generation of Clean Water Professionals," U.S. Environmental Protection Agency, October 5, 2020, https://www.epa.gov/newsreleases/epa-announces-water-workforce-initiative-help-recruit-and-prepare-next-generation-clean; U.S. Environmental Protection Agency, *America's Water Sector Workforce Initiative: A Call to Action,* October 2020, https://www.epa.gov/sites/default/files/2020-11/documents/americas_water_sector_workforce_initative_final.pdf.
[152] "USDA and EPA Announce Continued Commitment to Support Rural Water Systems," U.S. Department of Agriculture, February 20, 2020, https://www.usda.gov/media/press-releases/2020/02/20/usda-and-epa-announce-continued-commitment-support-rural-water; National Academy of Public Administration, *Enhancing Water Delivery and Waste Water Systems in the United States: An Agenda for 2021*, 2020, https://www.napawash.org/uploads/Create_Modern_Water_Systems.pdf.
[153] U.S. Environmental Protection Agency, *From M.O.S. to J-O-B: A Guide for Applying Military Occupational Specialties (M.O.S.) to Civilian Drinking Water and Wastewater Operations* (April 2014), https://www.epa.gov/sites/production/files/2015-11/documents/from_mos_to_job.pdf.

to younger generations. This program includes three phases, in which students take interest assessments, explore career options, and are placed in paid summer jobs in the industry.[154]

BAYWORK is an innovative regional partnership for Bay Area utility employers and workforce development stakeholders to recruit and train the next generation of water and wastewater industry professionals.[155]

PowerCorps Camden is a Camden, New Jersey-based training program for high school graduates aged 18 to 26, encouraging entrance into the Water Sector with a mixture of environmental stewardship and support services. Largely funded by the Corporation for National Community Service, PowerCorps Camden (as well as its sister organization in Philadelphia) has been successful at transitioning new workers from impoverished areas into the sector.[156] This program's success relied on the Camden County Municipal Utilities Authority's (CCMUA) partnership with the nonprofit Center for Family Services (CFS), the latter of which provided support services to PowerCorps.

In 2018, Atlanta's Department of Watershed Management (DWM) has created the Preparing Adult Offenders to Transition Through Training and Therapy (PAT^3) initiative designed to reach male adult offenders reentering society who have not been typical workers in the wastewater sector. PAT^3 is composed of a state partnership with a three-tiered process utilizing mandated vocational training, workforce development, and employment elements.[157]

Partnerships between government-run utilities and the private sector are often essential for the success of these programs. Owners and operators in the California Bay Area, for example, are partnering with local schools and neighborhoods to offer interactive learning opportunities and hands-on projects like green infrastructure demonstrations, allowing for better community engagement and communication.[158]

Several utilities have begun to direct hiring efforts to improve diversity; the East Bay Municipal Utility District in San Francisco has set up equal employment opportunity coordinators in its agency to increase hiring and diversify its workforce.[159]

Water utilities and operators have also undertaken several training programs for new and old employees. According to the American Water Works Association (AWWA), 42 percent of water utilities had fully implemented staff training programs in 2019.[160] Dozens of training and mentoring programs and internships have been developed across the industry through partnerships and sponsorships by

[154] "YH2O Mentoring Program," Baltimore City Department of Public Works, accessed September 1, 2021, https://publicworks.baltimorecity.gov/water-mentoring-program.
[155] "About Baywork," Baywork, accessed September 1, 2021, https://baywork.org/; Afia Zakiya, "BAYWORK: An Innovative Regional Water Workforce Partnership," Unpublished manuscript, July 2019.
[156] Kimberley Irby, "Bolstering the Water Workforce with Innovative Programs," New Jersey Future, June 12, 2020, https://www.njfuture.org/2020/06/12/bolstering-the-water-workforce-during-covid-19-recovery-current-programs-in-new-jersey/; Afia Zakiya, "PowerCorps: Leveraging Green Infrastructure Jobs for Youth Workforce Development," Unpublished manuscript, July 2019.
[157] "Launch of the PAT3 Program," OneAtlanta, April 2018, https://justicereform.atlantaga.gov/article/launch-of-the-pat3-program-2.
[158] Kane and Tomer, *Renewing the Water Workforce*.
[159] Kane and Tomer, *Renewing the Water Workforce*.
[160] American Water Works Association, *2019 State of the Water Industry Report* (2019), https://www.awwa.org/Portals/0/AWWA/ETS/Resources/2019_STATE%20OF%20THE%20WATER%20INDUSTRY_post.pdf.

schools, state or local governments, sector utilities, and the Department of Labor's Workforce Investment Agency.[161]

National industry associations have carried out many workforce initiatives. For instance, the AWWA and the Water Environment Federation (WEF) launched a public outreach campaign in 2010 to inform the public about water careers and encourage students, veterans, and other job seekers to enter the industry.[162]

Workforce Challenges or Issues

The Water Sector workforce faces many challenges, including a rapidly aging workforce and difficulty replacing retiring workers due to insufficient and unreliable funding. Water and wastewater operators cannot address challenges equally well across the sector, as smaller and more rural facilities lack the funding, personnel, and other resources to implement changes that larger organizations can.[163]

Aging Workforce

- The Water and Wastewater Systems workforce is aging quickly.
    - BLS projects that 8.2 percent of existing water operators will need to be replaced annually between 2016 and 2026.[164]

Diversity Gap

- The Water and Wastewater Systems Sector lacks gender and racial diversity.
    - In 2016, nearly 85 percent of the industry was male and over 72 percent was white.[165]
    - Apprenticeships provide important career paths for underserved and underrepresented communities.[166]
- Smaller utilities in rural areas struggle to recruit and retain a diversified workforce due to exclusive hiring, racism, and lack of enough long-term career opportunities.

Hiring and Outreach Difficulties

- The Water and Wastewater Systems Sector suffers from a lack of public visibility and struggles to attract new talent and conduct successful outreach efforts.
    - Many younger workers are unaware of job opportunities in the Water and Wastewater Systems Sector, and very few young people are employed in the sector. In 2016, only 10.2 percent of employees were under 24 years old.[167]

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[161] U.S. Environmental Protection Agency, *A Selection of Training Programs for Water and Wastewater Operations,* April 2013, https://www.epa.gov/sites/production/files/2016-01/documents/workforcefactsheetscompilation_revisedfinal.pdf.
[162] "Work for Water," Work for Water, accessed September 1, 2021, https://www.workforwater.org/.
[163] Kane and Tomer, *Renewing the Water Workforce*.
[164] U.S. Government Accountability Office, *Water and Wastewater Workforce: Recruiting Approaches Helped Industry Hire Operators, but Additional EPA Guidance Could Help Identify Future Needs* (2018), https://www.gao.gov/assets/690/689621.pdf.
[165] Kane and Tomer, *Renewing the Water Workforce*.
[166] Afia Zakiya, *Apprenticeships: Pathways Toward Workforce Diversity in the Water Sector*, Congressional Black Caucus Foundation, 2019, https://www.cbcfinc.org/wp-content/uploads/2019/10/REV1.FINAL-PRINTED-COPYRIGHTED.Apprenticeships-Pathways-Toward-Workforce-Diversity-in-the-Water-Sector-10-1-19.pdf; Afia Zakiya, *Towards Workforce Diversity and Inclusion in Water Professions: Apprenticeships as an Essential Pathway for African Americans and Minorities*, Congressional Black Caucus Foundation, September 2019, https://www.cbcfinc.org/wp-content/uploads/2019/10/REV1.FINAL-PRINTED-COPYRIGHTED.Apprenticeships-Pathways-Toward-Workforce-Diversity-in-the-Water-Sector-10-1-19.pdf; Afia Zakiya, *Water Careers and Opportunities for African Americans*, Congressional Black Caucus Foundation, 2019, https://www.cbcfinc.org/wp-content/uploads/2019/10/REV.1-FINAL-PRINTED-COPYRIGHTED.Water-Careers-and-Opportunities-for-African-Americans_Sept-6-2019.AZ-10.2-2019.pdf.
[167] Kane and Tomer, *Renewing the Water Workforce*.

    - Smaller and more rural facilities can be even less appealing to workers due to lower pay and benefits, remote locations, and weaker infrastructure that cannot be repaired or maintained at the same rate as in larger organizations.
- Hiring practices are often inflexible and make it difficult for employees with nontraditional backgrounds to apply or qualify for jobs in the sector.
    - Adopting the AWWA Competency Model Framework and AWWA Operator Licensing Requirements across the United States could provide a common foundation for employers to better advertise and the skills necessary in the sector.[168]
- Many water and wastewater utilities struggle to retain new employees who want to leave for higher pay, better benefits, or less remote locations.[169]
    - Most jobs in the sector have a long qualification process that can make entry and retention in the sector challenging; this includes unusually long on-the-job training requirements.

Budget and Resource Constraints

- Building a skilled workforce is challenging due to budget constraints, insufficient training programs, and disparate credentialing systems.
    - The education and certification requirements for systems operators, plumbers, and many other positions often vary drastically from state to state, and existing training programs are inflexible to workers moving between jurisdictions.
- The Water and Wastewater Sector struggles with a lack of funding to address aging infrastructure.
    - The AWWA's 2019 State of the Water Industry Report cites this as a top concern among water utilities.[170] Aging infrastructure becomes a major workforce challenge in the sector, requiring extensive knowledge of aging, legacy systems and making many facilities unappealing to a new workforce—particularly among smaller, more rural, and less funded operators.

Shifting Skill Requirements

- The changing nature of sector operations, such as increase in automated systems, growing dependence on supervisory control and data acquisition (SCADA) systems, updates to environmental or cybersecurity guidelines, and a new emphasis on digital intelligence as a requirement for workers, make it more difficult to build a skilled workforce.[171]
    - These changes necessitate additional training, which is unlikely to be implemented consistently across facilities, as well as a broader set of skills required for job applications and certifications, which potential employees are less likely to have.

[168] "Operator Licensing Requirements Across the United States," American Water Works Association, 2018, https://www.awwa.org/Portals/0/AWWA/ETS/Resources/Final_Report_Compiled_2.19.18.pdf?ver=2019-02-18-142536-257.
[169] Willamette Partnership, Evergreen State College, and Portland State University, *2019 Pacific Northwest Water Infrastructure Workforce Report* (August 2019), https://willamettepartnership.org/wp-content/uploads/2019/08/2019-PNW-Water-Infrastructure-Workforce-Final.pdf.
[170] American Water Works Association, *2019 State of the Water Industry Report* (2019), https://www.awwa.org/Portals/0/AWWA/ETS/Resources/2019_STATE%20OF%20THE%20WATER%20INDUSTRY_post.pdf.
[171] "Aging Infrastructure, Aging Workforce Deepen Challenges for the Water Industry," *Empowering Pumps & Equipment,* July 10, 2020, http://empoweringpumps.com/black-veatch-aging-infrastructure-aging-workforce-deepen-challenges-for-the-water-industry/.

Lifeline Sector Workforce Profile Summary

The energy, transportation systems, communications, and water and wastewater systems are critical sectors where the lack of a skilled workforce could have negative economic and national security consequences. Although each faces a unique set of difficulties, the sectors must also contend with issues that cut across industries, including an aging workforce and rapid technological changes. Some subsectors, like clean energy and information technology, are poised for continued and rapid growth, while others appear to be in sharp decline, such as operators of water and wastewater treatment plant systems. While there is no single solution to these challenges, better coordination at all levels of government and across sectors will help support the nimble and resilient workforce necessary to ensure the stability of critical infrastructure.

Appendix C: Comparison of U.S. and International Apprenticeship Systems

As part of its tasking, the NIAC was asked to identify successful international apprenticeship programs and determine if there are lessons learned or components of these programs that could be adopted for the U.S. workforce development system. This appendix includes a summary of research into the key features of U.S. and European apprenticeship models and describes opportunities to develop scalable and successful apprenticeship programs at the state level.

Summary

The translation of European apprenticeship frameworks into the U.S. workforce system will involve a long-term commitment to monitoring, tracking, and continually evaluating outcomes of the apprenticeship system at local, state, and national scales. European and American apprenticeship systems are more distinct than analogous, complicating the ability to adapt European models. Nevertheless, many states have established robust public-private collaborations to supplement increased investment in apprenticeships as an important tool of workforce development.

Overview of European vs. U.S. Models of Apprenticeships

As in the United States, European apprenticeship programs are centered on integrating educational curricula and hands-on training in coordination with employers, education providers, and industry representatives and are integral to the development of a skilled workforce. The European Center for Development and Vocational Training (CEDEFOP) reports there are 30 different apprenticeship schemes across 24 countries in Europe.[172] Germany offers a dual vocational and education training (VET) program that allows higher education students to acquire hands-on training while pursuing their degrees. Apprenticeships in England are considered full-time paid jobs comprised of on- and off-the-job training.[173] The Swiss workforce training system is recognized globally as a "gold standard" because its model incorporates diverse perspectives into workforce development, streamlines education-to-career programs, maintains low youth unemployment rates, and expands apprenticeships into cutting-edge career areas, among many other factors.[174]

Although details vary from country to country, European models share several core features. First, most European nations have adopted a centralized and closely regulated approach to economic planning and workforce development. Second, European countries tend to integrate the education system more fully into workforce development programs, providing a holistic and streamlined path from education to work. Third, European Works Councils ensure that the needs and rights of workers are compatible with economic planning objectives. Fourth, European countries have invested in significant social services

[172] European Centre for the Development of Vocational Training, *Apprenticeship Schemes in European Countries: A Cross-Nation Overview* (2018), p. 11, https://www.cedefop.europa.eu/files/4166_en.pdf.

[173] "UK vs. EU: How do their Apprenticeships Compare?" Allaboutgroup.org, accessed August 31, 2021, https://www.allaboutgroup.org/insights/article/uk-v-eu-how-do-their-apprenticeships-compare.

[174] Nancy Hoffman and Robert Schwartz, *Gold Standard: The Swiss Vocational Education and Training System* (Washington, DC: National Center on Education and the Economy, 2015), https://ncee.org/wp-content/uploads/2015/03/SWISSVETMarch11.pdf.

that enhance worker freedom to define new career or credentialing pathways (e.g., public health insurance; unemployment insurance).

Ultimately, the European system features robust collaboration between a range of government agencies, and individual European governments have adopted highly specialized apprenticeship programs fine-tuned to their specific regulatory, economic, and political conditions. For instance, Germany has a highly competitive manufacturing sector that trains more apprentices than many other countries, and the well-regulated sharing of administrative responsibilities between the central government and the 16 federal states creates a high level of efficiency.[175]

In the United States, by comparison, there is relatively little coordination across the system. The Departments of Education and Labor seldom collaborate. The Workforce Opportunity and Improvement Act (WOIA) provided important new funding mechanisms to federal agencies, but most workforce development programs are initiated and administered at the state level. State governments, meanwhile, often resist federal guidance, and private employers have no obligation to establish, develop, or maintain apprenticeship programs. This fragmented and largely unregulated state- and employer-centric approach to workforce development differs significantly from European systems.

Key Takeaways

European apprenticeship models vary but share many common traits that make them distinct from American apprenticeship programs.

- European countries pay all or a significant part of tuition for postsecondary educational and vocational programs, limiting students' and workers' exposure to financial risk and professional disruption as they pursue long-term careers.
- European employers pay all or most of the costs associated with hiring and training apprentices, though not all businesses experience a net positive return on their investment in the short-term.[176]
- European governments collaborate with educators, employers, and union representatives to develop standardized, scalable, and portable occupational and skill profiles to suit changing labor market or economic conditions.
- Many highly industrialized nations in Europe take a proactive role in guiding and positioning workers for long-term careers. For instance, social welfare programs often provide the wraparound services necessary to adjust to professional or personal changes.

[175] Elizabeth Matsangou, "Why French Education Could Learn from German Apprenticeships," EuropeanCEO, August 6, 2018, https://www.europeanceo.com/business-and-management/why-french-education-could-learn-from-german-apprenticeships/.
[176] Manuela Lodovici, et al., *The Effectiveness and Costs-Benefits of Apprenticeships: Results of the Quantitative Analysis* (Brussels, Belgium: European Commission, September 2013), https://research.brighton.ac.uk/en/publications/the-effectiveness-and-costs-benefits-of-apprenticeships-results-o.

Germany and Switzerland have implemented globally recognized and successful models of apprenticeship systems.

- In 2017, Germany spent 6.84 billion euros on apprenticeship and workforce development training, while Switzerland spent the equivalent of 3.3 billion euros. These numbers do not include private contributions to their respective workforce development systems.[177]
- Germany trained 1.32 million apprentices in 2017.[178]
- The German Vocational Education and Training (VET) system is distinguished by its centralized authority, widespread public awareness of apprenticeships, and significant involvement of employers.
    - The Federal Ministry of Education and Research (BMBF) and the Federal Institute for Vocational Education and Training (BIBB) collaborate with employers, educational institutions, and trade unions to establish and administer workforce development programs.
    - The dual VET system means that students engage in on-the-job training as they pursue their educational credentials, and the system is premised on cooperation between publicly funded vocational schools and private small, medium, and large corporations.
    - As of 2017, 52.9 percent of the population pursued VET programs.
    - As of 2017, 427,227 companies participated in the apprenticeship system, or 19.8 percent of all companies.[179]
- The Swiss Vocational and Professional Education and Training (VPET) system is distinguished by its robust intergovernmental collaboration, heavy national investment in vocational training, and widespread public confidence in the value of apprenticeships.
    - The VPET system is governed by the State Secretariat for Education, Research, and Innovation (SERI) in collaboration with the Swiss Conference of Cantonal Ministers of Education (EDK).
    - Like in Germany, students in the VPET system begin their programs in vocational and professional training as they pursue their secondary education.
    - 53 percent of the population opt for the vocational and professional education and training pathway, acquiring either a VET qualification or a professional education (PE) qualification.
    - 35 percent of the population opt for the generation education pathway, which allows them to obtain a baccalaureate or higher education qualification.[180]

[177] "Funding Arrangements in Germany," Apprenticeship Toolbox, accessed September 1, 2021, https://www.apprenticeship-toolbox.eu/financing/funding-arrangements/47-funding-arrangements-in-germany; "Funding Arrangements in Switzerland," Apprenticeship Toolbox, accessed September 1, 2021, https://www.apprenticeship-toolbox.eu/financing/funding-arrangements/46-funding-arrangements-in-switzerland.
[178] "Apprenticeship System in Germany," Apprenticeship Toolbox, accessed September 1, 2021, https://www.apprenticeship-toolbox.eu/germany/apprenticeship-system-in-germany.
[179] "Apprenticeship System," Apprenticeship Toolbox, accessed September 1, 2021, https://www.apprenticeship-toolbox.eu/germany/apprenticeship-system-in-germany.
[180] "Economic Context," Apprenticeship Toolbox, accessed September 1, 2021, https://www.apprenticeship-toolbox.eu/switzerland/economic-context-in-switzerland.

The United States spends far less in both government and private sector funds than do most European nations.

- Federal spending on workforce development has decreased from about $7.22 billion in 2001 to a proposed $4.54 billion for fiscal year 2020.[181]
- The fraction of workers who received employer-sponsored, on-the-job training also fell in the United States from 32.5 percent to 19.6 percent between 1996 and 2008.[182]
- The Organization for Economic Cooperation and Development (OECD) tracks different countries' public spending on labor markets, which is defined as national investment (as a percentage of Gross Domestic Product [GDP]) in public employment services, training, hiring subsidies, direct job creations in the public sector, as well as unemployment benefits. In 2018, the United States spent approximately 1/5 of many industrial European countries:
    - Germany: 1.39 percent
    - Switzerland: 1.17 percent
    - United States: 0.25 percent[183]

The United States' decentralized and state-led system of workforce funding, credentialling, and coordination has hindered the county's ability to increase the scale of apprenticeship programs.

- Many registered and industry-recognized apprenticeships do not produce portable and universally recognized skills or credentials, which restricts worker mobility across and within sectors, industries, or states.[184]
    - In 2020, the U.S. Department of Labor developed guidelines to ensure that industry-recognized apprenticeship credentials were portable. However, there were no enforceable standards or actions to move toward portability for credentials
- Pursuit of vocational apprenticeships may preclude students from pursuing aspirational jobs in technology, academia, finance, law, and medicine.[185]
- The lack of universal accountability standards and performance metrics contributes to a fragmented and opaque apprenticeship system.[186]

If set up properly, American public investment in apprenticeships can yield positive results but requires a deliberate structure.

- On average, many employers realize a return on investment of $1.47 for every $1 invested in apprenticeships. Additionally, every $1 invested in apprenticeships leads to a public return of approximately $28 in benefits.[187]

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[181] "Investing in America's Workforce: A National Imperative for the 21st Century," National Skills Coalition, September 2019, https://www.nationalskillscoalition.org/wp-content/uploads/2020/12/CIAW-Invest-in-AW-1.pdf.
[182] The White House, Council of Economic Advisors, *Economic Report to the President* (2015), https://obamawhitehouse.archives.gov/administration/eop/cea/economic-report-of-the-President/2015.
[183] "Public Spending on Labor Markets," Organization for Economic Cooperation and Development (OECD), accessed September 1, 2021, https://data.oecd.org/socialexp/public-spending-on-labour-markets.htm.
[184] Sarah Steinberg, "National Standards for Strong Apprenticeships," Center for American Progress, August 27, 2014, https://www.americanprogress.org/issues/economy/reports/2014/08/27/96088/national-standards-for-strong-apprenticeships/.
[185] Greg Ferenstein, "How History Explains America's Struggle to Revive Apprenticeships," Brookings Institute, May 23, 2018, https://www.brookings.edu/blog/brown-center-chalkboard/2018/05/23/how-history-explains-americas-struggle-to-revive-apprenticeships/.
[186] Sarah Steinberg, "National Standards for Strong Apprenticeships," Center for American Progress, August 27, 2014, https://www.americanprogress.org/issues/economy/reports/2014/08/27/96088/national-standards-for-strong-apprenticeships/.
[187] "Return on Investment (ROI)," Discover Apprenticeship, accessed September 1, 2021, https://nationalapprenticeship.org/roi; "IMT Apprenticeship Provides Positive Return on Investment for Employers," Jobs for the Future (JFF), accessed September 1, 2021, https://www.jff.org/what-we-do/impact-stories/center-for-apprenticeship-and-work-based-learning/imt-apprenticeship-provides-positive-return-investment-employers/.

- However, less than 1 percent of job seekers enroll in registered apprenticeship programs.[188]
- As coordination nationally between employers, workers, trainers, and trade associations is difficult, implementation of European-like apprenticeship models is more successful at the local level and can provide lessons to scale.

Models of State-Level U.S. Apprenticeship Programs

While the United States has invested relatively few resources into the development and maintenance of workforce development compared to Europe, some states have developed successful programs. For instance, Washington State and South Carolina have developed and administered programs designed to exploit some (but not all) attributes of European models. Carefully investigating how these models became successful may provide a template upon which other states can build their own skilled workforces.

South Carolina

In 2007, the government of South Carolina created Apprenticeship Carolina, a division of the South Carolina Technical College System. This registered apprenticeship program provides a $1,000 tax credit per apprenticeship to incentivize employer engagement. Apprenticeship Carolina has produced 36,354 apprentices, 1,186 registered programs, and 275 youth apprenticeship programs.[189]

South Carolina has also created a framework of incentives for foreign companies to base their operations in the state, a practice that fosters community engagement, provides a convenient way to integrate elements of European models into American workforce practices, and permits significant investment in local workers. For instance, the German-based company MTU worked with the Aiken County Career and Technology Center to develop an apprenticeship program like the one employed in the German apprenticeship system.[190] Established in 2012, this program allows students to earn a high school diploma while acquiring an industrial mechanic basic certificate, a German certification recognized in the United States.

Washington State

Apprenticeships are governed by the Washington State Apprenticeship and Training Council under the auspices of the Department of Labor and Industries (L&I).[191] L&I collaborates with business and labor leaders to strengthen and approve new apprenticeship programs, and officials submit policy recommendations to the governor and legislature for consideration. The state has committed to ensuring that apprentices are provided ample opportunity to acquire on-the-job experience and fair compensation, especially in public works industries. For instance, it requires that no less than 15 percent of the labor hours on large state public works projects be performed by apprentices.[192]

[188] Kelsey Berkowitz, "Why Do Only a Tiny Fraction of Jobseekers Participate in Registered Apprenticeships," Third Way, November 14, 2019, https://www.thirdway.org/report/why-do-only-a-tiny-fraction-of-jobseekers-participate-in-registered-apprenticeships.

[189] "Apprenticeship Carolina," Apprenticeship Carolina, accessed September 1, 2021, https://www.apprenticeshipcarolina.com/.

[190] "MTU Apprenticeship," Aiken County Career and Technology Center, accessed September 1, 2021, https://www.acpsd.net/domain/5634.

[191] "Washington State Apprenticeship & Training Council," Washington State Department of Labor and Industries, accessed September 1, 2021, https://lni.wa.gov/licensing-permits/apprenticeship/wsatc.

[192] Karla Walter, Malkie Wall, and Alex Rowell, "A How-To Guide for Strengthening State and Local Prevailing Wage Laws," Center for American Progress, December 22, 2020, https://www.americanprogress.org/issues/economy/reports/2020/12/22/494146/guide-strengthening-state-local-prevailing-wage-laws/.

Investments in apprenticeships have seen significant growth over the past decade. Between 2012 and April 2019, the number of apprenticeships increased from 11,249 to 19,568. More than 4,500 employers and 180 different occupations participated in the registered apprenticeship system as of 2019, in areas such as high technology, healthcare, and traditional trades such as electricians, carpenters, and iron workers.[193]

[193] Washington State Apprenticeship and Training Council, *First Quarter 2019 Report January-Marc*h, April 18, 2019, https://lni.wa.gov/licensing-permits/apprenticeship/_docs/April2019.pdf.

Appendix D: Case Studies

During the study, the NIAC found examples of successful policies and programs that demonstrate promise for their potential to address critical infrastructure workforce development challenges on a larger scale. This appendix includes case studies on a range of topics, fields, and models. Each has been labeled with keywords to help identify its relevance to a particular issue or challenge.

The Jobs Quality Framework at the San Diego Workforce Partnership

Keywords: diversity, equity, and inclusion; convening and coordinating; job standards; public-private partnerships

The San Diego Workforce Partnership (SDWP) empowers job seekers to secure quality employment that includes pathways for greater economic mobility while meeting the needs of employers seeking a diverse and skilled workforce. The Jobs Quality Framework developed by SDWP identifies a nexus of job opportunities, conditions, and features that offers a shared vision of what constitutes "a good job." This benefits job seekers and provides a competitive advantage for the regional San Diego economy.[194]

SDWP operates with an annual budget of more than $35 million derived from public and private funds to reach more than 100,000 job seekers annually.[195] The Jobs Quality Framework is central to that work and tracks indicators such as a living wage, safe working conditions, the availability of support services, health and wellness, and whether employees find their work meaningful. With equity and inclusion as core values, SDWP works deliberately to prioritize applicants who have been denied opportunities by historically discriminatory policies, priorities, and hiring practices.

To achieve its vision for meaningful employment and a skilled and diverse workforce, SDWP offers a variety of initiatives.[196] High Road Kitchens is a partnership program that provides jobs for restaurant workers and a subsidy for restaurant owners who commit to paying a living wage and follow equitable employment practices.[197] The Expanded Subsidized Employment program reduces costs for onboarding employees and provides reimbursement for on-the-job training. Resources for job seekers include several career centers across the county; a Connect2Careers program to meet the needs of young adults who are neither in school nor working; paid training for careers in the energy, construction, and utilities sectors; and services geared toward those who have been involved in the justice system. In the 2016 fiscal year alone, SDWP provided programs and services that helped fill 1,786 positions.[198]

SDWP's operating model and Jobs Quality Framework were designed to be scaled and readily adapted to other local communities around the country, offering a useful template for improving the lives and livelihoods of individuals, adapting to the evolving needs of businesses, and building a prosperous community.[199]

[194] "Job Quality," San Diego Workforce Partnership, accessed September 1, 2021, https://workforce.org/jobquality/.
[195] "San Diego Workforce Partnership, Inc.," GuideStar, accessed September 1, 2021, https://www.guidestar.org/profile/33-0660504.
[196] "Initiatives," San Diego Workforce Partnership, accessed September 1, 2021, https://workforce.org/whatwedo/.
[197] "High Road Kitchens," San Diego Workforce Partnership, accessed September 1, 2021, https://workforce.org/hrk.
[198] "Homepage," San Diego Workforce Partnership, accessed September 1, 2021, https://workforce.org/.
[199] "How to Build Job Quality into Your Workforce Development Approach," San Diego Workforce Partnership, accessed September 1, 2021, https://workforce.org/job-quality-wkdev-guide/.

The North America's Building Trades Unions' (NABTU) Multi-Craft Core Curriculum

Keywords: job training; curriculum; credentialing; apprenticeships; diversity, equity, and inclusion

Pre-apprenticeship programs provide entry-level workers with the opportunity to acquire some of the industry-recognized skills necessary to enter and succeed in a Registered Apprenticeship Program (RAP). Such programs are often a starting point for underserved or underrepresented communities, and pre-apprenticeship program administrators often work with community-based organizations, unions, employers, and other stakeholders to strengthen local workforce pipelines.[200]

Utilizing the Multi-Craft Core Curriculum (MC3), a standardized, comprehensive, 120-hour construction pre-apprenticeship curriculum, NABTU has developed one of the most successful industry-recognized training systems in the world. They invest more than $1.6 billion annually to support and promote over 1,600 RAPs as well as more than 150 Apprenticeship Readiness Programs (ARPs) in construction industries. NABTU also works with industry employers, community-based organizations, workforce development boards, educational institutions, contractors, and other stakeholders to streamline the secondary school-to-career pathway in support of underserved and underrepresented communities.[201]

Trade organizations have been instrumental in establishing pre-apprenticeship programs around the country. The National Tooling and Machining Association (NTMA) developed a suite of online training courses to help local communities acquire the entry-level professional skills, knowledge, and credits needed to enter registered apprenticeships. In 2015, the U.S. Department of Labor awarded the Electrical Training Alliance (ETA) a federal grant to establish its Electrical Training Alliance Pre-Apprenticeship Program (ETAP) to help underserved and underrepresented communities pursue careers in the electrical industry.[202]

AT&T's Nanodegree Program

Keywords: credentialing; job training; education

The pace of technological change is a constant challenge to the American workforce, which must remain nimble and adapt to new developments—like artificial intelligence (AI) and the "internet of things"—that are fundamentally changing the nature of work in the 21st century. As one of the Nation's oldest

[200] "What is Pre-Apprenticeship?" Apprenticeship.gov, accessed September 1, 2021, https://www.apprenticeship.gov/help/what-pre-apprenticeship; U.S. Department of Labor, *Pre-Apprenticeship: Pathways for Women in High-Wage Careers: A Guide for Community-based Organizations and Workforce Providers*, accessed September 1, 2021, https://www.dol.gov/sites/dolgov/files/ETA/apprenticeship/pdfs/pre_apprenticeship_guideforwomen.pdf.

[201] "Constitution of the North America's Building Trades Unions," North America's Building Trades Unions, accessed September 1, 2021, https://nabtu.org/wp-content/uploads/2017/03/28256_NABTU_Constitution_final.pdf; "About Us," North America's Building Trades Union, accessed September 1, 2021, https://nabtu.org/about-nabtu/; "Enhance Your Skills. Advance Your Life," North America's Building Trades Union, accessed September 1, 2021, https://nabtu.org/apprenticeship-and-training/; Mitchell Kilpatrick, "Southern Company Hosts Virtual Apprenticeship Accelerator," Alabama News Center, December 28, 2020, https://alabamanewscenter.com/2020/12/28/mobile-area-apprenticeship-readiness-program-accepting-applications-for-march-2021-class/; "Board of Airport Commissioners Approves 10-Year Extension of Project Labor Agreement," Los Angeles World Airports (LAWA), Press Release, November 19, 2020, https://www.lawa.org/news-releases/2020/news-release-063.

[202] "Only You Can Solve Your Skilled Talent Shortage," National Tooling and Machining Association, accessed September 1, 2021, https://ntma.org/programs/education/pre-apprenticeship-program/; "Electrical Training Alliance Pre-Apprenticeship Program," National Electrical Contractors Association-International Brotherhood of Electrical Workers (NECA-IBEW) Electrical Training Center, accessed September 1, 2021, https://nietc.org/pre-apprenticeship/.

telecommunications companies, AT&T feels that pressure acutely, and in 2014, the company partnered with online education provider Udacity to create a "nanodegree" program that helps employees transition from legacy technology into the digital age.[203]

Micro-credentialing programs like AT&T's nanodegrees focus on specific skills. Many courses run six to twelve months and focus on emerging fields or in-demand skills, like data science, coding, and software development. But the real value is the hands-on experience and real-world projects featured in such programs. In the future, faster and shorter training programs will help workers develop more portable, skills-based credentials that will allow them greater freedom to move between positions, employers, and fields.[204]

At companies like AT&T, certification programs offer employees the chance to continuously learn and update their skills. Since 2014, more than 4,000 AT&T employees have graduated from one or more of the company's 23 nanodegree programs.[205]

Micro-credentials can also offer a path to economic mobility for underserved communities, and in 2020, AT&T partnered with Udacity to create a scholarship program that licenses nanodegree courses to communities of need as part of a larger $10 million dollar investment in social equity and economic development programs.[206]

As technology continues to evolve at a rate that outpaces the training provided by traditional four-year degree programs, the rapid credentialing offered by programs like AT&T's nanodegrees stands to become an important strategy for maintaining a skilled and agile workforce.

Work-Based Learning in Delaware, Iowa, and Washington

Keywords: curriculum; education; job training

Work-based learning (WBL) programs provide young people with an opportunity to gain valuable hands-on work experience and develop the skills to compete in the labor market while in high school. A 2021 state-by-state analysis conducted by American Student Assistance and Bellwether Education Partners identified four key components of successful state WBL programs: broad eligibility requirements, state funding, quality and accountability standards, and infrastructure in place to support WBL programs.[207]

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[203] "Efficient, Accessible, Affordable Online Program Will Help Job Seekers Get High-Demand Technical Skills," *AT&T News*, June 16, 2014, https://www.att.jobs/article-nanodegree-program-provides-affordable-training-tech-jobs. See also: National Security Telecommunications Advisory Committee, *NSTAC Report to the President on Emerging Technologies Strategic Vision* (2017), https://www.cisa.gov/sites/default/files/publications/NSTAC%20Report%20to%20the%20President%20on%20Emerging%20Technologies%20Strategic%20Vision.pdf.

[204] Jordan Friedman, "What Employers Think of Badges, Nanodegrees from Online Platforms," *U.S. News and World Report*, January 22, 2016, https://www.usnews.com/education/online-education/articles/2016-01-22/what-employers-think-of-badges-nanodegrees-from-online-programs.

[205] "AT&T's Nano Degree Program Provides Affordable Training for High-Demand Tech Jobs," AT&T Jobs, accessed September 1, 2021, https://www.att.jobs/article-nanodegree-program-provides-affordable-training-tech-jobs.

[206] "AT&T is Collaborating with Udacity to Offer 1,000 Nanodegree Scholarships to Underserved Communities," *PR Newswire*, October 5, 2020, https://www.prnewswire.com/news-releases/att-is-collaborating-with-udacity-to-offer-1-000-nanodegree-scholarships-to-underserved-communities-301145679.html.

[207] Kelly Robson, Jennifer O'Neal Schiess, and Julie Lammers, *Working to Learn and Learning to Work: A state-by-state analysis of high school work-based learning policies*, (Washington, D.C.: American Student Assistance and Bellweather Education Partners, March 2021), p. 3, https://file.asa.org/uploads/Learning-to-Work-and-Working-to-Learn.pdf.

WBL programs vary significantly across the country, but the most successful states utilize some or all of these components.

Delaware's Pathways program makes Career and Technical Education (CTE) courses readily available and requires all high school students to take at least three to graduate.[208] The program is part of the "Delaware Promise," a commitment that by 2025, 65 percent of Delaware's workforce will earn a two- or four-year degree or professional certificate.[209]

Washington State has created one of the most successful WBL programs in the country by providing strong funding and building public-private partnerships. With a goal of enrolling 60 percent of the class of 2030, Washington invested over $25 million in Career Connect Washington (CCW).[210] CCW is now reaching into tribal communities to increase career-connected learning opportunities.[211] CCW's rigorous sponsor organization application and endorsement process holds schools and employers accountable to quality expectations.

Iowa's Intermediary Network Program connects students and businesses—including many critical infrastructure industries—to a range of WBL programs across the state, centered around community colleges.[212] During the 2019 fiscal year, Iowa's regional intermediary networks provided 85,213 students with WBL experiences using program funds, 34,017 WBL experiences with outside funds, and 2,451 educator experiences.[213]

Pacific Gas & Electric's PowerPathway Program

Keywords: diversity, equity, and inclusion; credentialing; job training

Launched in 2008, Pacific Gas & Electric's (PG&E) PowerPathway program is a highly selective, nationally recognized workforce development model to enlarge the talent pool of local, qualified, diverse candidates for skilled craft and utility industry jobs. To facilitate engagement with local communities, PG&E develops partnerships with unions as well as educational, community-based, and government organizations in northern and central California.[214]

The program is available to students both independently or as part of the curriculum offered by local community colleges and trade schools. Students receive approximately 8 weeks (320 hours) of industry-informed training to acquire the academic knowledge, baseline professional skills, and physical training necessary to make them competitive for entry-level employment opportunities. Eligibility requirements include having clean criminal and driving records and a high school diploma.[215]

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[208] Robson, et al., *Working to Learn and Learning to Work*, p. 11.
[209] "Delaware Pathways," Office of Delaware Work-Based Learning, accessed September 1, 2021, https://deowbl.org/delaware-pathways/.
[210] Robson, et al., *Working to Learn and Learning to Work*, p. 14.
[211] "Governor's Budget Provides Strong Support for Career Connect Washington," Career Connect Washington, December 2019, https://careerconnectwa.org/2020/11/23/governors-budget-provides-strong-support-for-career-connect-washington/.
[212] Robson, et al., *Working to Learn and Learning to Work,* p. 90.
[213] Iowa Department of Education, *Iowa's Work-Based Learning Intermediary Network Fiscal Year 2019 Report* (2019), p. 11, https://abbc0706-0ecf-41a0-bab8-14accf7f34df.filesusr.com/ugd/52c8a4_dd6309c1b8c04bbda529f4002a20c086.pdf.
[214] "Pacific Gas and Electric Company Launches Workforce Development Program," T&D World, January 16, 2008, https://www.tdworld.com/safety-and-training/article/20962301/pacific-gas-and-electric-company-launches-workforce-development-program; "Company Profile," PG&E, accessed March 16, 2021, https://www.pge.com/en_US/about-pge/company-information/profile/profile.page.
[215] "PG&E PowerPathway™," PG&E, accessed September 1, 2021, https://jobs.pge.com/powerpathway.

According to PG&E representatives, as of 2020, 85 percent of graduates have gained employment with companies such as the East Bay Municipal Utility District, AT&T, the Bay Area Rapid Transit (BART), and CalTrans. Of those that successfully completed the program, 25 percent have been women, and more than 50 percent have been veterans.[216] Additionally, PowerPathway has served as a template for other Bay Area workforce development programs. For instance, BART's Transit Career Ladders Training (TCLT) Program similarly works with educational institutions, community-based intermediary organizations, and local workforce development boards to promote transportation careers in low-income, underserved, and minority communities.[217]

Credential Engine: State Policy Partnership

Keywords: data; convening and coordination; credentialing; education; job training

Established in 2016 with support from the Lumina Foundation and JPMorgan Chase & Co., the Credential Engine offers a centralized, searchable database to bring greater transparency to credentialing and ensure a more streamlined pipeline of skilled workers.[218]

As of 2021, a total of 19 states have joined the Credential Registry and used the data it provides to better align the needs of workers and employers. In 2017, New Jersey created an index of every available postsecondary education credential and developed a publicly accessible dashboard to communicate state workforce performance data. In 2019, Credential Engine awarded Alabama a $50,000 technical grant to support credential transparency in accordance with the "Strong Start, Strong Finish" initiative. In 2020, Connecticut committed to establishing a state-wide credential registry system to improve educational access and equity, lifelong learning, and career pathway advancement.[219]

In the private sector, Credential Engine recently collaborated with the National Retail Federation Foundation, the National Restaurant Association, and the American Hotel and Lodging Association to identify, capture, and publish industry-recognized credentials.[220] Working with the U.S. Department of Education, the Credential Engine initiated two programs in 2020 to actively seek and publish information about credentials and competencies in formats aligned with interoperable learning records (ILRs).[221]

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[216] Interview with PG&E representative, virtual interview, November 13, 2020; "Taking Business to School: Pacific Gas and Electric Company," Association for Career and Technical Education (ACTE), https://www.acteonline.org/wp-content/uploads/2018/02/Taking%20Business%20to%20School_PGE.pdf.

[217] "BART Receives $750,000 DOT Grant for Workforce Development," *Bay Area Rapid Transit*, August 28, 2015, https://www.bart.gov/news/articles/2015/news20150828.

[218] "Credential Registry Overview," Credential Engine, accessed September 1, 2021, https://credentialengine.org/about/credential-registry-overview/.

[219] "Credential Engine and State Partnerships: Clear Data Powers Better Decisions," Credential Engine, accessed August 31, 2021, https://credentialengine.org/state-partnerships/; Credential Engine, "The Role of States in Credential Transparency," March 2021, http://credentialengine.org/wp-content/uploads/2021/02/The-Role-of-States-in-Credential-Transparency.pdf; Credential Engine, "Making Sense of Credentials: A State Roadmap and Action Guide for Transparency," November 2020, https://credentialengine.org/wp-content/uploads/2020/10/State-Roadmap-and-Action-Guide.pdf; "New! SETC Performance Dashboard," State of New Jersey State Employment and Training Commission, accessed September 1, 2021, https://www.nj.gov/njsetc/performance/; "Governor Ivey Moves Alabama's Workforce Development Efforts Forward," The Office of Alabama Governor, July 2, 2019, https://governor.alabama.gov/newsroom/2019/07/governor-ivey-moves-alabamas-workforce-development-efforts-forward/; Connecticut Governor's Workforce Council, "Workforce Strategic Plan 2020," October 22, 2020, https://portal.ct.gov/-/media/Office-of-the-Governor/News/20201028-Governors-Workforce-Council-Strategic-Plan.pdf.

[220] "Join the Retail and Hospitality Credentials Initiative," Credential Engine Accounts, accessed September 1, 2021, https://apps.credentialengine.org/accounts/custompage/RetailHospitalityCredentialsInitiative.

[221] "Notice Inviting Applications (NIA) for the FY 2020 Education Stabilization Fund-Reimagine Workforce Preparation (ESF-RWP) Grants Program," Federal Register, June 23, 2020, https://www.federalregister.gov/documents/2020/06/23/2020-13480/notice-inviting-applications-nia-for-the-fy-2020-education-stabilization-fund-reimagine-workforce.

The "Children's Cabinets" Model

Keywords: convening and coordination; funding

Collaborative-action bodies that bring government agencies together with nonprofits, public interest groups, and service providers at the community level are an effective mechanism to compensate for fragmented funding systems and policy areas. In the realm of childhood development and education, the "Children's Cabinet" model plays an important role in building connections for a more coordinated approach at the municipal and county level.

Children's Cabinets have worked to pool resources at the local level for decades, and in April 2019, several nonprofits came together to launch the Local Children's Cabinet Network to better coordinate action across the country. Co-managed by the Forum For Youth Investment, Harvard Education Redesign Lab, and Children's Funding Project, the Local Children's Cabinet Network partners with local leaders in 47 communities across the Nation to share and compare data, map career pipelines, conduct gap analysis, identify resources and needs, and design and implement strategies to ensure that children receive the support they need to be successful inside and outside the classroom.[222]

Directing and aligning funding is one of the most important ways that Children's Cabinets add value. Local Children's Cabinet Networks utilize a variety of funding models based on community needs and resources. The Children's Cabinet identifies four policy levers to organize funding streams—Find, Align, Generate, and Activate—to either leverage existing funds, identify gaps and make strategic adjustments to budgets, generate new revenue, or develop infrastructure to administer funds in a collaborative way.[223] Models like the Children's Cabinet pinpoint resources and build connections for a more coordinated approach at the local and municipal level.

Many localities do not have sources of dedicated funding. Denver saw the importance of the Children's Cabinet Network and folded the program into a local government office, providing it with dedicated funding and staffing, and the office has since become a leader in data analytics. The Denver Children's Cabinet (DCC) conducts cutting-edge research, like geospatial mapping, to help steer resources and attention.[224] The DCC is unique in its data collection, aggregation, and usage, which helps better coordinate services for children and youths across 22 City agencies and partners.

BAYWORK

Keywords: diversity, equity, and inclusion; job training; convening and coordinating; education

Established in 2009, the Bay Area Water/Wastewater Workforce Development Collaborative (BAYWORK) is a regional consortium of San Francisco Bay Area stakeholders dedicated to recruiting and training the next generation of water and wastewater industry professionals. The partnership is made up of 39 signatories, each of which has invested resources to promote workforce development through

[222] "Local Children's Cabinet Network Toolkit: A Roadmap for Getting Started," Education Redesign Lab, Harvard Graduate School of Education, July 2019, https://edredesign.org/files/childrens_cabinet_toolkit_a_roadmap_for_getting_started.pdf.

[223] "Homepage," Local Children's Cabinet Network, accessed September 2, 2021, https://localchildrenscabinets.org/home.

[224] "Denver Profile: Denver Mayor's Children's Cabinet," The Forum for Youth Investment, July 3, 2018, https://static1.squarespace.com/static/5b75d96ccc8fedfce4d3c5a8/t/5cd19f5df9619a91337d2520/1557241693535/FINAL+Denver+profile.pdf.

various outreach activities.[225] BAYWORK's annual budget is approximately $175,000, and the organization's executive committee convenes annually to evaluate priorities, strategies, and goals, and each year the executive committee publishes a report of these proceedings.[226]

BAYWORK is an important and widely recognized part of a regional effort to recruit, train, and retain a skilled workforce to ameliorate a "crisis in workforce reliability" in the water, wastewater, and stormwater utilities industries.[227] The organization's regular engagement with diverse stakeholders and its regional approach to networking and collaboration increases the visibility of viable careers in water and wastewater industries, facilitates and strengthens relationships between disadvantaged communities and trade professionals, and helps remove barriers to entry in water and wastewater careers.[228]

While the COVID-19 pandemic has slowed or stalled many outreach activities, BAYWORK has continued to shape pathways of success for women, veterans, and other underrepresented and disadvantaged workers and students.[229] For instance, BAYWORK has organized 21 career fairs and high school career events, hosted 30 teachers at six utility facilities, and built a website to communicate more effectively with the public.[230] While its activities focus almost exclusively on networking and public outreach within California, the American Water Works Association (AWWA) has commended BAYWORK for its various outreach activities, and the Water Environment Federation has integrated the "BAYWORK model" into their workforce development strategies.[231]

Connected Nation

Keywords: convening and coordinating; data; job training, education

Training for critical infrastructure jobs often depends on access to digital broadband and the digital skills to utilize online platforms and resources. Major disparities in both access and adoption, however, have created a digital divide that risks slowing the development of a well-trained workforce. Connected Nation is a national nonprofit organization with a core mission to improve lives through the expansion of technology to underserved populations.[232] Working directly with federal and state government

[225] "About BAYWORK," Bay Area Water/Wastewater Workforce Reliability (BAYWORK), accessed September 1, 2021, https://baywork.org/about-us/#signatory-agencies; Afia Zakiya, "BAYWORK: An Innovative Regional Water Workforce Partnership," Unpublished manuscript, July 2019.
[226] "Strategy Planning Meetings," Baywork, accessed September 1, 2021, https://baywork.org/about-us/strategic-planning-meetings/.
[227] "As Workforce Crisis Approaches, Baywork Wants to Build New Pathways into the Profession," California Water Environmental Association (CWEA), accessed September 1, 2021, https://www.cwea.org/news/as-workforce-crisis-approaches-baywork-finds-opportunity-to-build-new-pathways-into-the-profession/.
[228] Joseph Kane, "Five Steps to Prepare the Next Generation of Water Workers," Brookings Institute, June 29, 2018, https://www.brookings.edu/blog/the-avenue/2018/06/29/five-steps-to-prepare-the-next-generation-of-water-workers/; Joseph Kane, "Investing in Water Infrastructure and Workers: Examining the Bay Area's Regional Approach," Brookings Institute, March 7, 2018, https://www.brookings.edu/blog/the-avenue/2018/03/06/investing-in-water-infrastructure-and-workers-examining-the-bay-areas-regional-approach/.
[229] "BAYWORK Annual Report 2019-2020," Baywork, October 12, 2020, https://baywork.org/wp-content/uploads/2020/10/Baywork-CA-Annual-Report-Web-1.pdf.
[230] "Baywork: 2019-20 Annual Signatory Meeting," June 12, 2019, https://baywork.org/wp-content/uploads/2020/07/BAYWORK-2019-20-Signatory-Meeting-1.pdf.
[231] Catherine Curtis, Steve Miksis, Veronica Siwy, and Jeff Tucker, "Baywork Creates North Bay Cross-Training Series," American Water Works Association, May 2020, https://baywork.org/wp-content/uploads/2020/08/awwa.1505-1.pdf; "America's Water Sector Workforce Initiative: A Call to Action," Environmental Protection Agency, October 2020, https://www.epa.gov/sites/production/files/2020-11/documents/americas_water_sector_workforce_initative_final.pdf.
[232] "Vision and History," Connected Nation, accessed September 1, 2021, https://connectednation.org/vision-and-history/.

agencies, Connected Nation provides an array of tools and resources to help local communities close the digital divide.[233]

Building on the success of several state-level organizations, Connected Nation was formed as a parent organization in 2007 to help coordinate digital access initiatives at the national level. In 2009, twelve states partnered with Connected Nation to lead all broadband mapping and planning efforts under the National Telecommunications Information Administration's (NTIA) State Broadband Initiative.[234]

Connected Nation continues to be a leader in using data analytics to drive programs. In Texas, it collected data from over 200 broadband providers and 18,000 Texas Community Anchor Institutions, engaging with 4,000 state and local stakeholders to facilitate community-level technology action planning to serve 1.8 million Texans lacking access to high-speed internet service.[235] Connecting those households led to improvements in civic engagement, accelerated community and economic development, and greater job opportunities.[236]

Moving beyond access, Connected Nation also works with local partners to build digital skills through the Digital Works program. In remote Marfa, Texas, the Digital Works program created a job incubator to retrain and upskill workers for technology-based jobs and helped residents connect with employers outside of the community. Nationwide, the Digital Works program helps many communities and states modify their economic and workforce development policies to nurture, attract, and retain teleworkers.

STEM Education at UMBC

Keywords: diversity and inclusion; micro-credentials; cyber; information technology; public-private partnerships

The University of Maryland, Baltimore County (UMBC) administers a range of programs to foster the development of a diverse and inclusive workforce in STEM-related fields. These programs streamline the acquisition of alternative micro-credentials in IT and cyber-related fields and strengthen professional relationships between the military, universities, federal civilian agencies, and private businesses.

UMBC's commitment to creating a diverse and inclusive workforce is highlighted in its record of success. The Meyerhoff Scholars Program, established in 1988, provides underrepresented and minority students with tailored guidance to successfully manage the rigors of college-level instruction. Since 1993, more than 1,400 students have graduated from the program. Graduates of the program are also 5.3 times more likely to have graduated from or be currently enrolled in a STEM Ph.D. or M.D./Ph.D. program than those who declined to join the program.[237] The Sherman STEM Teacher Scholars Program pairs UMBC faculty with local schools to train educators to bring a more culturally responsive and compassionate approach to STEM education.[238] The Maximizing Access to Research Careers Undergraduate Student

[233] "Vision and History," Connected Nation.
[234] "State Broadband Initiative," National Technology and Information Administration, accessed September 1, 2021, https://www2.ntia.doc.gov/SBDD.
[235] "Rural Broadband: a Texas Tour," Connected Nation, October 15, 2018, p. 101 https://connectednation.org/wp-content/uploads/2018/11/The-Future-of-Rural-Texas-2018_5-Rural-Broadband.pdf.
[236] "Broadband in Texas: A Briefing Prepared for the Governor's Broadband Development Council," Connected Nation, April 2020, p. 7, https://gov.texas.gov/uploads/files/business/Texas_Broadband_Briefing_Book_-_April_2020.pdf.
[237] "About," University of Maryland, Baltimore County, accessed September 1, 2021, https://meyerhoff.umbc.edu/about/; "Results: Meyerhoff by the Numbers," University of Maryland, Baltimore County, accessed September 1, 2021, https://meyerhoff.umbc.edu/about/results/.
[238] "Sherman STEM Teacher Scholars Program," University of Maryland, Baltimore County, accessed June 14, 2021, https://sherman.umbc.edu/.

Training in Academic Research (MARC U*STAR) program connects select UMBC students with research opportunities and robust support to pursue research careers, especially in the biomedical sciences.[239] These programs and others have produced more Black M.D. and Ph.D. degree-earners than any other college in the United States.[240]

UMBC's academic curricula is closely aligned with the economic and workforce development needs of Maryland and the Nation at-large. Established in 1991, the UMBC Research and Technology Park is a nationally recognized science and technology business campus, home to more than 90 resident companies at all stages of development. Envisioned as an incubator for entrepreneurs, each company leverages UMBC's leadership in STEM education to develop real-world solutions for the government, military, and private industries.[241] Established nine years later, UMBC Training Centers partner with industrial leaders, such as Oracle and CISCO, to provide technical training and access to micro-credentials for individuals and organizations through seven unique IT and cyber-related programs.[242]

CTE CyberNet

Keywords: professional development; cybersecurity; training; curricula; secondary education

Launched in 2020 by the U.S. Department of Education, CTE CyberNet is a professional development initiative to increase the number of career and technical education (CTE) instructors qualified to prepare students for careers in cybersecurity.[243] The CTE CyberNet approach is based on the National Initiative for Cybersecurity Education (NICE) Framework, ensuring the kind of high technical standards that encourage more portable credentials.[244] In June 2020, the program established three pilot CyberNet academies at leading National Centers of Academic Excellence (NCAE) institutions: Moraine Valley Community College; Dakota State University; and San Antonio College.[245]

At each academy, teachers receive more than 80 hours of professional guidance from cybersecurity professionals, as well as opportunities to engage industry leaders and local employers. They also learn how to use sophisticated digital tools to help students navigate employment and educational opportunities in cutting-edge fields such as network security analysis, blockchain, and AI.[246] For instance, teachers can incorporate CyberSeek, an online tool that maps cyber talent demand and supply across the United States, into their curriculum.[247] Educators can also share their experiences through the CTE CyberNet teacher network, which helps establish and maintain pedagogical best practices.

[239] "UMBC to Receive $7.7 M for U-RISE, a Research Training Program Focused on STEM Leadership," UMBC News, April 29, 2020, https://news.umbc.edu/umbc-to-receive-7-7-m-for-u-rise-a-research-training-program-focused-on-stem-leadership/.
[240] "UMBC Leads Nation in Producing African-American Undergraduates who Pursue M.D.-Ph.D.s," UMBC News, January 2, 2018, https://news.umbc.edu/umbc-leads-nation-in-producing-african-american-undergraduates-who-pursue-m-d-ph-d-s/.
[241] "Bwtech@UMBC Research and Technology Park," University of Maryland, Baltimore County, accessed September 1, 2021, https://bwtech.umbc.edu/; "Northrop Grumman and bwtech@UMBC Launch Cyber Incubator Tech Champions," Northrop Grumman, November 20, 2017, https://news.northropgrumman.com/news/releases/northrop-grumman-and-bwtech-umbc-launch-cyber-incubator-tech-champions.
[242] "UMBC Training Centers," University of Maryland, Baltimore County Training Centers, accessed September 1, 2021, https://www.umbctraining.com/.
[243] "CTE CyberNet," Perkins Collaborative Resource Network, accessed September 1, 2021, https://cte.ed.gov/initiatives/cte-cybernet.
[244] For more information on the NICE Framework, see https://niccs.cisa.gov/workforce-development/cyber-security-workforce-framework.
[245] "SAC to Host CTE CyberNet Academy for High School Teachers," San Antonio College, May 18, 2020, https://www.alamo.edu/collegecontainer/sac/news-events/news/2020/may/cte-cybernet-academy/.
[246] Palacios, A., "CTE CyberNet: Strengthening Cybersecurity Education," National Institute of Standards and Technology, September 18, 2020, https://www.nist.gov/itl/applied-cybersecurity/nice/nice-enewsletter-fall-2020-government-spotlight.
[247] "CyberSeek: Cybersecurity Supply/Demand Heat Map," CyberSeek, accessed September 1, 2021, https://www.cyberseek.org/heatmap.html.

To streamline students' transition from secondary to postsecondary education, administrators continually adjust the CTE CyberNet program to align with curricula of universities, colleges, and community colleges designated as NCAEs.[248] This alignment ensures that students have the baseline skills, knowledge, and competencies to identify and pursue individualized career pathways.

The Virtual Apprenticeship Network by the American Association of Community Colleges (AACC)

Keywords: community college; advocacy; apprenticeships; diversity and inclusion; public-private partnerships

Community colleges play an essential role in U.S. workforce development by providing quick and affordable training to meet the needs of rapidly changing labor markets. The Expanding Community College Apprenticeships (ECCA) initiative, a $20 million partnership between the American Association of Community Colleges (AACC) and the Department of Labor (DOL), will further expand that role by extending new apprenticeship opportunities into the digital realm. [249]

ECCA administers the Virtual Apprenticeship Network, a searchable database that connects businesses with over 100 AACC partners and member colleges to find qualified and credentialed workers. Between May 2019 and April 2021, the ECCA successfully trained 11,082 new apprentices in 454 different occupations, 85.3 percent of which were in construction or advanced manufacturing.[250]

With a current membership of nearly 1,200 associate degree–granting institutions enrolling over 12 million students, AACC is the "voice of America's community colleges."[251] AACC also helps administer $100 million in grants from DOL's America's Promise Job-Driven Grant Program. Established in 2016, this program accelerates the development of regional workforce partnerships and strengthens the pipeline of skilled workers in key critical infrastructure sectors.[252]

In partnership with the Bill & Melinda Gates Foundation, AACC has also established the AACC Pathways Project to track and minimize the range of variables that inhibit student success.[253] Additionally, AACC helped to establish the Equity Transfer Initiative (ETI), a partnership between community and four-year colleges to increase transfer and completion rates for disadvantaged student populations.[254]

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[248] "CAE Institution Map," Centers of Academic Excellence in Cybersecurity Community, accessed September 1, 2021, https://www.caecommunity.org/cae-institution-map.

[249] "AACC, DOL Partner to Expand Apprenticeships," Community College Daily, January 24, 2019, https://www.ccdaily.com/2019/01/aacc-dol-partnership-aims-expand-apprenticeships/.

[250] "Existing Success: AACC's Expanding Community College Apprenticeships (ECCA)," American Association of Community Colleges, PowerPoint Presentation, May 7, 2021, https://www.dol.gov/sites/dolgov/files/ETA/jobcorps/JC%20Scholars/American%20Association%20of%20Community%20Colleges%20Discussion%20with%20Job%20Corps%20Scholars%20Grantees-20210506.pdf.

[251] "Building a Nation of Learners by Advancing America's Community Colleges," American Association of Community Colleges, accessed September 1, 2021, https://www.aacc.nche.edu/about-us/mission-statement/.

[252] "America's Promise Initiative: Technical Assistance," American Association of Community Colleges, accessed September 1, 2021, https://www.aacc.nche.edu/programs/workforce-economic-development/americas-promise-initiative-technical-assistance; "US Labor Department Announces $100M America's Promise Grant Competition to Strengthen, Expand Regional Job Training Partnerships," U.S. Department of Labor, June 6, 2016, https://www.dol.gov/newsroom/releases/eta/eta20160606.

[253] "AACC Pathways," American Association of Community Colleges, accessed September 1, 2021, https://www.aacc.nche.edu/programs/aacc-pathways-project/.

[254] "Equity Transfer Initiative," American Association of Community Colleges, accessed September 1, 2021, https://www.aacc.nche.edu/programs/equity-transfer-initiative/.

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This study is dedicated to Margaret "Peg" Grayson, whose service and dedication to the NIAC was unmatched.

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Appendix F: Bibliography

The appendix lists all sources for this study, including those for the scoping effort and Study Group.

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