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Energy Workforce Development in the 21st Century

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Energy Workforce Development in the 21st Century

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Abstract

Solutions to climate change will require the mass deployment of new energy technologies and infrastructure. Two fundamental questions emerge from this reality. First, is the U.S. workforce training system capable of providing the next generation of labor for these positions in a timely fashion? Second, will this transition in jobs and skills result in a more equitable American society? This paper will provide a review of existing workforce development programs, a profile of the existing energy workforce, and the challenges and opportunities presented by a thirty-year transition to a low carbon economy. This paper will also present a job-quality strategy for the energy, energy efficiency, and motor vehicle sectors to ensure that this transition maximizes economic equity and racial and gender diversity. Finally, the paper will assess the historic policy tool kit utilized to respond to stranded workers and communities, including job training programs and trade adjustment assistance, and consider the trade-offs between person-level interventions versus community level interventions.

Introduction

World War II in the U.S. was characterized by some of the most massive government interventions ever witnessed in an economy—from the construction of three Liberty Ships every two days in the Kaiser shipyards of Oakland, CA, (Heiner, 1991) to the creation of the Hanford nuclear site in Washington which, almost overnight, created the nuclear processing industry, employing 45,000 people on a site larger than the state of Rhode Island (Atomic Heritage Foundation, National Museum of Nuclear Science & History, n.d.). While much has been written about the accomplishments of these interventions, scant attention has been paid to the workforce challenges and dislocations created during their implementation.

In the case of Hanford, an army of nuclear construction workers needed to be trained and assembled while indigenous communities and the existing residents of Hanford and White Bluffs were relocated. At the Kaiser shipyards, Rosie the Riveter or Wendy the Welder (since elimination of riveting was key to the Liberty Ship's mass manufacture) became the living symbols for the large-scale recruitment of women into the industrial workforce, increasing their overall participation from 27% in 1940 to 37% in 1944. (Schweitzer, 1980). Subsequently, women's participation in the U.S. workforce also declined precipitously in the late 1940's to 28%. (US DOL, n.d.)

In today's economy, some are now calling for similar interventions into the U.S. and global economies to solve climate change. However, it is reasonable to question whether an intervention of such scope is necessary when the implementation period for the transition to a net zero economy is 30 years. More important is the need to make an assessment of the capacity of our existing workforce training system and test its ability to scale up on the appropriate timeline.

This paper examines these questions within the context of a macroeconomic system that has been driven by automation, globalization, and financialization at a dizzying pace over the last four decades. The resulting economic inequality in the United States and in most other industrialized countries has become a topic of vigorous debate that is often intermixed with the debate over solutions to the climate crisis. However, no matter how strongly one feels about the importance of addressing social inequality, it is critical to assess the scope of the energy system's transformation independently and the workforce demands that it will require before speaking to how those solutions can promote greater equality.

In that regard, it is helpful to repeat the advice of Nobel economist, Joseph Stiglitz, in his recent book, *People, Power, and Profits*,

> The real onus of blame, though, should be on ourselves. We mismanaged the consequences both of globalization and of technological progress. If we had managed these well, both could have generated the blessings that their advocates claimed. We need better, fairer international rules. But what America needs most is better management of the changes being brought about both by globalization and technology. (Stiglitz, 2019)

We do not believe that solutions to climate change, by themselves, can solve deindustrialization, eliminate inequality, or create a permanent model for global sustainable development, but they can make a contribution in that direction with thoughtful, pragmatic, and well-managed policies. We also believe that they can do so, without the level of intervention that took place in WWII.

While acknowledging that we live in a world of discontent and exaggeration, it has never been more important to rely on fact-based analyses of our challenges and to design policy responses that closely adhere to the reality they are designed to correct. Thus, we note that today our energy sector makes up only 6.4% of U.S. GDP (EIA, Annual Energy Outlook, 2019) and includes a workforce of only 5.8 million Americans (EFI, NASEO, & BW Research Partnership, 2020). a mere 3.9% (QCEW, Q2, 2018) of the U.S. labor force. Although energy is a critical contributor to virtually every sector of the U.S. economy, that criticality does not allow it to transform the way in which health care is delivered, retirement security is maintained, or wage disparities are eliminated.

As the United States transitions to a low carbon future, large infrastructure and technological investments will offer new job opportunities while threatening some current employment. This will require the energy sector and its workforce to update skills to meet demands as well as find new opportunities for displaced workers from declining industries. But in truth, we don't know today the full extent of that job loss or the degree to which one technology might win out over another. Thus, we don't know the exact degree to which fossil fuel use will decline in 20 or 30 years and be replaced with zero emissions' electricity and/or hydrogen or augmented with direct air CO_2 removal. Nor do we know the extent to which natural gas and/or coal may be utilized with carbon, capture and sequestration (CCS), both in the U.S. and in other parts of the world. What we do know is that maintaining our optionality will be critical to the long-term success of our climate solutions. Accordingly, optionality will be critical in how we think about workforce skills as well.

Key purposes of this paper are to conduct an overall assessment of the new skills required for the next generation energy system workforce, identify those occupations which are most at risk of displacement, and identify successful training strategies that will best prepare those entering the workforce while maintaining our optionality to move quickly on deployment of the most promising technologies.

This paper is structured as follows: Section 1 provides historical background of the workforce and educational system. Section 2 describes the current energy workforce and training programs, highlighting demographic and skills distribution trends over the past few years. Section 3 discusses the expected infrastructure and energy workforce demands for a low carbon future based on qualitative interviews with various stakeholders and input/output modeling, using the IMPLAN system, of three scenarios built around a suite of different technologies and summarizing general findings of ten other studies using both REMI and IMPLAN. Section 4 examines some of the emerging clean energy technologies and associated skill requirements that will aid in the low carbon transition and assesses how great a challenge they might pose. Section 5 considers how technological advancements such as automation and AI may affect future job opportunities and business models. Finally, Section 6 offers policy recommendations based on the above-mentioned challenges gained from the literature review and qualitative interviews.

These opening paragraphs were written several months before the first case of COVID-19 was reported in Wuhan, China and well before the pandemic struck the United States, resulting in catastrophic job loss and economic lockdowns. Today, the challenges facing the American economy are staggering and many of its macro-economic assumptions are being stressed as never before. Indeed, the need for government intervention may now well require investments of the magnitude of WWII.

One additional parallel should be underscored. The economy that emerged from WWII created a generational change in America—a middle class that was far more accessible to working class Americans than ever before. In the last thirty years, much of that progress has eroded. As a result, our examination of the energy workforce transition underway in America takes place within a larger social mandate to restore economic stability and a pathway for all Americans to gain access to the middle class. We hope that the choices that we make as a country in the coming months will lay the groundwork not only for a just and equitable transition for our energy workforce, its businesses, and communities, but for the rebuilding of a more resilient economy that can provide safe, quality jobs for all Americans.

1 Background of the United States Workforce and Education System

The United States workforce and workforce training system have experienced dramatic changes in the post-World War II period, reflecting underlying shifts in the economy. For 35 years, from 1947–1982, manufacturing contributed the largest share of GDP in the U.S. economy, ranging from a high of 27.2% in 1952 to 19.2% in 1982 (U.S. BEA, Value Added by Industry Historical, 2019). Then in 1991, the financial, insurance and real estate sector emerged at 17.8% as the largest contributor to GDP, overtaking manufacturing at 16.9% (U.S. BEA, Value Added by Industry Historical, 2019). That trend has continued with finance, insurance and real estate and professional and business services both contributing more to GDP in Q1, 2019 at 20.9% and 12.7% than manufacturing, at 11.1% (U.S. BEA, Value Added by Industry, 2019). Not surprisingly, the US workforce training system has adjusted itself to reflect these changes.

In the past century, the U.S. labor force has transitioned from a period shaped by two key assumptions. First, workforce development should focus primarily on vocational education to meet industry worker shortages, and second, unemployment was a federal responsibility to be addressed by the U.S. government (Steelman, 2013). Today, the architecture of both our economy and our workforce development system have shifted. Understanding these shifts, and how to correct them, will be critical to the country's capacity to solve the growing climate crisis by decarbonizing our economy in a way that promotes social equity, rather than exacerbating the country's growing inequality.

Starting in the 1980's, the growing shift of manufacturing investment to southern states and the initial growth of globalization, accompanied by legislative changes to the workforce system led to a fundamental shift in the federal government's involvement in labor markets (Donald L. Barlett and James B. Steele, America: What Went Wrong?). Unionization rates in the private sector began a long, slow decline, falling from an estimated 16.8% in 1983 to 6.4% today (US BLS Members of Unions, n.d; US BLS Union Members Summary, 2019).

Now in an era where globalization, technological change and the move towards a gig economy have stressed both the workforce system and even the definition of an "employee," especially those in low-skilled positions, it is important for policy makers to reflect on the structural changes that have led the country to this point. While we have noted that the energy sector cannot solve these challenges by itself, it is important to understand the economic environment in which climate solutions are crafted so that they can contribute to change and avoid exacerbations.

1.1 Policy and its Influence in the Evolution of the US Workforce System

The first major act of the federal government to influence workforce policy came in 1917 with passage of the Smith-Hughes Act, a law that created a federal fund for vocational education programs and workforce development for agricultural and industrial trades (Steffes, 2014). While this piece of legislation was intended to support educational programs and provide secured economic opportunities for younger populations, critics say that such programs did not meet industry needs and unintentionally caused curriculum disparity between different student populations. This piece of legislation among others, sparked the educational and occupational divide between particular classes and races, pushing underrepresented minorities toward vocation programs (Steffes, 2014).

At the end of World War II and in the wake of the Great Depression, the Employment Act of 1946 was passed as part of a vigorous debate to define the role and responsibilities of the federal government in providing employment for all Americans. It was especially important to address employment concerns of American soldiers returning home from the war and guarantee employment to those who were willing and able to work (Steelman, 2013). However, the final bill was watered down, making it more aspirational than a guarantee. The struggle to define the federal government role in providing employment continued on for decades, finally culminating in the passage of the Humphrey-Hawkins Act, shortly after the death of U.S. Senator Hubert Humphrey. This came to be known as the Full Employment and Balanced Growth Act of 1978, essentially requiring the federal government to become the employer of last resort when unemployment exceeded 2.5% in specific locations (Steelman, 2013).

However, funds were never appropriated for the jobs' programs authorized by Humphrey-Hawkins and additional legislation eventually focused on training and education, while eliminating the requirement for a public service option (Steelman, 2013). The Job Training Partnership Act of 1992 (JTPA) "provided both classroom and on the job training to low-income and dislocated workers" (Congressional Research Service, 2015). The JTPA was later replaced by the Workforce Investment Act of 1998 that established an educational one-stop system, where centers were created for state and local training, employment activities, and the delivery of support services.

Most recently, the Workforce Innovation and Opportunity Act (WIOA), passed during the Obama administration in 2014, focused on reforming workforce development across the country by more closely aligning the needs of employers with the training programs offered by community colleges, apprenticeship programs, and employers themselves (Congressional Research Service, 2015). For the first time, WIOA required each state to produce an annual workforce strategy plan to the federal government. The Obama Administration created an interagency effort, led by the Department of Labor, the Skills Working Group, to coordinate each agency's efforts to better align federal efforts with employers' needs thus diminishing the "skills gap"—the term used to describe the roughly 3 million vacant positions in the labor market that could not be filled because of a lack of qualified candidates.

Within the Skills Working Group a subcommittee was created, the Energy and Advanced Manufacturing Workforce Initiative (EAMWI), led by the Department of Energy and including the Departments of Labor, Education, Defense, Commerce, and the National Science Foundation. EAMWI's mission was to align the work of these five agencies and the NSF to develop a common mission, curricula, and focus on the workforce skills needed to facilitate an energy transition and the advanced manufacturing sector.

Other important legislative reforms to the workforce system over the years included amendments to the Wagner-Peyser Act of 1933 that integrated the US Employment Service into a One Stop system, the Rehabilitation Act of 1973 that integrated vocational rehabilitation for those with disabilities into the One Stop System, the transitional provisions from the Workforce Investment Act of 1998, and the Trade Adjustment Assistance for Workers (TAA) program (Congressional Research Service, 2015).

TAA dates back to the Trade Expansion Act of 1962 and the Trade Act of 1974 and is considered by some to be the model for how economic dislocation should be managed in the U.S. economy and potentially expanded to include those who experience job dislocation from climate solutions or climate-related impacts. TAA provides workers, once they are certified under the program, with extended unemployment benefits of up to 130 weeks, tuition reimbursement for training, occasional relocation support, and a short-term wage subsidy for participants over the age of 50. Over the years, millions of Americans have been certified under the program, although only a minority of those have actually participated in the program. In 1980, alone, for instance, 600,000 workers were certified for retraining. (Congressional Research Service 2018)

Between 2004-2018, the TAA program averaged $821 million per year in program benefits to participants. In the nine years between 2010 and 2018, the program provided services to roughly 247,000 new entrants out of the 994,000 who were certified for eligibility. During that period there was considerable variation with 287,000 certified in 2010 and only 57,000 in 2015. DOL participant data has generally shown re-employment rates of participants in the 72-76% range in recent years. (DOL AnnualReport18). In 2010, during the height of the Great Recession, the re-employment rate for participants was much lower at 59%. (DOL AnnualReport10).

Unfortunately, other recent studies have shown that certified non-participants have had equivalent re-employment rates to participants. A detailed survey of TAA participants and non-participants in 2012, performed for the DOL, found that only 37% of participants were employed in the occupations for which they received training. (Mathematica Policy Research/SPR). That study also found that TAA recipients did not enjoy higher wages or better benefits than non-participants after re-employment. For participants, over the age of 50, this phenomenon was especially pronounced. This spotty track record should be addressed before considering the TAA program as an effective model for how to deal with economic dislocation (McCarthy, 2019).

1.2 The Influence of Cultural and Technological Shifts

Reviewing previous US legislative actions on workforce development, it is evident that there has been a significant societal cultural shift on unemployment and training. As demonstrated by the passage of Humphrey-Hawkins and the Comprehensive Employment and Training Act of 1973 in particular, the US government and the general population have moved from thinking of unemployment as a failure of labor markets in that era to a failure of the individual who is unable to find a job. As the shortcomings of the TAA demonstrate, this should be a cause for concern as policy makers will now have to address both the institutional barriers that exist in politics, as well as the cultural bias of society.

The divide between higher education and vocational training is another cultural challenge that has been influenced by policy and then exacerbated in the general population. During the development of the Manpower Development and Training Act of 1962 (MDTA), there was debate in Congress over whether retraining programs should be designed and managed by the US Labor Department or the local educational authorities (Kremen,1974). Those in favor of workforce development being managed by DOL, advocated that the department could leverage corporate partnerships as companies were the true beneficiaries of high-skilled workers and could potentially lower the federal funding needed to carry out MDTA. However, others argued that local educational authorities should be the recipients of MDTA funding in fear that DOL management would create a dual-education system and believed that the current education system should be strengthened in order to better prepare the future workforce. In the end, oversite was given to the Department of Labor, but vocational state boards were the ones to create and implement training (Kremen,1974). However, costs were shared between federal and state governments while placing heavy reliance on the public-education system.

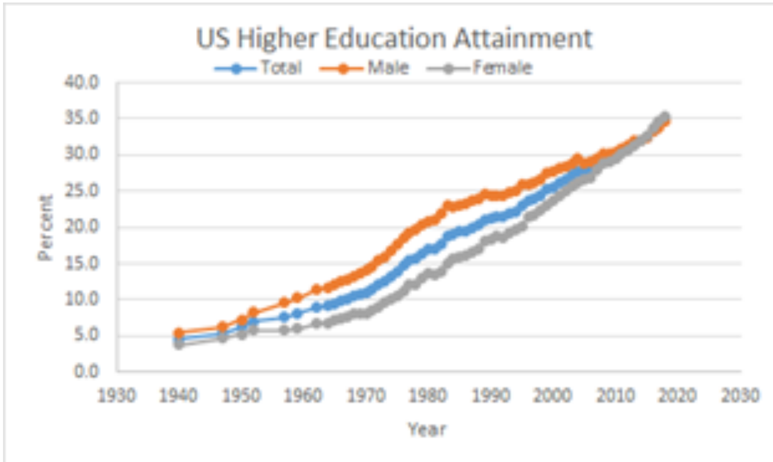


Figure 1: Higher educational attainment levels (US Census Bureau, 2018).

One of the most notable changes in the U.S. workforce since the end of World War II has been the increase in college educated employees. As seen in Figure 1 above, in 1970 only 11% of individuals 25 years and older completed a college degree, while 20 years later that number had more than doubled (US Census Bureau, 2018). Today, 35% of the U.S. workforce has a college degree and almost 90% have completed high school (US Census Bureau, 2018). Data shows that the average lifetime career earnings of someone with a 4-year college degree are likely to be $1M more than someone with only a high school education (Carnevale, 2011). As shown through the US Energy and Employment Report, there is an increased need for individuals in vocational training, which must be addressed as the US decarbonizes.

Lastly, a review of the legislative history of workforce development also illustrates the role of federal policy in trying to address the impacts of technological advancements. The hearings of the Joint Economic Commission in 1955 and 1960, first displayed national concerns over losing jobs as a result of new technology and automation (Kremen,1974). Such concerns ultimately contributed to the previously mentioned Manpower Development Training Act of 1962, one of the first instances of federal policy addressing automation and its effects on the workforce.

Another relevant policy effort to address the impacts of dislocation in the energy sector was the work of the SJR 91 Joint Subcommittee and the Consumer, Environment and Education Task Force in 1999 that worked with the International Brotherhood of Electrical Workers (IBEW) to address displaced utility workers that were affected by the restructuring of electric utilities. The IBEW pushed to institute a "systems benefit charge" to provide financial assistance and support schemes for affected workers, but in the end that responsibility was left to the states (Stinger, 1999).

The history of workforce development at the federal level illustrates an evolution away from a focus on maintaining full employment through public spending, industrial policy and/or economic development to creating a workforce system focused on providing educational and training opportunities for the individual. Unfortunately, as the critiques of TAA have shown, a singular focus on retraining the individual cannot address the underlying failure of labor markets whether due to globalization, automation, or resource depletion. As this paper further looks at the US energy sector and specific challenges in the following sections, the goal is to use this historical background as context and build upon it in making policy recommendations for local, state and federal government officials to meet the demands of a new energy workforce and respond to the dislocation of stranded workers.

1.3 Apprenticeship Programs

The state apprenticeship system was first created in Wisconsin in 1911 and built out through the National Apprenticeship Act in 1937 (US Department of Labor, March 2019). While apprenticeships were typically in manufacturing, construction and utilities in the 1940s, they have expanded to include service and safety workers, health professionals and others.

After the Great Recession, overall apprenticeship participation fell until 2013 but has since been making a comeback. Over the past five years, 282,000 individuals have graduated from apprenticeship programs and an additional 10,800 new programs have been created (US Department of Labor, September 2019). As of 2018, the Bureau of Labor recorded that 585,000 apprentices are currently enrolled, a 56 percent increase from 2013, in 23,400 registered apprenticeship programs across the country (US Department of Labor, September 2019). However, as seen in Figure 2 below, active apprenticeships and program availability vary significantly based on geography. The northern Midwest region has a consistently high apprenticeship participation rate with Minnesota, Wisconsin, Michigan, Missouri, Illinois, Indiana, Ohio, and Pennsylvania having between 11,100 to 20,500 apprenticeships per state. On the other hand, the western parts of the United States such as Montana, North Dakota, South Dakota, Nebraska, and Oklahoma have between 400 and 2,000 apprenticeships in the region.

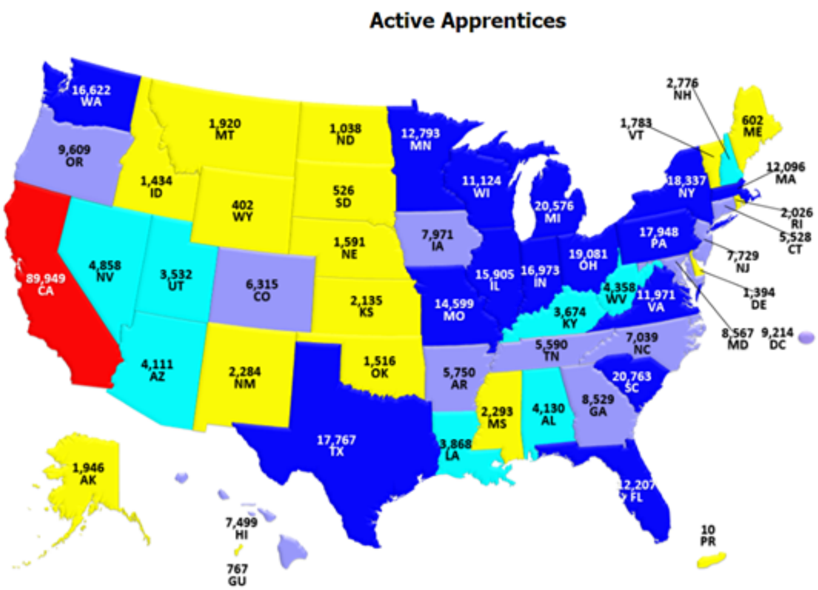


Figure 2: Active Apprenticeships in 2018

Apprenticeship opportunities also vary according to industry and occupational areas. Construction oversees over 166,600 apprentices, more than all apprentices in the military, public administration, manufacturing and utility combined. This is evident as the top occupations with active apprenticeships are electricians (43,814), carpenters (25,921), construction craft laborer (15,612), plumbers (14,472), and heavy truck drivers (11,410). Occupations such as mining and extraction, finance and the arts are areas with few apprentices. There have been increased efforts by the current administration to increase participation in training programs and fill the 6.4 million job openings reported in the United States (US Department of Labor, February 2020). In February, 2020, the current administration announced that $100 million will be invested in apprenticeship grants for the Apprenticeship: Closing the Skills Gap grant program, awarding grants to 28 public-private apprenticeship partnerships that are in advanced manufacturing, healthcare and information technology.

2 Energy Sector Workforce

In 2019, the production, generation, transmission, distribution, and storage of energy employed almost 3.5 million Americans and included occupations as varied as roustabouts in the west Texas oil fields to cyber security experts monitoring hacker attacks on nuclear power plants. Another 2.38 million Americans worked with energy efficiency technologies and were focused on "the production and installation of energy-saving products and the provision of services that reduce end-use energy consumption,…includ[ing] the manufacture of ENERGY STAR energy-saving products and the provision of services that reduce end-use energy consumption" (EFI, NASEO, & BW Research Partnership, 2020).

Together, these 5.8 million Americans (excluding the 1 million workers in retail gasoline stations) provide the energy that powers the American economy while also working increasingly on reducing its consumption (EFI, NASEO, & BW Research Partnership, 2020). Surprisingly, this critical workforce translates to only 3.9 percent of the US labor force of approximately 149 million working adults (QCEW, 2019).

This section of our paper will provide an overview of the four major sectors of the energy and energy efficiency workforces, identify the 56 major technologies within them and diagram the eight major industrial classifications that cut across most of these technologies. These industrial classifications, which are common to most technologies, explain why so many energy occupations require common skills' training and provide the basis for understanding the skills' requirements for the transition to a low carbon economy.

We will also provide a profile of the demographic makeup of the energy and energy efficiency workforce by race, gender, age, veterans' status, median pay, and unionization rates. Understanding this profile will be critical in setting expectations for the outcomes to be achieved by significant investments in energy technologies over the next three decades. It will also provide the context for why job displacements in one technology and/or geography can have disproportionate impacts on communities and specific demographic groups. For instance, veterans compose from 8 to 10 percent of the energy workforce, compared to the national average of 6 percent (EFI, NASEO, & BW Research Partnership, 2020). Consequently, when jobs are lost with the closing of a power plant, it almost always has a disproportionate impact on veterans.

2.1 Energy Sectors, Technologies, and Industrial Classifications

As mentioned earlier, it is easiest to understand the interlocking nature of the energy and energy efficiency workforce by mapping out the relationship between its different sectors, technologies, and industrial classifications. Table 1 below provides an understanding of how the 5.8 million energy and energy efficiency employees are classified by both technology and industry.

	Fuels	Electric Power Generation	Transmission, Distribution, Storage	Energy Efficiency
Major Industry	Construction Professional Services Manufacturing Mining & Extraction Agriculture & Forestry Other	Construction Professional Services Manufacturing Utilities Other	Construction Professional Services Manufacturing Wholesale Trade Utilities Other	Construction Professional Services Manufacturing Wholesale Trade Other
Technology	**Fossil Fuels:** Coal, Petroleum, Natural Gas, Other Fossil Fuels **Alternatives:** Corn Ethanol, Non-woody Biomass, Woody Biomass, Other Biofuels, Nuclear Fuels, Hydrogen	**Fossil Fuels:** Natural Gas, Advanced Natural Gas, Coal, Petroleum/Oil **Renewable:** Solar, Wind, Offshore wind, Geothermal, Bioenergy and Biomass, Low Impact Hydro, Traditional Hydro, Tidal, Wave **Other:** Nuclear, combined heat and power (CHP), Small Modular Reactors (SMR)	Traditional T+D Pumped Hydro Fuel cells Battery Storage Thermal Storage Other Storage Smart Grid Microgrid Other Modernizing	Energy Star Appliances Efficient Lighting Traditional HVAC Energy Star HVAC Renewable HVC Advanced Build Materials Recycled Build Materials Reduced water Other*

Table 1: Energy and Energy Efficiency sector breakdown by subsector in grey, major industries in yellow and specific technologies relative to each in blue.

Table 2 below breaks out the numerical size of each industrial sector. Construction makes up the largest overall industrial sector in energy and energy efficiency with almost 36% of all employees, followed by professional services with 17% and manufacturing with 13%. The largest single industrial sector by technology is energy efficiency construction with 1.3 million employees.

Industry	Construction	Professional Services	Manufacturing	Wholesale Trade	Utilities	Mining and Extraction	Agriculture	Other
Jobs	2,085,156	986,769	758,125	630,592	601,225	535,210	35,616	91,059
Entry Pay	$14.77	$22.10	$16.75	$21.83	$25.06	$16.68	NA	NA
Median	$21.82	$33.44	$26.63	$33.35	$36.61	$26.56	NA	NA
Highest	$34.60	$52.62	$44.38	$51.64	$55.43	$40.87	NA	NA

Table 2: Number of Jobs (2020) and Pay Scales (2019) in Energy and Energy Efficiency Sectors (EFI, NASEO, & BW Research Partnership, 2020, 2019).

Detailed state data correlating these wage rates to both technologies and industries have shown that wages generally correlate to the industry rather than to a specific technology. For instance, construction worker pay rates tend to be more similar regardless of whether they are employed in solar, hydroelectric, or energy efficiency technologies (EFI, NASEO, & BW Research Partnership, Minnesota and Florida EER 2019). Notably, utility employment offers the highest entry level, median and highest pay rates within the sector. This fact corresponds to both higher rates of unionization than in the private sector generally, as well as the high degree of regulation.

Lastly. it is also worth noting that 60% of these positions have entry level pay rates that average below $17 an hour. This implies that the majority of these positions in the energy and energy efficiency sectors do not require four-year degrees and do offer substantial opportunities when promoting to median level pay rates. Mining and extraction and manufacturing industries both offer increases of 59% from entry level to median wages.

In this section of the paper we will give a brief overview of each of the four sectors of the energy and energy efficiency workforce and note relevant trends to the transition to a low carbon economy. We will also identify recent changes in the workforce, project future skill demands and highlight areas of new opportunities for underrepresented populations and those entering the workforce as found through USEER survey reports, EIA energy model projections, Bureau of Labor statistics and company interviews.

2.2 Fuels

The fuels sector encompasses mining, extraction and processing of petroleum, natural gas, coal, and other liquid fuels such as corn ethanol and biomass. Of the 1.1 million individuals, over 600,000 work in petroleum and 270,000 in natural gas. In 2019 the fuels sector saw a 1.9 percent growth in its workforce, adding a total of 26,100 jobs with the majority of that growth in oil and natural gas. Employers predict another 1.7% increase over the next year, with most of the growth in oil and natural gas (EFI, NASEO, & BW Research Partnership, 2019; EFI, NASEO, & BW Research Partnership, 2020).

Much of the growth in domestic oil and gas employment is a direct result of the adoption of hydraulic fracturing and horizontal drilling which have revolutionized the U.S. industry over the last decade. Between January 1, 2009 and October 1, 2014, the oil and gas extraction and support services industries alone added over 157,000 jobs (BLS, 2019). However, as a result of price volatility in these global commodities almost all of these jobs were lost in the subsequent two years. Not until 2017 did the industry add almost 10,000 jobs, followed by the robust growth in 2018 (EFI, NASEO, & BW Research Partnership, 2018; EFI, NASEO, & BW Research Partnership, 2019).

However, petroleum production is predicted to decrease over the next 30 years while natural gas will continue to rise as coal decreases (U.S. Energy Information Administration, 2020). Clearly, no other sectors of the energy workforce could be more impacted by the transition to a low carbon economy than those in the fossil fuel sector and its transmission, distribution and transport sectors. When employment in petroleum, natural gas, and coal is consolidated to include all these sectors along with fossil fuel driven generation, it includes a total of 1,646,000 Americans (EFI, NASEO, & BW Research Partnership, 2020).

Fortunately, a majority of these employees are working in industry sectors—including construction, manufacturing, and professional services—with more readily transferable skills than those employed in mining and extraction. As the reduction in coal mining in Appalachia over the last three decades has shown—caused by automation, low cost natural gas, the opening of Western coal fields, and the closure of coal-fired power plants—an inadequate public policy response will have a devastating impact on community and workers.

While a rapid transition from oil and natural gas is unrealistic in the near term because of the dependence of the industrial and transportation sectors and the long capital life of their equipment, the downsizing and reskilling of this workforce is one of the most important transition challenges. As past transition failures dealing with deindustrialization have shown, relying exclusively on labor market solutions is inadequate at best. Section 6 of this paper will address some of these issues. However, it is also important to note that fuel production and consumption is subject to external factors such as oil prices, global market trends and technological development, which has resulted in job growth in the natural gas industry as well as displacement in coal.

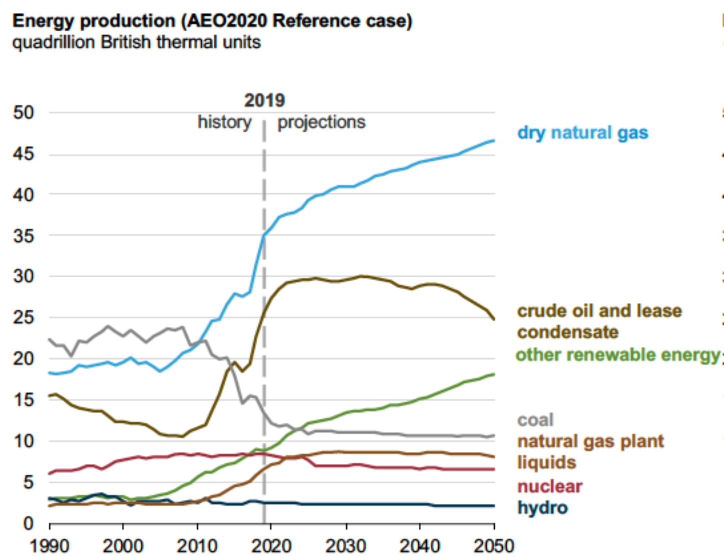


Figure 3: Projected fuel energy consumption (US EIA AEO, 2020)

The uncertainty of where technology RD&D will take us in the next three decades speaks to the importance of also maintaining optionality for workforce solutions as well. For instance, will the development of low-cost CCS technology provide a better solution for the variability of renewable generation than battery storage? Will the demands for battery storage and vehicle electrification result in a rebirth in North American mining of a range of clean energy minerals such as copper, lithium, nickel, uranium, and rare earth minerals, creating demand for mining skills? Will the growth of biofuels provide a use for existing transmission and distribution pipelines?

Fuels' employment is distributed across several industries, as shown below in Figure 4. Mining and extraction made up almost half of the workforce with 535,000 employees in 2019. Manufacturing followed with 247,000 and professional and professional services with 170,000.

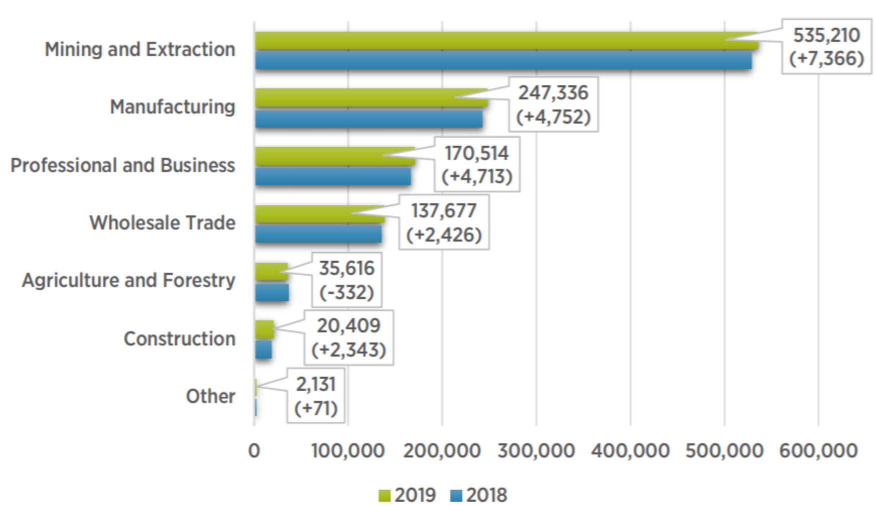


Figure 4: Fuels sector employment by industry in 2018 and 2019 (EFI, NASEO, & BW Research Partnership, 2020).

It is interesting to note that 89% of fuels' employers found it difficult or very difficult to hire new professional and business service employees in 2019. As Jennifer Pierce, Senior Vice President of TransCanada Energy's Human Resource Department observed in a 2019 interview, "it takes [TC Energy] 20-30% longer to fill engineering positions in the United States compared to the Canadian side of our business."

While some of this is due to the lack of experience or needed technical skills that are required by these positions, within the fuels' sector, companies are noticing a general cultural shift in the millennial workforce. Younger workers are becoming less interested in working for fossil fuel corporations despite the high pay rates. Corporate and social responsibility are playing a larger role in the decision making of young talented workers entering in specific sectors. As TC Energy noted, "Higher wages are not an issue in hiring workers; we see our biggest threat in the future is the lack of interest in the fossil fuel industry. That is why we make a priority out of our sustainability report and environmental track record."

One of the most notable demographic challenges faced by the fuels' sector is the geographic density of its mining and extraction industry. Over 88% of its 535,000 mining and extraction employees are located in just 10 states (EFI, NASEO, & BW Research Partnership, 2020). This resource density underscores the challenges that will be faced if decarbonization results in the rapid or significant decline in the oil, natural gas, and coal sectors.

Overall, the fuels' sector is predominantly male with women making up only 25% of the workforce. Racial minorities make up 23% of the workforce, slightly above the national average of 22%; however, African Americans and Hispanics are below the national average. Veterans represent 10% of the workforce well above the national average. Fuels' employers have a 3% unionization rate, half the national private sector rate of 6%.

2.3 Electric Power Generation

Electric Power Generation (EPG) includes 13 different technologies that generate electricity such as fossil fuels, renewables, and nuclear. This sector employs over 896,000 (including over 97,000 solar employees who spend less than 50% of their time on solar), increasing by 2.4 percent in 2019, a pivot from the employment decline in 2018. Although solar employees make up the largest share of the EPG workforce with over 248,000 workers, solar produces only 1.8 percent of the nation's electricity (EFI, NASEO, & BW Research Partnership, 2020; Energy Information Administration, n.d.). Natural gas produces the largest share of electricity, followed by coal and nuclear; collectively these three sources produce 82% of the nation's electricity generation with 262,000 employees. Wind generation employs 114,000 individuals while producing 7.3 percent of the country's electricity (EFI, NASEO, & BW Research Partnership, 2020; Energy Information Administration, n.d.).

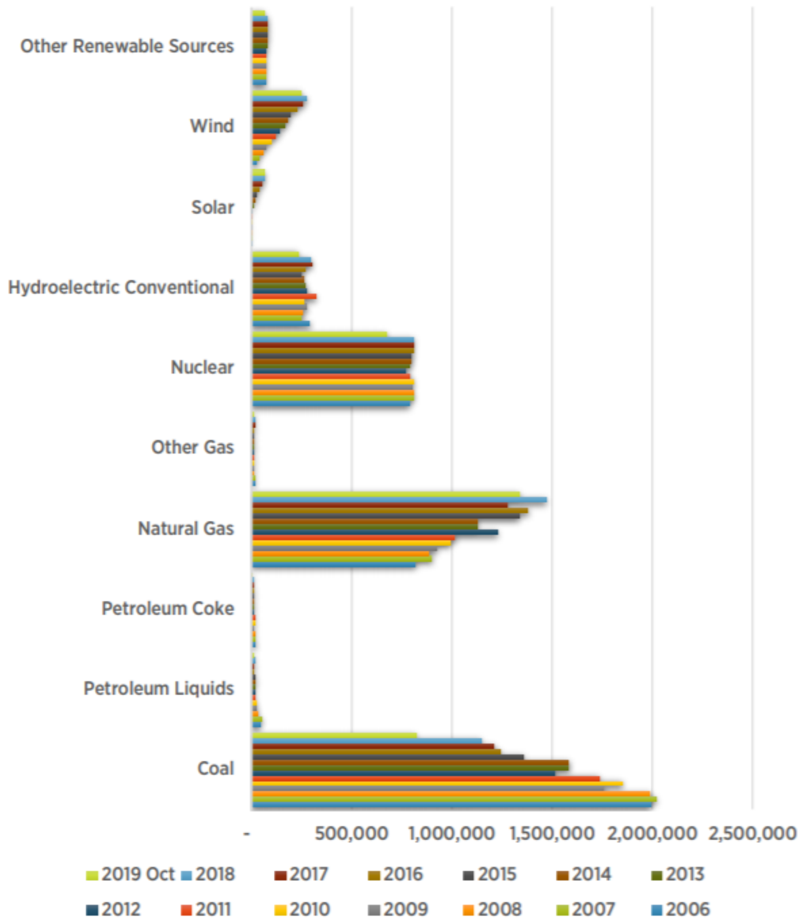


Figure 5: Electricity generation per energy source (MWh) from 2006 to 2019 (EFI, NASEO, & BW Research Partnership, 2020).

As shown in figure 5 above, employment has shifted over the last decade, based on the changes in generation sources. Solar, wind, and natural gas generation have all grown while coal generation has contracted, most recently by 6,400 employees in 2019 (EFI, NASEO, & BW Research Partnership, 2020). More recently, the solar workforce increased by 5,600 workers in 2019 after contracting the previous two years by almost 8,000 employees in 2018 (EFI, NASEO, & BW Research Partnership, 2020 & 2019). While the solar workforce continued to grow rapidly in 25 states, the declines have been attributed to a range of factors including the market saturation of residential solar in some states, growth of utility scale solar projects which are less labor intensive, solar panel tariffs, and increased workforce productivity. In 2019 advanced natural gas generation added the largest number of EPG employees at 9,100 with most of that in advanced low emissions' technologies.

However, the composition of the workforces in these different technologies varies significantly. Construction makes up the largest portions of the workforce for solar at 74% and wind at 33% while coal and natural gas are primarily utility workers. This variation underscores another significant transition issue with lower paying, less unionized technologies (wind and solar) displacing existing ones in stationary base load power plants.

Overall, construction consists of the largest industrial sector of the EPG workforce with 299,391 workers or roughly 33%. However, construction makes up only 13% of the natural gas EPG workforce, 11% of coal EPG, and only 4% of nuclear EPG. A majority of the employees in all three of these technologies are in the utility industry which, as referenced in Table 2, provide the best entry level, median and highest wage rates throughout the energy sector.

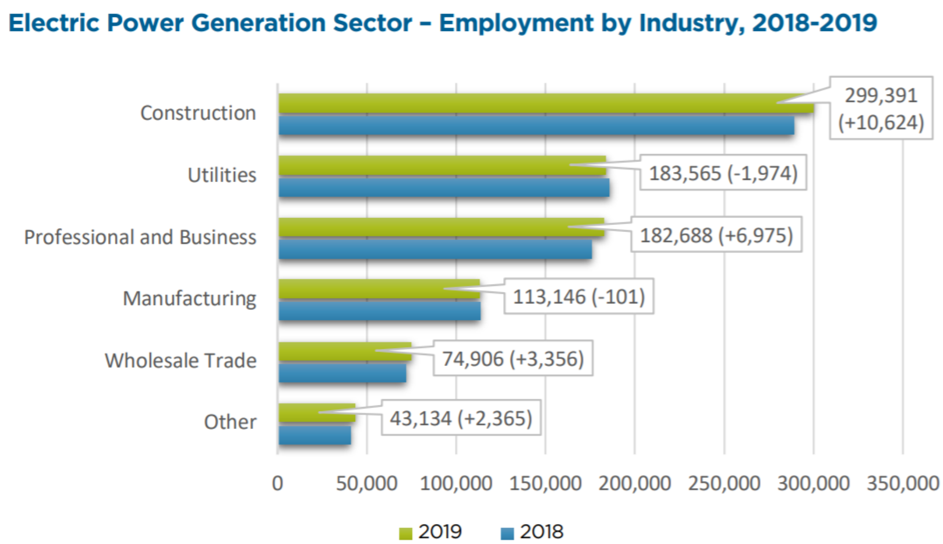


Figure 6: Electric power generation employment in 2018-2019 (EFI, NASEO, & BW Research Partnership, 2020).

In 2019, 90% of EPG employers expressed difficulty in hiring installation workers, customer support, electricians, and construction laborers due to lack of individuals with proper experience and small applicant pools. Skills in the construction trades are fairly transferable, meaning an electrician or technician for one technology does not have to significantly retrain for new technologies. As one representative from the International Brotherhood of Electrical Workers (IBEW) workers stated, "Electrical repairs and maintenance do not vary much. The primary difference is how electrical systems are laid out which is easy to learn and adapted as needed."

However, a more important obstacle to hiring appears to be the declining interest of the next generation in careers in both construction and utilities. Unions across the construction trades such as the International Association of Sheet Metal, Air, Rail and Transportation workers (SMART), the United Association of Plumbers and Pipefitters (UA) and IBEW have asserted that while they do have the capacity and resources to train more workers, that there are not enough new candidates interested in working in their fields. Instead, graduating high school students are focused on attaining college degrees in hopes of financial and career security, even though the trades pay $60-100,000 and do not require as much debt. All three unions noted that a typical apprentice is now in their mid to late 20's, frequently with several years of college, when previously a majority were directly out of high school.

Recruitment in EPG is not only a problem for the construction sector. Utility and professional and business services employers have also reported trouble in finding managers and engineers with the proper technical and leadership experience. MJ Horner from Xcel Energy described their difficulty in hiring data scientists for which there is a growing demand throughout the company, ranging from grid management to human resources.

One of the most developed efforts at improving the workforce development systems in the energy sector is managed by the Center for Energy Workforce Development (CEWD), a non-profit consortium of electric and natural gas utilities that was recently expanded to include related construction companies. Founded a decade ago to help utilities prepare for an anticipated retirement boom, CEWD created a network of state-based partnerships between local utilities, community colleges, unions, and other stakeholders to develop recruitment pipelines, prepare curricula, organize boot camps, and focus on veterans' hiring initiatives. In 2019 only 7% of EPG utility employers reported that it was "very difficult" to hire new employees compared to 29% of EPG construction employers.

Ann Randazzo, the Executive Director of CEWD (2006-2019), describes the rapid pace of change in the energy sector as something that demands immediate and constant attention. "Technology is changing so quickly, we have to speed up training if we are to keep up." Xcel Energy described its own efforts at reorganizing its workforce to help meet its recently adopted carbon reduction goals. As seen in Figure 7 below, Xcel Energy is moving away from plant technical services that required workers in the field to occupations that focus more on customer service and grid management. Xcel Energy and other companies are increasingly searching for data scientists to interpret collected data to improve operational efficiency for customer service and infrastructure maintenance.

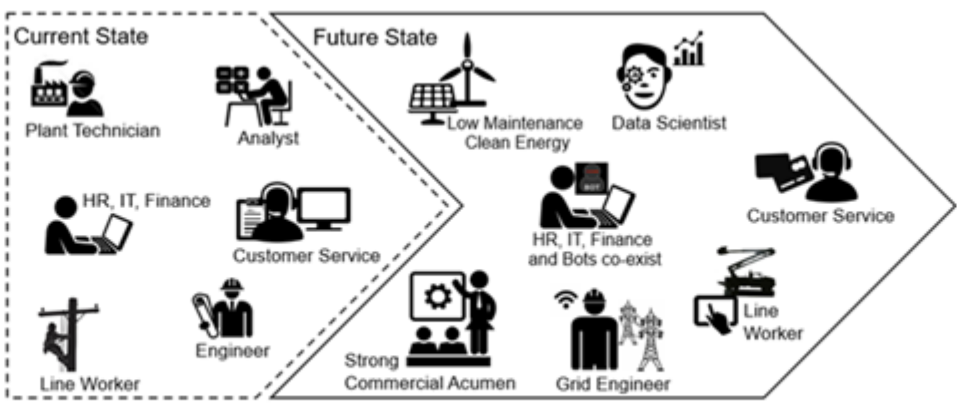


Figure 7: Xcel Energy future occupation opportunities (Xcel Energy, n.d.)

In order to respond to the growing recruitment challenges, virtually all respondents agreed that the EPG sector recruitment problems could be mitigated by getting middle and high school students interested earlier in energy careers. IBEW has found that by allowing students to get field experience and an idea of what it is like to work in the trade from a younger age, more students would consider alternative career paths. Xcel Energy recruits heavily from its internship programs for both high school and college students.

With the rapid deployment of new technologies over the last decade, the EPG sector has become an important model for demonstrating how workforce training and recruitment systems can be modernized to reflect new technologies, business models, and workforce skills' shifts. In addition, EPG employers are focused on the importance of integrating the mission of low carbon transition into a talent recruitment advantage.

Overall, the electric power generation sector is more racially diverse than the US workforce with 31% minorities (EFI, NASEO, & BW Research Partnership, 2020). However, only 32% of the workforce is female. Hispanics account for 18% and Asian-Americans 10%, equal to or surpassing the national averages of 18% and 6% respectively. There are also more veterans employed at 9% versus 6%. Approximately 7% of employees belong to unions, roughly the private sector average.

However, these demographics vary significantly by technology. Generally, the nuclear, coal, and natural gas EPG employers are more diverse, with higher percentages of women and minorities than the wind and solar employers. In addition, they have much higher rates of unionization, tending to be 50%-100% higher than the private sector average while wind and solar are below the national average (EFI, NASEO, & BW Research Partnership, 2020). The nuclear EPG sector leads in virtually all these sectors with 36% of its workforce female and 34% minority.

These demographic variations are particularly important when thinking through the social effects of an energy transition. The data shows that the existing EPG workforce, particularly in the nuclear, coal, and natural gas technologies, is employed in better paying jobs with more racial diversity and higher percentages of women, than the energy sector as a whole and in many cases than the country as a whole. Consequently, the deployment of new technologies, designed to reduce emissions, must be designed within a policy architecture that reinforces the existing accomplishments toward social equity. Some of these policy tools will be discussed in Section 6.

2.4 Transmission, Distribution and Storage (TDS)

Transmission, Distribution, and Storage infrastructure links energy supplies to intermediate and end users. It includes:

- 2.6 million miles of interstate and intrastate pipelines;
- 414 natural gas storage facilities;
- 330 ports handling crude petroleum and refined petroleum products;
- 140,000 miles of railways that handle crude petroleum, refined petroleum products, liquefied natural gas (LNG), and coal;
- 642,000 miles of high-voltage transmission lines;
- 6.3 million miles of distribution lines (DOE, 2015)

In 2019, TDS employed 1,383,000 workers. However, this excludes the roughly one million Americans who are employed in gas stations. Throughout this paper we exclude employment engaged in retail sales of energy products and services such as those selling EnergyStar appliances at big box stores since it is currently impossible to determine what percentage of time retail sales employees spend on energy or energy efficiency products. However, gas stations present a unique problem since the average gas station or convenience store which also sells gasoline makes 75-80% of its revenue from petroleum products. (Statista.com, 2019) Thus, the transition to an electrified transportation system would have a significant impact on employment within this industry.

Within TDS, the construction sector employed 36% of the workforce compared to the utility sector which employed 30%. While employment in most TDS industry sectors has been quite stable during the last three years (see Figure 8), the construction sector has seen considerable growth, adding over 40,000 employees in the last two years alone. This reflects the growing investments in energy infrastructure, hardening and resilience. In 2019, 42% of TDS employers reported that a majority of their revenues came from utility-funded modernization projects, a decrease of 6 percentage points in 2018 *(EFI, NASEO, & BW Research Partnership, 2020).*

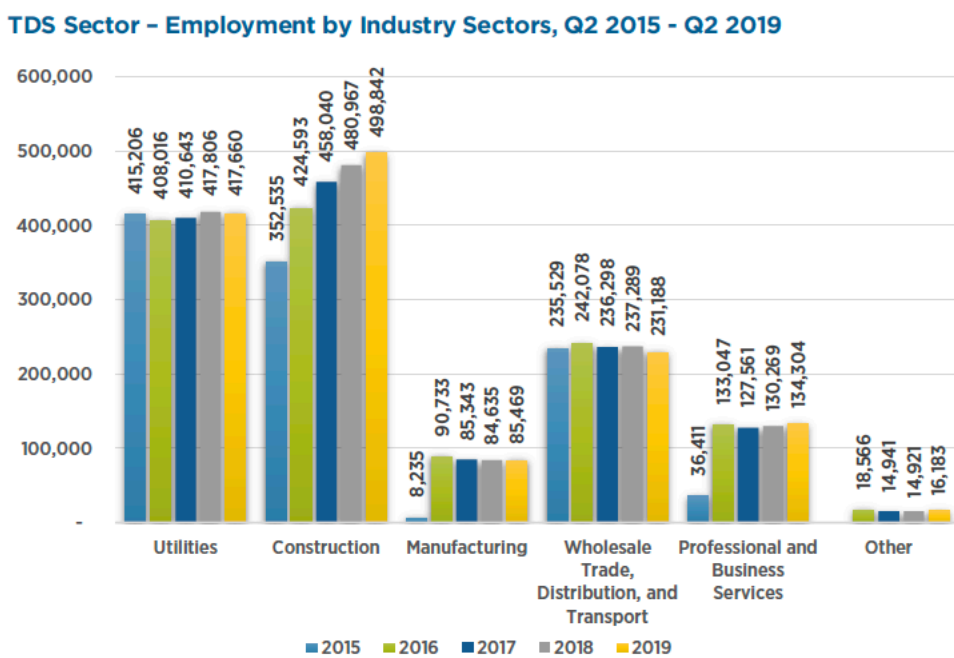


Figure 8: Transmission, distribution and storage employment from 2015 to 2019 (EFI, NASEO, & BW Research Partnership, 2020).

The overwhelming majority of TDS employees, almost 1.2 million, work with the transmission, distribution and storage of electricity, natural gas, petroleum and coal. Figure 9 below illustrates current employment by TDS sub-technology. However, it is interesting to note the growth taking place within grid modernization and storage technologies. With over 65,000 workers already in battery storage, this number is expected to increase by another 7.1% in the next year as more distributed electricity technologies and electric vehicle charging stations are installed around the country.

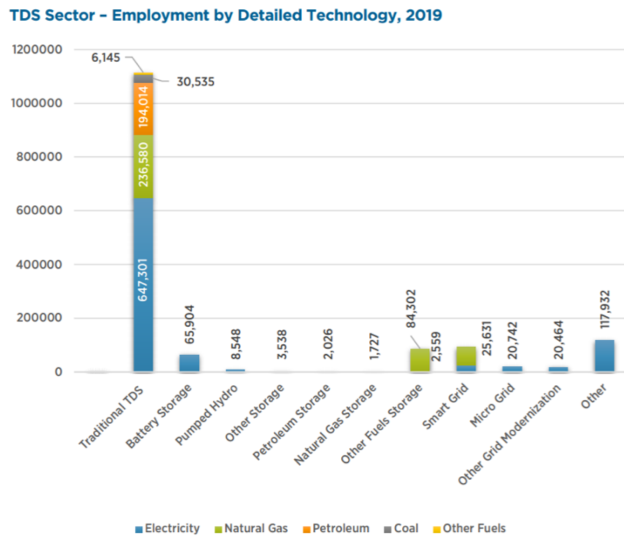


Figure 9: Employment by technology in Transmission, distribution and storage sector (EFI, NASEO, & BW Research Partnership, 2020).

Similar to the EPG sector, TDS, with a high concentration of both construction and utility industry employees, has experienced recruitment challenges. In previous years, the difficulty has been notably higher in the construction sector. In 2018, 79% of construction TDS employers reported difficulty in hiring with 34% stating it was "very difficult". In that same year, only 56% of utility TDS employers reported difficulty with just 12% saying it was "very difficult". However, in 2020 utility TDS employers experienced a significant increase in hiring difficulty.

Generally, the work of CEWD in this arena has paid off over the last decade and their current effort to recruit the participation of major construction firms in the TDS sector should produce results in the years ahead. In addition to the shift away from vocational training to four-year college by the millennial generation, location is reported to be another one of the reasons why construction contractors and utilities report difficulty in hiring. In order to install long transmission lines, construction workers and technicians are needed in remote areas with temporary positions.

As an Xcel Energy executive stated, "Xcel has generally hired around 1000 new employees a year for the past five years; however, in the past 6 months we have found it increasingly difficult to find people who are willing to work far from their homes, even for only short periods at a time." MJ Horner also reported that "one of the biggest factors for someone leaving the company is distance" and that the "biggest indicator of someone leaving the company is that they live 22 miles or more from their primary work location. Some companies and unions like the UA have said they will lease temporary housing or blocks of rooms at hotels in project locations, so that the burden of finding housing is not on the workers. Unions, in particular, have noted that to develop infrastructure in rural locations, it will be vital to receive federal support for remote training and housing.

The TDS sector shares some of the demographic characteristics of the EPG sector. Only 24% of its employees are women, about half the national average. Racially, it is more diverse than the US workforce as a whole with 69% of its employees Caucasian and 31% minorities, compared to a national average of 78%-22%. Most minority groups are more heavily represented among TDS employees with the exception of African-Americans who make up 10% of the workforce. Veterans again are over-represented at 8%, while the workforce as a whole tends to be younger with a smaller proportion of employees over age 55.

TDS is the most highly unionized sector of the energy workforce, with unionization rates (17%) that are almost 3-times higher than the national average in the private sector. A recent study on California's climate solutions and energy workforce showed that construction workers in the TDS sector received pay rates $4-$8 an hour more than the median pay for such skills nationally. As with EPG workers it will be critical to match or exceed these outcomes in the expanded TDS labor force created by investments in the infrastructure for a low carbon transition.

2.5 Energy Efficiency

At the start of this section, we defined the energy efficiency workforce as those producing and installing products and services that help to decrease energy consumption. This sector produces the most jobs of any energy sector with over 2.38 million in 2019 and is the fastest growing, having added over 54,000 jobs in the last year.

It is also the most important sector for achieving GHG reductions in the near term. As a recent assessment of California's climate policies concluded, the most significant tool for emission reductions over the next decade in virtually every sector of the economy is energy efficiency whether in manufacturing, commercial buildings, or transportation (Energy Futures Initiative, Optionality report, 2019). Energy efficiency, thus, is the most consequential policy bridge for reaching a low carbon economy while at the same time creating significant economic opportunity. In addition, energy efficiency has the added benefit of being able to reduce energy costs and create jobs in virtually every corner of the country.

Unlike the fuels sector which is geographically specific and confined largely to where natural resources were discovered, the energy efficiency sector applies to every community and every activity of human society. Thus, energy efficiency jobs can readily supply the replacement employment in adversely impacted communities or in other high unemployment regions of the country.

For purposes of this paper, our discussion of the energy efficiency sector is largely focused on the built environment, including both commercial and residential buildings. Transportation energy efficiency and the motor vehicles industry, while critical, will be dealt with separately in a paper on energy and manufacturing. The 2.38 million energy efficiency workers in America are distributed across five different industrial sectors as shown in Figure 10 below.

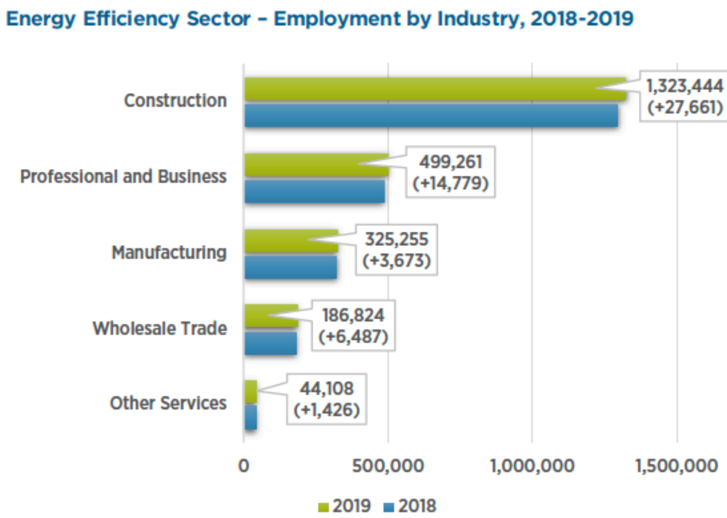


Figure 10: Energy Efficiency Employment by Industry Sector, 2018-2019 (EFI, NASEO, & BW Research Partnership, 2020).

The construction sector is by far the largest, comprising 56% of the overall workforce. Manufacturing makes up 14% of the energy efficiency workforce and produces a broad range of products such as LED light bulbs, high efficiency HVAC systems, and insulation.

Although large states tend to have the greatest numbers of energy efficiency jobs such as the number one and two states, California and Texas, many smaller states have relatively large numbers of energy efficiency jobs, reflecting the implementation of energy efficiency standards, the comparative advantage of manufacturing infrastructure, or an RD&D focus on these technologies. Massachusetts, for instance, with a longstanding EE standard, has a greater than average share of EE jobs and a higher intensity rate of utilization. Ohio, with a significant manufacturing base, is one of the largest manufacturers of energy efficiency products, while North Carolina, with a research focus on energy efficiency products and grid modernization at the Research Park Triangle Cleantech Cluster, is out-producing its neighboring states with energy efficiency jobs.

The energy efficiency sector, particularly in construction, is also facing a serious hiring crisis with hiring expectations significantly outpacing actual growth over the last few years. In 2016, the energy efficiency construction workforce grew by 12%. The following year, construction employers predicted 11% growth, but actually contracted because of the difficulty in hiring and training new employees. Nonetheless, construction energy efficiency employers again predicted 11% growth but were only able to expand their workforce by 1.6% in 2018. Over 50% of all energy efficiency construction employers reported that it was "very difficult" to hire new employees. In 2018, construction employers expected 8.8% growth, while overall the energy efficiency sector predicted 7.8% growth. However, the construction sector only grew by 2.1% in 2019. This growth is projected at 3.6% in 2020.

It is worthwhile comparing the hiring difficulty, reasons, and most in-demand occupations in the two leading sectors of energy efficiency which make up 75% of the employment—construction and professional services. These two sectors rely on two different components of the workforce development system, with construction relying on vocational programs and union apprenticeships, while professional and business services rely on four year and advanced degree training institutions. In 2019, 91% of all energy efficiency construction firms reported it was “very difficult” or “somewhat difficult” to hire new employees. By comparison, 80% of professional services employers reported hiring “very difficult” and “somewhat difficult”. As a result, the much smaller professional services sector, out hired the much larger construction sector by almost 2 to 1.

However, both sectors cited the same top reason for hiring difficulty:

1. Lack of experience, training or technical skills

In the case of the construction employers, the hardest to fill occupations were technicians or mechanical support, electricians, and installation workers, while the professional services employers were looking for engineers/scientists, management, and designers or architects.

It is especially important to align the workforce training system with the most significant opportunities presented by climate change solutions. Energy efficiency in America occupies that important juncture. Employers in all energy efficiency sectors have predicted significant growth. All have been stymied by insufficient skills’ training and tight labor markets. But where even incremental improvements have been achieved, as is the case with professional services, the job rewards have been significant.

One immediate conclusion that can be drawn from applying the experience of the utility sector with CEWD in both EPG and TDS is that a concerted effort by the energy efficiency private sector to engage with its unions and the workforce training system would have immediate and measurable results. A similar approach to solving the hiring crisis in energy efficiency, and particularly in the construction sector, should provide both economic and environmental benefits.

The demographics of the energy efficiency workforce are in many ways similar to TDS which also has a significant construction component. Energy efficiency workers are largely male with women making up only 24% of the workforce. Racially, the workforce is 77% Caucasian and 23% minority, reflective of the overall U.S. workforce. Hispanics are represented at 15% (18% nationally), while African-Americans are underrepresented at 8% (12% nationally). Similar to TDS, the workforce is younger than average and with a higher concentration of veterans (9%).

The energy efficiency workforce is also much more unionized than the private sector overall at 10%, almost double the national private sector average of 6%. In addition to the wage premium generally associated with unions in the construction industry at 15%, the recent California energy jobs wage report, found that construction workers with energy efficiency skills in the U.S. received an additional premium of $.50-$.90 an hour.

3 Climate Solutions and Workforce Demands

In the preceding sections, we examined the history and structure of the U.S. workforce training system and the composition of the energy and energy efficiency sectors of the workforce that would be most directly impacted by the transition to a low carbon economy. Two other sectors, motor vehicles and manufacturing will be examined in a second paper, *Energy & Manufacturing in the U.S*. In this section, we will examine three scenarios for addressing the climate crisis and estimate the workforce demands that those scenarios will place on our workforce system. We will also estimate the negative impacts that these scenarios will have on existing sectors of the economy.

The job creation estimates will be arrived at using the input/output modeling system, IMPLAN, and will be focused only on the initial 10 years of implementation for each scenario. We are restricting our time horizon because of the inherent vulnerability of these scenarios to shifting technology over a thirty-year time period. The primary questions that we want to answer with this exercise are:

- *Can the existing workforce system meet the demands for increased skills under each scenario?*
- *Where will the principal opportunities for job growth be located, by both skill sets and geography?*
- *What will be the greatest challenges to worker dislocation?*
- *How much flexibility can be maintained to adjust to different technology pathways?*

Before laying out each scenario, however, we want to provide some additional analysis of one of the principal areas of energy job growth over the last decade—Transmission, Distribution and Storage to provide a baseline understanding of its structural needs.

3.1 Transmission, Distribution and Storage or "Energy Infrastructure" Demands

According to the American Society of Civil Engineers it is estimated that energy consumption will be growing at a modest rate, averaging 0.4% per year from 2015 through 2040 (Amercian Society of Civil Engineers, 2017). However, little consideration has been provided to ensure the long term sustainability of the nation's energy infrastructure, its resilience in the face of increasing extreme weather events, or its greater efficiency.

<u>Electricity Infrastructure</u>

When we look at the electricity sector, we see an aging, complex, patch work system of power generation facilities, transmission and distribution (T&D), local distribution lines, and substations (Amercian Society of Civil Engineers, 2017). Most of the T&D lines were constructed in the 1950's and 60's with a 50 year life expectancy and were not engineered to meet today's resilience or efficiency demands. These views are supported by the 2015 Quadrennial Energy Review (QER) (U.S. Department of Energy, 2015) which details how technological advancements are altering expectations of grid usage. For example, the QER describes how individual consumers and companies increasingly want to control the production and delivery of their electricity and employ the enabling technology that has become available for these functions. The Edison Electric Institute estimated in 2008 that by 2030 the U.S. electric utility industry would need to make a total infrastructure investment of $1.5 trillion to $2.0 trillion, with transmission and distribution expected to account for about $900 billion (U.S. Department of Energy, 2015).

Oil and Natural Gas Infrastructure

Most oil refineries within the U.S have been operating above 90% capacity since 1985 to keep up with existing demand for gasoline and other fuels and raw products for manufacturing (Amercian Society of Civil Engineers, 2017). As a result of the rising production and consumption of natural gas, we are also seeing greater needs for consistent monitoring and maintenance. Significant Investment will be required to meet long overdue repair and improvements to our pipelines, rail systems, ports, and waterways (U.S. Department of Energy, 2015). According to analysis conducted by the QER, natural gas interstate pipeline investment will range between $2.6 billion and $3.5 billion per year between 2015 and 2030, depending on the overall level of natural gas demand. The total cost of replacing cast iron and bare steel pipes in gas distribution systems is estimated to be $270 billion (U.S. Department of Energy, 2015).

Infrastructure Funding and Future Need

The 2015 QER reports that climate reduction policies could result in reduced impact of wear and tear on current infrastructure, hence impacting investments required in maintaining these infrastructure (U.S. Department of Energy, 2015). However, the ASCE in its 2017 report evaluated the current infrastructure needs and estimated that the cumulative investment gap in electricity infrastructure alone between 2016 and 2025 was $177 Billion. At least a portion of this sum included the lack of investments in renewable sources of energy for power generation, heating and cooling, transportation and process heat industries' infrastructures.

A comprehensive analysis of the ASCE report concluded that meeting the entire infrastructure gap, beyond just energy and raising the overall infrastructure grade in the U.S. from a D+ to a B would cost $2.25 trillion and create 1.45 million jobs over 10 years (Amercian Society of Civil Engineers, 2017). Such an approach to all infrastructure deficits in the U.S., including, for instance, roads and bridges, public transit, increased recycling, smart grids, and replacing leaking water pipes would also result in reducing GHG emissions by at least 543 million metric tons per year before addressing the actual sources of emissions in electric power generation, fuels, and industry (Amercian Society of Civil Engineers, 2017).

3.2 Scenario Modeling.

One of the trends reported by energy and energy efficiency employers in the 2016-20 USEER's has been the increased difficulty in hiring new employees. While this has been true generally across all sectors, it has been especially acute in a number of "low carbon" technologies. The greatest hiring difficulty of all occurred in the energy efficiency construction sector where 52% of all employers reported that it was "very difficult" to hire new employees. (USEER, 2019). Technicians, electricians, and installation workers were identified as the most difficult to hire. When asked the main reasons for that hiring difficulty, employers responded that the top three reasons were:

1) Lack of experience, training, or technical skills (48%),
2) Competition/small applicant pool (24%), and
3) Insufficient non-technical skills (24%). (USEER, 2019).

The reported hiring difficulty in energy efficiency construction firms appeared to result in lost opportunity during the subsequent years. These firms had predicted hiring growth of 11% in 2017, 11% in 2018, and 8.8% in 2019 after actual employment growth of 12% in 2016. Instead, these firms actually contracted by 100,000 (-7.2%) employees in 2017 and only grew by 1.6% in 2018 and 2.1% in 2019. (USEER, 2016-2020). Labor shortages and lack of skills clearly impacted firm performance and the deployment of energy efficiency technologies and the resultant reduction in GHG emissions.

In part, energy efficiency construction firms responded to this lack of qualified employees by increasing the "intensity" or proportion of energy efficiency work that their employees did, compared to the amount of non-energy efficiency work that they performed. The USEER, for instance, reported an increase in 2017 of intensity (the proportion of firm employees who spent the majority of their time on energy efficiency technologies) from 72% to 80%. That number has held relatively steady for the subsequent two years at 79% and 78%. (USEER, 2016-2020).

Nonetheless, the lack of qualified employees is a real threat to the implementation of climate solutions, particularly when the primary tool available to reduce GHG's in the next decade will be energy efficiency as numerous studies have shown. In order to gauge the scope of this problem, this paper has modeled three scenarios for GHG reduction investments, attributing those reductions to different technology mixes and resulting skills' demands. After reviewing the job multiplier effects of energy and related-construction investments produced by the University of Massachusetts' Political Economy Research Institute (PERI) (Garrett-Peltier, 2017), the Economic Policy Institute (EPI) (Bivens, 2019), and the National Renewable Energy Laboratory's JEDI model (NREL, 2020), we used a set of job multipliers developed from IMPLANv3 (PERI) by Heidi Garrett-Peltier. While there is some variation in the direct, indirect, and induced jobs created by each $1 million of investment in solar, wind, energy efficiency and infrastructure, for the purpose of doing a workforce training assessment these variations were immaterial. (Note that the Garrett-Peltier model does not include induced jobs which are defined as the jobs created by the increased spending from the employees holding the direct and indirect jobs. However, these jobs are generally not competing in the job markets held in positions created by the direct jobs, i.e. restaurant, hotel or retail employees vs. construction employees.)

Scenarios A, B, and C model investments for the 2020-30 timeframe at the rate of $50 billion per ye-ar, $100 billion per year, and $250 billion per year, for total investments of $500 billion, $1 trillion, and $2.5 trillion. These scenarios all rely on existing technologies. During the subsequent two decades we did not perform similar modeling because the results, in many cases, would be dependent on investment estimates that we deemed too speculative to provide worthwhile results. This is because of the variability in cost curves for new technologies. However, in Section 4 we do include some of the possible job impacts and skills' demands for some of these new technologies if they were added into the solutions portfolio.

Finally, it is important to note that job multiplier impact assessments of specific investments do not provide net job impacts caused by these investments. This is especially important when many of the investments are specifically designed to displace existing energy assets or reduce the consumption of energy. To assess the net jobs impact of the ongoing energy transition, White Paper #7 reviewed existing modeling literature and engaged in our own modeling exercise using REMI, a computable general equilibrium (CGE) model, for three additional scenarios: Sluggish Transition based on the Energy Information Administration's 2020 Annual Energy Outlook, Paris Transition which meets the Paris Climate Accord targets, and finally the Ambition Scenario which will reduce global temperature rise to 1.5 degrees Centigrade. The results of these three scenarios will be released in a separate study along with four case studies that detail the opportunities and challenges faced by specific regions of the U.S. by deep decarbonization.

Job Multiplier Scenarios

According to the 2019 US Energy and Employment Report the industry composition of the solar, wind, energy efficiency, and transmission, distribution and storage (energy infrastructure) sectors looks as follows:

USEER 2019 Comparison						
Sector	Construction	Professional Services	Manufacturing	Utilities	Wholesale Trade	Other
Solar	53%	14.4%	13.9%	1%	8%	9.8%
Wind	33.1%	24.4%	23.9%	5.6%	10.6%	2.6%
Energy Efficiency	55.9%	20.9%	13.9%	0	7.8%	1.8%
TDS	35.2%	9.5%	6.2%	30.6%	17.4%	1.1%

Table 3: USEER Employment 2019 Findings for Comparison

These relative compositions are important in assessing the effects that decarbonizing the US energy sector has on U.S. labor markets and the relatively modest demands that these investments put on the U.S. workforce training system.

In Scenario A, we assume that the effort at carbon reductions will be driven mostly at the state level and will result in annual GHG mitigation investments of roughly $50 billion a year over the next decade. In Scenario B, we assume that the first decade of mitigation investments will be approximately $100 billion per year or $1 trillion in total. And in Scenario C, we assume that investments in the first 10 years will be $250 billion per year or $2.5 trillion. To give a sense of the magnitude of spending, almost $700 billion were spent in 2019 on the US Armed Forces and $1.1 trillion on healthcare in 2018 (Tax Policy Center, 2019).

Scenario A. Scenario A results in the creation of approximately 291,700 direct jobs per year, based on an allocation of $10B (6.4 direct jobs per $1M) on solar, $10B (4.8 direct jobs per $1M) on wind, $20B (6.0 direct jobs per $1M) on energy efficiency, and $10B (6.1 direct jobs per $1M) on energy infrastructure. In addition, this spending would create an additional 196,000 indirect jobs.

Scenario A – 291,700 direct jobs							
Sector	Construction	Professional Services	Manufacturing	Utilities	Wholesale Trade	Other	**Total**
Solar	33,920	9,216	8,896	640	5,120	6,272	**64,064**
Wind	15,888	11,712	11,472	2,688	5,088	1,248	**48,096**
Energy Efficiency	67,080	25,080	16,680	0	9,360	3,120	**118,520**
TDS	21,472	5,795	3,782	18,666	10,614	671	**61,000**
Total	**138,360**	**51,803**	**40,830**	**21,994**	**30,182**	**8,511**	**291,680**

Table 4: Scenario A job creation table

Scenario B. Scenario B results in the creation of approximately 587,100 jobs per year, based on an allocation of $15B on solar, $20B on wind, $50B on EE and $15B on energy infrastructure. These investments would also create 405,000 indirect jobs.

Scenario B – 587,100 direct jobs							
Sector	Construction	Professional Services	Manufacturing	Utilities	Wholesale Trade	Other	**Total**
Solar	50,880	13,824	13,344	960	7,680	9,408	**96,096**
Wind	31,776	23,424	22,944	5,376	10,176	2,496	**96,182**
Energy Efficiency	167,700	62,700	41,700	0	23,400	7,800	**303,300**
TDS	32,208	8,693	5,673	27,999	15,921	1,007	**91,501**
Total	**282,564**	**108,641**	**83,661**	**34,335**	**57,177**	**20,711**	**587,079**

Table 5: Scenario B job creation table

Scenario C. Scenario C results in the creation of approximately 1,482,000 jobs per year, based on an allocation of $20B on solar, $30B on wind, $125B on EE and $75B on energy infrastructure. These investments would create another 1,023,000 indirect jobs.

Scenario C – 1,482,000 direct jobs							
Sector	Construction	Professional Services	Manufacturing	Utilities	Wholesal e Trade	Other	**Total**
Solar	67,840	18,432	17,792	1,280	10,240	12,544	**128,128**
Wind	47,664	35,136	34,416	8,064	15,264	3,744	**144,288**
Energy Efficiency	419,250	156,750	98,000	0	58,500	19,500	**752,000**
TDS	161,040	43,463	28,365	139,995	79,605	5,033	**457,501**
Total	**695,794**	**253,781**	**178,573**	**149,339**	**163,609**	**40,821**	**1,481,917**

Table 6: Scenario C job creation table

The base case scenario is only slightly more than the clean energy investments made by the Obama Administration during the first two years of the American Recovery and Reinvestment Act (ARRA) from 2009-10, roughly $93 billion. Studies completed by the National Council of Economic Advisors (Obama White House Archives, 2019) and by the BlueGreen Alliance, *Rebuilding Green*, (BGA, 2011) computed that just under 1 million person years of work were created by these investments, equivalent to approximately 500,000 jobs per year. These included direct, indirect, and induced jobs.

In Scenario B, which amounts to $1 trillion of climate investments over the first decade with a heavier emphasis on energy efficiency than Scenario A, slightly over 587,000 direct jobs are created along with 405,000 indirect jobs. The direct jobs are still less than a .4% increase in the U.S. labor force.

Finally, in Scenario C, which contemplates $2.5 trillion of climate investments over the first decade, at a rate of $250 billion of new spending every year, 1,482,000 new direct jobs are created. This amounts to an expansion of the U.S. workforce of 1%, less than the overall job growth rate in recent years. From 2015-2019, the U.S. economy added over 11 million new jobs in the private sector ranging from 2.7 million in 2015 to 1.8 million in 2019, considerably more than those required for an aggressive strategy to implement climate change solutions.

However, it is also important to examine how this spending affects specific industry sectors of the workforce to see if the system is stressed by such expansions. In the third quarter of 2019, the construction sector employed just under 7.7 million Americans. Under Scenario C, the construction workforce would expand by 695,800 employees or roughly 9%. While meaningful, that is significantly less than the contractions and expansions that occurred during and after the Great Recession when, according to the Current Employment Statistics (CES) survey produced by BLS, the residential and commercial construction workforce went from 6.698 million in March, 2007 to 5.403 million in March, 2009 (BLS, 2019). During the four-year period from March, 2015 to March, 2019, the U.S. construction workforce added 1,119,000 employees, and then added another 590,000 to its August, 2019 level of 7,586,000. (BLS-CES, 2019)

The utility sector is the other sector that would experience a significant influx of employees, almost 150,000. In March, 2019 (QCEW-BLS), the gas and electric utility sector employed 497,000, (BLS, 2019) so this is an increase of 30.2% and could require an expanded training system to prepare employees for the new transmission, distribution and storage build outs and systems.

Workforce Conclusions

While the investments required to decarbonize the U.S, economy will undoubtedly create jobs in large numbers, we conclude that they will remain a relatively small sector of the economy overall. Note that these impact estimates do not take into account the loss of some portion of the 1.6 million jobs in fossil energy technologies that would decline, depending on their rates of retirement or displacement. As a result, the net jobs impact of these investments would certainly be offset to a significant degree.

It is our assessment that the existing workforce training system, including building trades apprenticeship programs in the construction industry, utility intern and apprenticeship programs, the community college system, 4 year and advanced degree colleges, is more than sufficient to provide a skilled workforce to handle a significant ramp up in the deployment of renewable, energy efficiency, and smart grid technologies Indeed, compare the relatively small addition of 1.48 million employees entering the workforce under Scenario C with the 8 million women who entered a much smaller workforce during WWII to staff America's factories.

However, there are clearly larger systemic issues that must be addressed to assure that the transition to a lower carbon economy is not impeded by low workforce participation rates, lack of industry-standard curricula, close coordination between affected industry partners such as the construction and utility industries, access to pre-apprenticeship programs, utilization of best practices to promote diverse recruitment, and many other barriers to full employment.

3.3 CGE Review—The Net Jobs Impact

Our review of existing CGE climate and jobs impact literature had three primary goals: 1) to better understand the macro economic effects of climate policy design, 2) to identify policy levers that could be used to ameliorate negative job impacts, and 3) to understand the geographic impacts of decarbonization. Ten papers were included in the review. (List attached.)

Macro-Economic Effects

Virtually all GHG reduction scenarios rely on an escalating carbon price, introduced at some point during the transition. However, there are significant differences over timing, escalation curves, dividend design, and the use of a portion of revenues to fund offsetting programs such as low-income energy assistance, energy intensive industry transition assistance, land reclamation, or border adjustments.

Generally, carbon taxes slow economic and job growth in their first years of enactment. However, the models do not result in negative economic growth or net job loss in any one year. What is notable is that job growth and GDP are generally slower in the earlier years of carbon taxes than most base case scenarios. However, 10-20 years out, job growth recovers and exceeds most base cases. In some cases, GDP exceeds as well.

Other notable trends revealed in different modeling scenarios include the following:

- Regional differences can be significant. For instance, one study showed significant job loss over twenty years in the South Central States which included Texas and Louisiana. This was due to a significant projected decline in the oil, gas, and chemical industries. Another showed nominal job decline in the Pacific Coast States.
- Border adjustments were used in multiple studies to keep energy intensive industries competitive with businesses located in countries that did not have comparable carbon prices.
- Where dividend payments were used to reduce taxes on labor more job creation resulted. Studies indicated that this was the most effective way to create employment to replace jobs lost in fossil

fuel dependent employment. However, job increases were primarily seen in sectors such as health care and retail, accelerating current trends.

- Energy efficiency jobs did not figure meaningfully into the job calculation, in part, because most studies are constructed around job definitions from BLS NAICS codes which do not currently identify jobs in energy efficiency separately from other construction, manufacturing, utility, and professional services' jobs.
- Most studies presume continued trends toward automation in manufacturing and consequently see declines in spite of opportunities in new energy technologies.
- Finally, most studies see the motor vehicles' parts manufacturing sector declining as a result of growth in electric vehicles and the discontinuation of internal combustion engines (ICE). However, some studies have found increased EV assembly jobs in the U.S. and that charging infrastructure buildout results in a partial offset of the ICE job loss.

3.4 Policy Levers to Respond to Job Loss

Specific policy levers to respond to the modeled job loss are discussed in more detail in Section 6. The sectors that need specific attention include construction, manufacturing, and mining and extraction. Among the specific policies that could be adopted to respond to sluggish growth, job loss and the decline of fossil fuel use are targeted efficiency and infrastructure investments, carbon tariffs, supply chain management, manufacturing tax credits, retraining programs, and RD&D investments in new industries such as CCUS, hydrogen and next generation nuclear that could utilize both existing skillsets and portions of existing fossil fuel infrastructure.

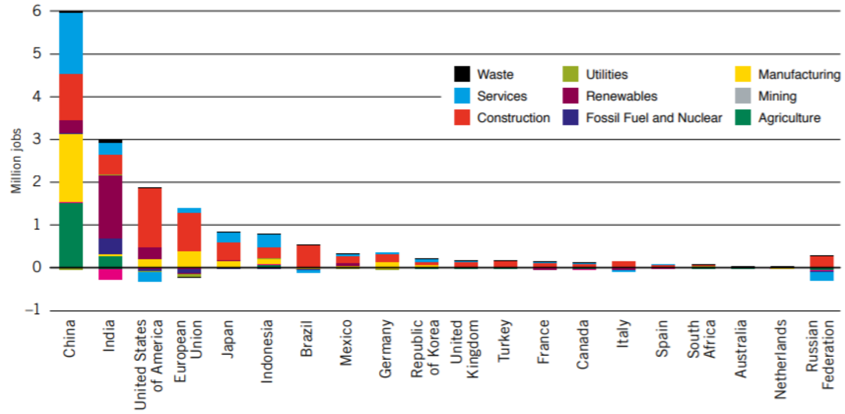
3.5 Geographic Impacts

The most important finding of these studies is that a very significant portion of the 1.6 million direct jobs that produce, transmit, distribute, and store fossil fuels and use them to generate electricity will be lost during the transition. In addition, these jobs along with many energy intensive industry jobs are highly concentrated in 15 states. As a result, the timing of climate policy implementation with the coordination of economic development response mechanisms is critical. In addition, the absence of significant geographic overlap between low carbon energy resources and fossil fuel resources means that a significant number of the current energy workforce may need to transition into different industries.

3.6 Climate Resiliency & Adaptation and Environmental Remediation

While not included as an input in the REMI model, it is important to acknowledge that climate resiliency and adaptation efforts will increase as the impacts from climate change affect particular regions like Louisiana, Florida and other states. As a result, there are employment gain opportunities. One report by the University of Toronto predicted that Europe will create 500,000 additional jobs by 2050 and potentially save 136,000 jobs that would be impacted by climate change if the EU Adaptation Strategy was carried out (International Labour Organization, August 2018). This reference scenario could further extend employment gains with more aggressive efforts, adding up to one million jobs directly and indirectly, and saving 330,000 jobs. These predictions are based on analyzing industries that rely either "directly or heavily on ecosystem services" such as agriculture, infrastructure, renewables, and paper (International

Labour Organization, August 2018). Distribution of employment effects from climate resiliency and adaptation will vary across countries as illustrated below.



Notes: This figure illustrates the employment outcomes that could be achieved by 2030 in a scenario of energy sustainability as opposed to the business-as-usual scenario. The energy sustainability scenario combines the IEA's 2°C scenario (IEA, 2015) with projected electric vehicle sales (UBS Research and UBS Evidence Lab, 2017). It further assumes that all energy efficiency savings are invested in construction to retrofit existing buildings. The scenarios are implemented in a multi-regional input–output model. See Appendix 2 in ILO (2018a) for methodological details.

Source: ILO calculations based on EXIOBASE (version 3).

Figure 11: Global employment impacts from energy sustainability (International Labour Organization, August 2018)

Another source of potential employment in negatively impacted regions is in environmental remediation and services. The multi-decadal clean-up of the nation's nuclear production sites, the largest such program in the world, provides the clearest example of how communities can be supported through federally funded environmental remediation programs. (U.S. Departmet of Energy, Office of Environmental Management). Over the last three decades, tens of thousands of Americans have been employed at 107 nuclear clean-up sites; 91 have been completed with additional decades of work required at the remaining sites.

Another remediation example is the Abandoned Mine Land Reclamation Program, funded since 1977 by operating coal mining companies. Excess funding in the remediation fund was recently used to guarantee continued solvency of pension and retiree health insurance benefits for over 100,000 retired coal miners, thus shoring up the economic stability of their communities. (UMWA, 2019)

Although there is no current job data on environmental remediation employment in the U.S., the Bureau of Labor Statistics' Green Goods and Services survey in 2010 found that just under 285,000 Americans were employed in the Waste Management and Remediation Services Industry. (BLS, 2010). This survey underscored the potential job benefits of a concerted effort to support communities impacted by an energy transition through environmental remediation.

4 Effects of Emerging Technology

In the previous section, we modeled several investment scenarios for climate solutions based on the mass deployment of existing technologies to quantify the scope of the workforce demands facing the U.S. economy. We readily acknowledge that such an approach has several shortcomings, principally that it cannot account for the introduction of new technologies, the declining cost curves for individual technologies that might sway the deployment mix, or other variables that might raise or lower demands for specific skill sets In this section we will examine how emerging technologies might affect the skills' demands of the energy workforce. We undertake this exercise to demonstrate two specific points—first, that the needed skill sets fall well within the scope of existing industries and their training systems and, second, that these new technologies represent significant economic and job creation opportunities for American businesses and workers in the race to develop the most efficient means to reduce greenhouse gas emissions.

Specifically, we focus on the following three technologies--1) Carbon capture and sequestration (CCS), 2) Small modular reactors (SMRs) and 3) Hydrogen fuels--to identify the job skills required for large scale deployment and to determine if our current workforce is capable of responding to these demands.

We begin with a brief review of the nuclear power industry in the US to highlight some key workforce development milestones and challenges faced during the first generation scale up of nuclear reactors in the 1950's and 60's to see if we can identify any similarities and lessons that can be applied to modern emerging technologies.

4.1 Upscaling of Nuclear Reactors

Based on "The Future of Nuclear Power in the United States" by the Federation of American Scientists (FAS) and Washington and Lee University (John F. Ahearne et al., 2012), we identified four key workforce challenges to the first generation scale up of nuclear. These included the following:

1) Education & Training

As part of the scale up of nuclear technology, there was an increased demand for the broad range of skills that made up the nuclear industry workforce. These included not only the requirements to design and operate nuclear equipment, but also the expertise and construction skills to build nuclear plants. For example, there were significant delays in the building of nuclear plants as a result of the lack of the higher degree of sophistication required by craftsmen, architects, engineers and contractors in designing and building new types of power plants. In an effort to meet this demand, the government, educational institutions and nuclear-related companies developed a three-prong approach to increase education and training opportunities by integrating their efforts in each of these spheres.

Government. To manage the nation's overall atomic energy program, the Atomic Energy Act of 1946 established the five-member U.S. Atomic Energy Commission (AEC). One important objective of the AEC was to oversee and plan for additional education and training. There was also increased financial investment from the U.S government at both the federal and state level, to build training institutions and facilities to meet research and regulatory responsibilities.

For example, we saw the development of radiation measurement laboratories, both teaching and research, established on university campuses to help educate scientists, engineers and technicians for the nuclear workforce. Other institutions and courses that were set up by the AEC (to increase more training opportunities) included:

1. The AEC lab relations branch - aimed at expanding cooperation education programs (including use of lab facilities),
2. The University Relations Branch - to administer nuclear assistance programs at universities, and
3. Special courses such as Radioisotope Techniques, Medical Qualifications, and Mobile Isotopes Labs. These were on top of specialized fellowships and traineeships in nuclear engineering provided by AEC.

Educational Institutions. Increasing tertiary education programs, which include any education beyond high school such as diploma, undergraduate and graduate education, also played a big role in improving the supply of training. Particularly in universities, which began adding nuclear engineering technology undergraduate and graduate programs. At the high school and college level, AEC increased its sponsorship of the number of projects to provide guidance and instruction aids in nuclear sciences. This included providing career guidance brochures as well as experimental or demonstration materials and even teaching materials (e.g. "Stimulation of Nuclear Education at pre-college Level.").

Private Sector Companies. Internally, companies were also working to improve the skills of their workers. Utility companies began adding internal nuclear training programs to meet their workforce needs. In addition, as an increasing number of private firms began engaging in civilian applications of nuclear energy, their employees became eligible for training through work experience in plants and in the laboratories of the AEC.

This coordinated, multi-tiered approach from the government, educational institutions, and private sector nuclear companies provided an effective model for how widespread adoption of new energy technologies can be replicated for training the workforce in other new energy skills today.

2) Health & Safety

A second important lesson from the era of nuclear power scale-up concerned health and safety. There are natural health risks for workers associated with the operation and development of nuclear technology. In the wake of the Three Mile Island disaster, the Institute for Nuclear Power Operations (INPO) was established in December 1979 to "promote the highest levels of safety and reliability - to promote excellence - in the operation of commercial nuclear power plants". The INPO developed performance objectives, criteria and guidelines for the nuclear power industry and evaluated every power plant against these objectives. They further participated heavily in the training and accreditation of training programs at the nuclear power plant level to ensure that its safety training, in particular, met the relevant safety objectives.

3) Nuclear Infrastructure & Supply Chain

Most nuclear power plants in the U.S. were built between 1970 and 1990 (U.S. Energy Information Administration, 2017), To meet the infrastructure demands of the nuclear industry during the scale-up, power plant vendors and their suppliers had to overcome initial challenges and develop supply chains for large and small components and parts while the utility industry built and operated these large industrial facilities. These supply chains faced multiple difficulties, including delayed delivery of reactor vessels, which slowed the overall construction schedule. There were also delays in nuclear reactors resulting from various engineering problems, including cracks in some components (M.V. Ramana, 2015).

Eventually, these supply chain problems were resolved by expanding the capacity of current suppliers (such as Babcock & Wilcox) as well as recruiting new vendors into the market, including imports (from Japan and Europe). Managing these expansions and resolving technical problems, in turn, required additional workforce training. These solutions are again relevant when we look to scaling up new technologies, coupled with modern techniques to improve supply chain efficiencies. Indeed, managing global supply chains is already an issue in the wind and solar industries. For example, in 2005, there was a shortage of polysilicon, a key component for solar PVs (BlueGreen Alliance & Stone & Associates, 2011). Competing successfully for the jobs created by new energy technology supply chains is one of the important opportunity lessons drawn from the nuclear industry example.

4) Certification and Licenses

A fourth factor that accelerated the growth of the nuclear scale-up was the efficient use of licensing and certification. The AEC was given wide discretion in establishing promotional and regulatory policies. This was crucial in ensuring that public health and safety were protected without imposing overly burdensome requirements that would have impeded industrial growth. At the time a critical priority of the AEC was to create an industry that could compete with the other two global leaders in nuclear technology—the UK and the USSR (Walker et al., 2010).

The AEC's regulatory staff, created soon after the passage of the Atomic Energy Act of 1954, confronted the task of writing regulations and devising licensing procedures rigorous enough to ensure safety but flexible enough to allow for new findings and rapid changes in atomic technology. If we can have similarly seamless policies in place today, the US can become a global leader in other new energy technologies such as those examined below. Developing the full range of workforce skills necessary for research, development, design, deployment, construction, and operation is a critical component of reaping the economic benefits of climate solutions.

4.2 Emerging technology and workforce skill requirements

We now examine three emerging technologies within the energy sector and examine the skills' requirements for their scale-up during the coming decades. These technologies were selected because of the growing acceptance that meeting climate targets may be impossible without them.

According to the International Energy Agency, 80% of the global electricity supply was generated from fossil fuels in 2018. Numerous studies by the IPCC have all concluded that reaching a 2 degree Celsius threshold by 2050 would be more expensive and maybe impossible without CCS (U.S. Department of Energy, 2016). Currently, 20% of US electricity is produced by nuclear plants which also produce the majority of carbon-free electricity. Thus, a next generation nuclear technology could be enormously important for reducing GHG's. Finally, hydrogen is regarded more and more frequently as a necessary fuel to add in long haul freight transportation and the production of process heat for the reduction of industrial emissions.

1) Carbon Capture Storage (CCS)

The CCS process consists of the separation of carbon dioxide (CO_2) from industrial and generation sources such as power plants, its transport to a storage location, and long-term isolation from the atmosphere. This allows for a reduction of CO_2 that is essential to meet several of the energy policy goals proposed by the scientific community. As CCS deployment accelerates, similar to the first nuclear scale-up, a workforce will need to be equipped with the necessary skills. What are those skill sets and are we ready to meet these challenges?

In the Carbon Capture and Storage Skills Study, Doosan Babcock, in conjunction with the Industrial & Power Association (IPA), assessed the economic benefits, employment possibilities and skills' needs arising from a major global program of CCS in the United Kingdom (Alan Young et al., 2010).

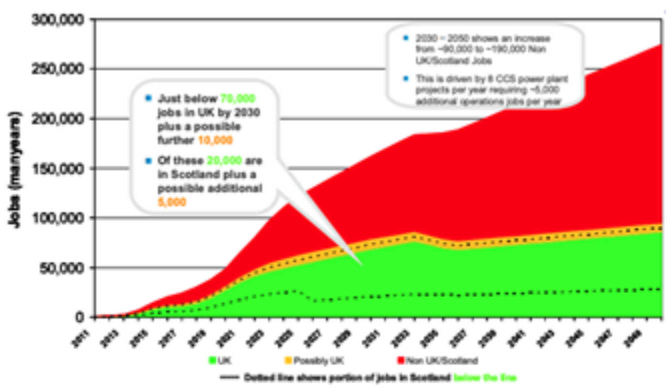


Figure 12: Total CCS jobs in UK (Alan Young et al., 2010)

From figure 12 above, Doosan Babcock found that the United Kingdom could expect a significant growth in CCS jobs in the future. This correlates with what we expect within the U.S as well as other industrialized countries with significant industrial emissions and fossil fuel electrical generation. As such, we can use this study as a proxy for the kinds of jobs and skills required for the deployment of CCS. Table 7 shows some of the skills' requirements found in the study and anticipated additional training requirements. It splits the workforce into its respective job disciplines and identifies the number of jobs required in the upcoming years to meet their CCS rollout program. These numbers were an estimate done in 2010 for the subsequent 10 years, and while the exact numbers do not necessarily apply, we note the general trend of workforce skill requirements as we prepare our workforce for a similar transition.

Discipline	Number of Jobs pa required each year to meet CCS Programme (additionally)										Additional Training Requirements
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Mechanical Engineering	188	448	477	938	1,503	2,155	2,890	3,700	4,772	6,388	Degree plus post grad training
Civil Engineering	32	72	67	355	878	923	739	1,075	1,640	2,239	Degree
Electrical Engineering	48	98	72	157	213	284	356	485	581	748	Degree plus post grad training
Process Engineering	62	133	113	199	267	347	442	600	717	896	Degree plus post grad training
Offshore Engineering	27	68	68	119	253	447	562	607	792	1,074	Degree plus post grad training
Geology	25	57	50	88	193	350	452	491	633	859	Degree plus post grad training
Crafts	0	0	37	1,624	4,744	5,767	5,492	6,633	10,040	14,487	Modern apprenticeships
TOTALS	382	876	884	3,480	8,051	10,273	10,933	13,591	19,175	26,691	

Table 7: Skill requirements for CCS

Although a similar study, modeling employment effects, has not yet been conducted within the U.S., universities and government divisions are already developing some of the skills needed to deploy CCS. For example, the Columbia Climate Center has initiated a new Masters' program in Carbon Management (Ivy Morgan, 2010).

Since 2011, the Office of Fossil Energy (FE), a division within the U.S. Department of Energy, has implemented, through the National Energy Technology Laboratory, seven highly specialized training centers, funded under the American Recovery and Reinvestment Act of 2009 (ARRA), to develop and implement CCS training (U.S. Department of Energy, 2011). Similar to the nuclear scale up, these training programs are a necessary precursor as the demand for CCS increases.

In reviewing the overall skills' demands, modelled by the Doosan Babcock study, it is important to note that these are largely skills that the existing workforce training system can readily address. The majority of jobs are "craft" positions and can be filled through utilizing "modern apprenticeships". Even the more unique positions, relating to geologic storage and process engineering are based upon standard degree training for geologists and engineers. As in most cases of new energy technologies, a few unique skills may be added, but, as in nuclear, these are more additive than transformative.

Another more recent study on the jobs' impact of CCS, "Industrial Opportunities and Employment Prospects in Large-scale CO_2 Management in Norway" provides additional insight into the economic benefits of this technology (Størset, 2018). Full implementation of a carbon management program in Norway centered on CCS development and offshore storage was estimated to improve the competitiveness of 160,000-200,000 jobs and create 70,000 jobs by 2050 within the process industry, natural gas operations and shipping in Norway alone. These numbers were affected by the ambition of the ultimate target of temperature limitation of 2 degrees or 1.5 degrees centigrade. Domestically, a similar employment trend is expected as well. Based on a white paper on Carbon Capture, Utilization and Storage released by the DOE in 2016 (U.S. Department of Energy, 2016), there is a strong emphasis on the importance of CCS in meeting existing climate goals. As deployment of CCS expands, the paper predicts CCS will maintain the relevance of some level of fossil fuel related employment which accounted for more than 1.65 million jobs in 2019 including production, electrical generation, and transmission, distribution and storage. (USEER, 2020)

2) Small Modular Reactors (SMR)

There is strong interest in SMR technology today because of its potential ability to reduce the total capital costs of nuclear power plants and to provide zero emissions' power to small grid systems (OECD & Nuclear Energy Agency, 2016) Relatively little work has been done on the workforce requirements and challenges to scaling up the production of SMR's. In the UK, Energy Digital reports on a deficit of skilled employees for such an effort (Robert Plana, 2004). SMR deployment could create over 40,000 skilled jobs in the UK over the next 20 years, but would require a skills' injection and a specific strategy to carry this forward.

Within the U.S, there is no specific research on the overall workforce demands for SMR deployment. However, the APS Panel on Public Affairs' Committee on Energy and Environment published a report on the "Readiness of the U.S Nuclear Workforce for 21st Century Challenges" that discusses the workforce requirements of the nuclear industry generally, including SMR development (APS Physics, 2008). This report, in summary, mentions several workforce shortages for nuclear scientists, engineers and technicians in sectors of nuclear design, construction and maintenance (typically employed by private firms). There are also shortages in the safety and emergency response sectors (typically employed within the government). This can be attributed largely to a diminishing pool of university-based training programs within the nuclear sector. Ultimately, to meet growing workforce demands within the nuclear industry, this study recommends that both federal and state governments continue to train and maintain this workforce with private industry and academia also playing their respective roles.

Currently, there are several SMR projects that are being funded in the US, such as NuScale Power that was formed in 2007 to complete and commercialize SMR's. A total of at least $850 million has been invested in these projects, which includes $226M funded by the DOE as part of the DOE Funding Opportunity for matching funds (Lenka Kollar, 2019).

NuScale estimates that it will deploy 73 SMR plants by 2030, creating over 110,000 jobs for plant operations and construction of these facilities, in addition to a minimum of 13,500 jobs related to the domestic supply chain for manufacturing components. Table 8 below shows examples of expected skills and education requirements for the operation of one NuScale plant. Further expertise will also be required in manufacturing jobs for piping, instrumentation and control equipment, civil material architectural, and pressure vessel forgings among others (Refer to NuScale Human Capital & Workforce Development in the appendix). Based on NuScale's estimates, SMR plants can be expected to have capital cost savings of approximately $100 million if they are located on existing power plant sites. With greater development of SMR's, more examples and cost estimates will be made available and provide greater understanding of the potential workforce requirements within the sector.

Number of Job Positions	Required Education Level	Job Position Examples
95	Bachelor of Science	Department Managers Technical Supervisors Engineers
140	Associates Degree, Vocational Education	Plant Operators Nuclear Maintenance Craftsmen Radiation Protection Technicians Training Staff
60	High School or GED	Non-nuclear Craftsmen Security Officers Site Support
5	Entry Level	Administration Support

Table 8: Job position and education requirements for one NuScale Plant

3) Hydrogen Fuel

The scope of hydrogen use in the current economy is not widely known and already has significant growth potential. Hydrogen production and distribution is forecasted to increase $33 billion over the next 4 years, from a $122 billion industry in 2018, a significant growth rate of over 30% in this period (Bezdek, 2019). Despite this, the acceptance of hydrogen as a source of transportation and industrial fuels is still limited, due to its high cost and difficulty of production (Institute of Physics, 2010). However, with recent advancements in technology, there has been a significant decrease in its cost of production (from a high of $1000/KW to low of $61/KW) (Institute of Physics, 2010). It is now much more feasible for hydrogen fuel to be used as a clean transportation and industrial fuel. Coupled with tighter regulations for desulfurization of petroleum products, the size of the hydrogen economy is expected to grow rapidly over the next few years. (Bezdek, 2019),

In his study, “The hydrogen economy and jobs of the future” (Bezdek, 2019), Roger Bezdek estimates that anywhere from 700,000 to 1 million jobs could be created in the U.S. by the utilization of hydrogen as a fuel alternative to petroleum for transportation and to generate process heat in industrial applications. Using a methodology developed in the ASEA/MISI study and refined in various subsequent analyses (American Solar Energy Association and Management Information Services, Inc, 2008; Management Information Services Inc., 2009), Table 1 of this article documents the results of emerging jobs, salaries, minimum education, and training requirements in the hydrogen and fuel cell industries (Bezdek, 2019). These labor and employment forecasts use an existing set of job descriptions provided by the U.S Labor Department (U.S. Department of Energy, 2019). Within the projected education requirements, we see a good mixture of existing skills’ training programs ranging from apprenticeships and on-the-job training to Bachelor’s and Master’s Degrees. Thus, expansion of the hydrogen industry seems eminently achievable from a workforce perspective.

A current example of the rapid development of the hydrogen industry can be seen in Japan, where there is a strong emphasis on hydrogen fuel as the main driver towards clean transportation (Jack Chaben, 2019). Japan’s current renewable energy strategy focuses on promoting the adoption of hydrogen fuel cell (FC) vehicles. This is accomplished by pricing hydrogen fuel more competitively against gasoline and liquefied natural gas in order to reach the target of 40,000 FC vehicles on the road by 2020. To further encourage a seamless transition towards FC vehicles, the Japanese government is implementing new regulatory reforms to increase the number of hydrogen fueling stations nationwide. This has obvious impacts to the workforce within their auto manufacturing industry (Japan Automobile Manufacturers Association, 2018). Motor vehicles employs about 5.39 million people in Japan, 8.3% of the country's total employment.

5 Technological change and its effect on the energy workforce

In addition to the forecasted growth and dislocation modeled in the decarbonization scenarios of Section 3, the energy sector will also be affected by technological change. With the integration of automation and artificial intelligence (AI), the major energy sectors, including utilities, construction firms, mining and extraction companies, professional services' contractors, and renewable energy developers will all change how work is conducted in the future. However, on balance, these technologies appear to offer more employment opportunities and fewer job losses than in other sectors of the workforce.

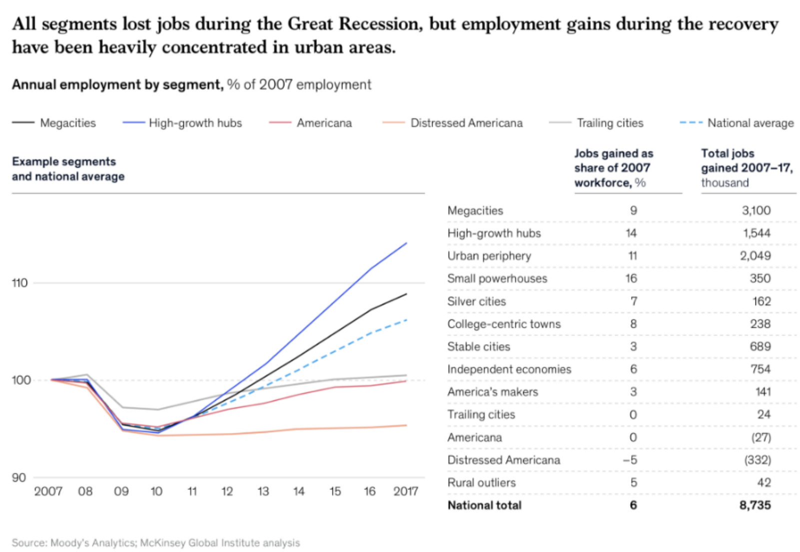
Predictions on the extent of change caused by automation and AI vary. One study by Genesys says that by 2022, 60% of U.S. companies expect to be using AI or advanced automation to support efficiency in operations, staffing, budgeting or performance (Genesys, 2019). Additionally, Genesys reported that "currently 24% of companies are using AI or advanced automation with an additional 36% planning to use it within three years — and half of those (18%) within the next year alone." Another study from the Brookings Metropolitan Policy Program, estimated that 25 percent of total employment in the US faced "high exposure" and 36 percent have "medium exposure" to automation by 2030 (Muro, Maxim, & Whiton, 2019). While there is a wide range of studies that predict everything from massive shifts to minor changes in the workforce, for our purposes it is more important to highlight the changes that are occurring in the energy sector now and how companies expect it to change in the next 5-10 years. This section will discuss how automation and AI are expected to affect the energy workforce and highlight the opportunities and challenges that confront employees.

Automation, according to the MIT Work of the Future Taskforce, "at its most basic level serves to substitute for workers in performing a subset of work tasks, often those that involve physically demanding, repetitive and rote activities" (Autor, Mindell, & Reynolds, 2019). Examples go as far back as the 19th century, including such things as electricity, the internal combustion engine, integration of telecommunications and the internet. As technology has made significant advancements, it has also improved the quality of work life for a wide range of occupations while also increasing productivity. However, it has also simultaneously caused concerns for job security.

While there are a number of studies that point to "end of the world" scenarios for technology replacing valuable American skills and jobs, there is a general consensus that displacement will be uneven and vary considerably based on the sector and tasks. In addition, there will be considerable job growth in other sectors. However, it is important to note that across all studies there is agreement that certain distinct populations will be more affected than others—a critical concern for policymakers to address.

A recent McKinsey report on the "Future of Work in America" found that less than 5 percent of jobs can be totally automated, but that 60 percent of jobs and 30 percent of activities can be partially automated (McKinsey, 2019). Additionally, the report acknowledges that workers with a high school degree or less, Hispanic and African American populations, men and individuals over 50 years old have the highest risk of being displaced. One of the more concerning statistics is that an estimated 11.5 million workers over 50 could lose their jobs to automation. Men will be most impacted by A.I. and automation since they are the primary demographic working in manufacturing, driving and other manual, repetitive occupations that are easier to automate. Women, who make up a significant portion of the healthcare and caretaker work force, will be less affected as these occupations will be increasingly in demand.

The McKinsey study also points to how geography will be a large indicator on how Americans will be affected by technological change. Since the Great Recession, megacities and high growth hubs generated almost two thirds of job growth, but the 54 “trailing cities” and 2,000 rural counties in the United States have not had any growth since 2007. This can be attributed to the fact that these areas contain one quarter of the older workforce, low educational attainment rates and high unemployment. Jobs in these locations are particularly prone to displacement by automation while not attracting the investment for growth industries. By comparison, cities like New York, Boston, and the District of Columbia will not be as impacted by the negative aspects of automation and AI since their growth sectors require fewer repetitive tasks and more leadership and critical thinking skills. Nonetheless, even in these locations, many jobs in office support, food service, production and retail sales are all at risk from automation and AI.



	Jobs gained as share of 2007 workforce, %	Total jobs gained 2007–17, thousand
Megacities	9	3,100
High-growth hubs	14	1,544
Urban periphery	11	2,049
Small powerhouses	16	350
Silver cities	7	162
College-centric towns	8	238
Stable cities	3	689
Independent economies	6	754
America's makers	3	141
Trailing cities	0	24
Americana	0	(27)
Distressed Americana	–5	(332)
Rural outliers	5	42
National total	**6**	**8,735**

Figure 13: Post Great Recession employment trends by geography (McKinsey, 2019)

Another study by the World Economic Forum estimated that machine learning and algorithms will make up 42 percent of total task hours by 2022 which is a jump from the recorded 29 percent of tasks in 2018 (World Economic Forum, 2018). However, Deloitte and the Manufacturing Institute highlight that manufacturers are also turning towards automation and artificial intelligence in order to fill vacancies caused by the lack of qualifications and skills in the current workforce. Deloitte points out that familiarity with computer and digital technologies as well as programming skills will be critical alongside leadership and problem-solving capabilities in the next generation manufacturing workforce (Deloitte, 2018).

Technology will also be central in supporting workers in three areas: productivity, decision making and learning. WeAR, augmented reality wearable devices, connect engineers to other internet of things devices as well as allow users to give commands and reference informational displays. SkillsPro will allow designers and engineers to update and learn new skills that sync with upcoming projects and current performance. Technology strategies are already being put in place as shown in an apprenticeship program in South Carolina where schools work with nearby companies to train students from an early age. Through the program, technology training is integrated in high school curriculum, producing over 28,000 apprentices since 2007, serving as an inspirational model for future initiatives.

As David Autor points out, labor substitution is only part of the story. Technological advancement complements workers and can provide a platform where creativity and innovation move quickly from idea conception to material reality, as seen in 3D printing and rapid prototyping. Ideas that were previously difficult to build by hand, are easily testable and can come to life in a span of hours. Looking forward, augmented and virtual reality, artificial intelligence, internet of things and other technologies will shift business models throughout the economy and in the energy sector. But these shifts have the potential to create winners and losers. Winners typically are firms and customers who experience profits and low prices, while displaced workers and their communities become the losers.

Similar to the McKinsey report, the MIT Work of the Future Taskforce expects that there will be a worker under-supply problem due to an increased number of retirees, stricter immigration policies and lower labor force participation rates. It is estimated that workers over the age of 55 will increase from 17 to 25 percent between 2006 and 2026 while those who are between 25 and 54 will decrease by 3 percent (Autor, Mindell, & Reynolds, 2019).

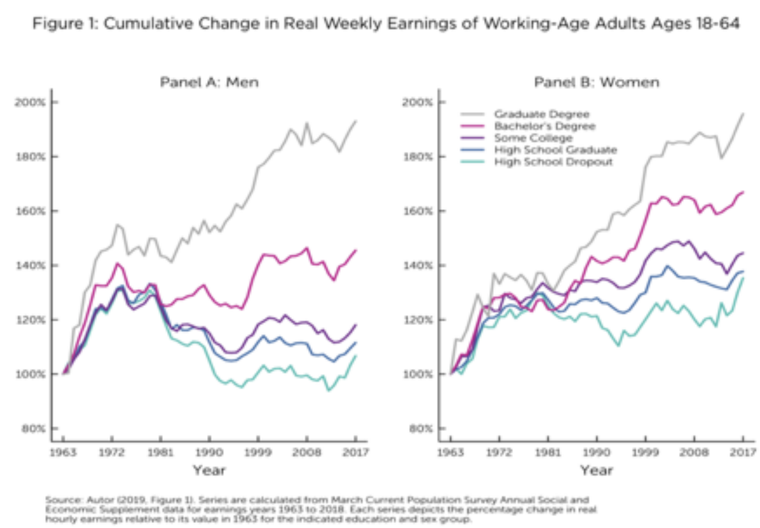


Figure 14: Real weekly earnings of working age adults by educational attainment (Autor, Mindell, & Reynolds, 2019).

The MIT study also highlights the divergence between wages and education in the US workforce, as illustrated above in Figure 14, where individuals who went to college or received post-college degrees experienced earnings that follow high productivity returns. In 2017, those who did not have a college degree were 10 to 20 percent below 1980 wages, while men in that category fell below 1963 levels. Overall, Autor believes that there is no shortage of workers from high-education or low-education backgrounds, but that strong vocational training does provide opportunities for those who have limited education. Autor emphasizes that digitization is different from previous experience with industry automation and that there is a need for quality jobs, and not quantity to improve opportunities for marginalized populations.

Across the above-mentioned studies, there is a consensus that less skilled manufacturing and service industries will be particularly vulnerable to technological change. However, energy and energy efficiency are less susceptible to the negative impacts from automation and artificial intelligence. Instead, as we will further discuss below, data scientists and specialists in cybersecurity are in high demand across the country. And there is great interest from utilities and other energy sectors to use technology to help recruit younger students as they enter the workforce. Table 9 below, outlines the opportunities and challenges that technological advancement will play within the energy sector.

	Opportunities	**Challenges**
Utilities	**Artificial Intelligence** Ability to sort through large data reserves and identify patterns/ potential problems in order to make operations more efficient. Improve employee recruitment processes, reducing time Human Resources spends on searching for qualified applicants. Increase abilities to interpret computer or device issues so that IT departments can more efficiently use their time.	**Artificial Intelligence** Lack of cyber and data scientists in the field which will become even more critical to address as more Internet of Things (IoT) devices and electric vehicles (EV) are plugged in making the grid more vulnerable to hacking and attacks. Aside from data management from IoT and EV, data ownership and privacy concerns will need to be addressed.
	Cybersecurity Maintaining system security is a problem that is overarching in utilities and has fostered partnerships and open information sharing.	**Cybersecurity** Increased risk of hacks will require an increased number of specialized workers in the field.
Mining & Extraction and TDS	**Unmanned Aerial Vehicles** Used to monitor and repair pipes and hard to reach infrastructure. Reduces potential for workers to be injured when monitoring equipment in the field.	**Entering Workforce Characteristics** Hiring younger, more diverse populations will be challenging as there is a growing resistance against fossil fuels. Social responsibility becomes more important.
	Sensor driven & Data management Equipment sensors collect and monitor data on components. Large data sets will give	**Sensor driven & Data management** Reduces number of field workers and increases demand for data scientists.

	insight into how to improve operational efficiency and identify potential threats before they become critical.	Companies will need to overcome perceptions held by younger generations entering the workforce.
Construction Firms	**Augmented and Virtual Reality** AR/VR will provide opportunities for training remotely where there is limited teaching staff. Provide new employees with assisted on the job training. Streamline work processes that required manual data entry and referencing blueprints and other important documents.	**Skill Training** Integration of technology will displace some skills and entail new ones. Time efficient and effective training curriculum will be required to bring workers up to speed.
Renewable Energy Developers	**Big data and data management** With the growing deployment of renewable electric generation with variable output, intermittent resources' management and prediction are critical to decarbonizing the US economy. New data monitoring and analytic tools will give grid operators increased capability of on and offloading the grid as well as provide datasets that can be used to better predict future patterns.	**Cybersecurity** Distributed residential solar and renewable electric power generation technology will increase number of potential entry points for cyber attacks. To mitigate potential threats, more specialized data and cybersecurity workers are needed.
Energy Efficiency	**Internet of Things & Data Management** Energy savings devices like Google Nest that allow homeowners to control temperatures indoors to fit preferences and reduce energy usage when users are not at home.	**Cybersecurity** Increased demand and use of IoT devices in residential and commercial applications will amplify risk for cyber attacks. To mitigate potential threats, more specialized data and cybersecurity workers are needed to address security concerns.

Table 9: Technological change opportunities and challenges

5.1 Utilities

Utilities will experience the most change from technological advancement through the integration of artificial intelligence and the growing presence of the internet of things (IoT) as the US moves towards smart cities. Artificial intelligence will allow utilities to access large data reserves and quickly identify operational patterns, inefficiencies and potential threats that they previously were not able to do. Additionally, one utility described using AI to improve the hiring process and find more workers who have the right job qualifications. While this will change utilities' internal organizational structure, it will provide employees in human resources and informational technology departments with opportunities to make operations more efficient. However, it will require companies to solve the shortage of specialized data experts.

Engineers	Lineworkers	T&D Technicians	Generation Technicians	Plant/Field Operators	Contractors
		Infrastructure Modernization			
High Impact	Medium Impact	High Impact	Low Impact	Low Impact	Medium Impact
		Cleaner Energy Mix			
High	Low	Low	High	High	High
		New Build			
High	Low	Low	High	High	High
		Physical/Cyber Security			
High	Medium	Medium	Low	Low	High
		Aging Workforce Impact			
Medium	Medium	Medium	High	High	High

Source: Company documents.

Table 10: Workforce Impacts of Utilities Industry Trends (Kerr, Norris, & Raman, 2018).

The Center for Energy Workforce Development (CEWD), a nonprofit consortium of electric, natural gas and nuclear utilities represents 85% of the nation's utility companies. In the table above, their recent study found that new technologies will have a variety of impacts on the principal occupations in their workforce. In particular, this study found that their partnered utilities had a need for employees with experience in cybersecurity and big data management to protect the grid and organize and interpret large data sets. This is especially important as more IoT devices and electric vehicles are plugged in, forcing the current electrical grid system to manage the growing number of devices and entry points for attacks.

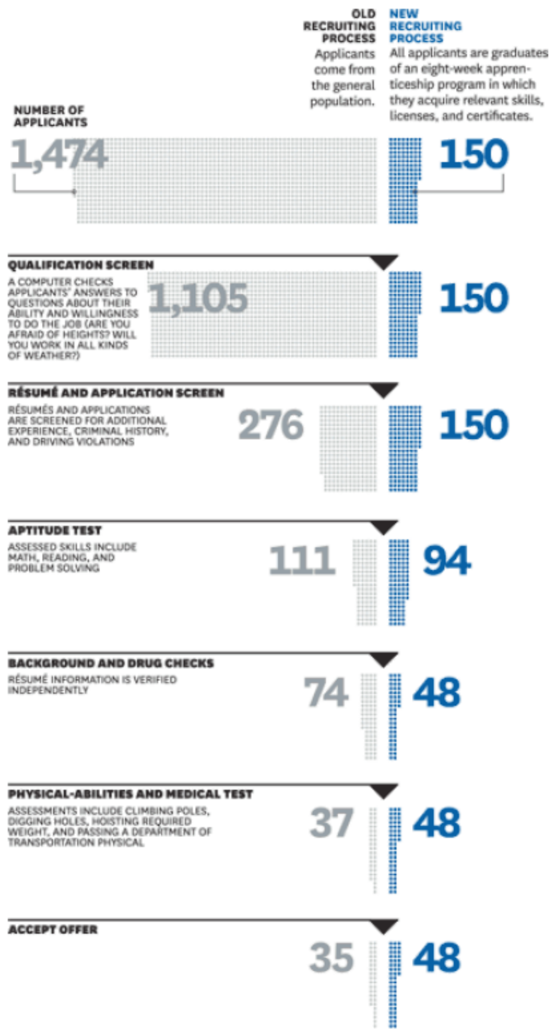


Figure 15: Employee recruitment process for Wisconsin Technical (Kerr, Norris, & Raman, 2018).

Efforts to address these problems go beyond general worker training programs, and also affect utility contractors and workforce needs. CEWD estimated that contractors perform 50 percent of utilities' core work, making these companies critical to manage the overall employee skills' gap (Kerr, Norris, & Raman, 2018). The last four editions of the USEER have documented the growing difficulty faced throughout the energy sector, and particularly its construction sector, in hiring qualified employees. A study conducted by Paul Osterman, an MIT Sloan Professor, highlighted Georgia Power's recruitment of electrical line workers from a training program that raised retention rates from 75 to 93 percent, while reducing initial training costs by over 30 percent. Additionally, individuals who went through the program saw wage increases compared to old recruitment methods. This is further backed by the Wisconsin Regional Training Partnership where industry, schools and unions work together to create technical training programs that have resulted in high participant wages.

5.2 Mining and Extraction and TDS Companies

Technology is also playing a role in mining and extraction and transmission, distribution and storage. As shown in Table 11 below, mining and extraction companies are already integrating advanced data monitoring and analytics throughout the planning, exploration, processing and logistics stages. Data management is growing capabilities for extraction companies for monitoring and predictive maintenance as well as removing workers from dangerous conditions. By replacing workers with sensing technology, technicians and mechanical support can still carry out duties when necessary and work towards preventing devices from failures that could put others at risk. Future technology that is close to commercial integration includes quantum computing to optimize supply chains and advanced sensing technology.

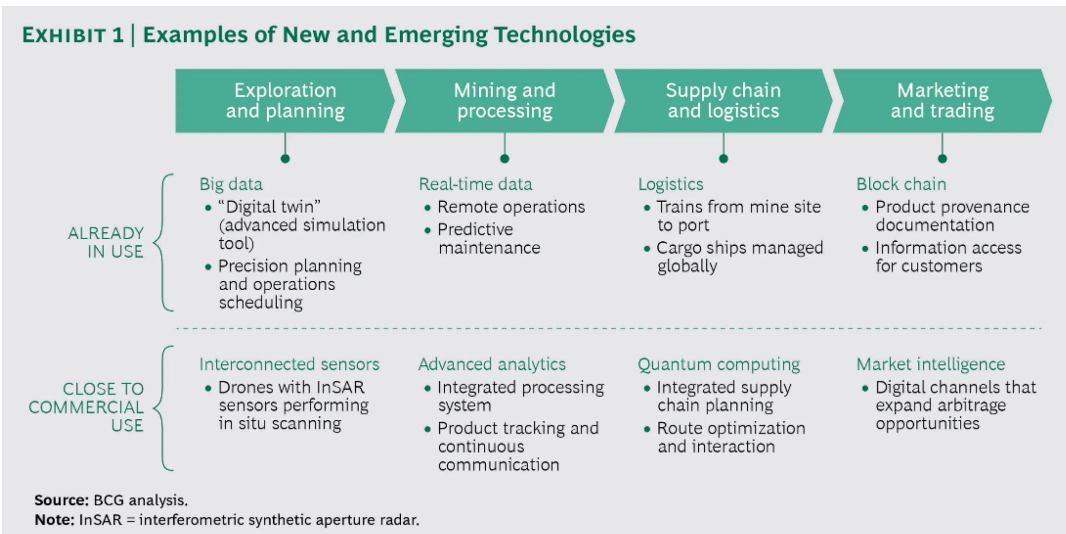


Table 11: New and emerging technologies in mining and extraction by process (Tauber, Bender, & Steinberg, 2018)

For TDS companies like TransCanada Energy (TC Energy) that operate both in the United States and Canada, unmanned aerial vehicles (UAVs) and drones make up the growing technology being deployed in order to monitor and maintain infrastructure. While UAVs reduce the amount of dangerous and remote work that technicians do, it requires workers to become familiar and comfortable in using these devices to carry out their jobs. Aside from UAVs, infrastructure companies use more and more sensors to gather operational data, increasing the use of big data for predictive maintenance which will require companies to find more workers with these skills. However, there is not major concern over whether jobs will be automated or threatened by advanced technology. In general, oil and gas companies are very capital intensive and not as labor intensive. For instance, TC Energy operates $99 billion of energy infrastructure assets with only 7,500 employees (excluding construction workers). Technologies like AI and UAVs appear to increase the company's efficiency while not threatening the workforce.

5.3 Construction Firms

Within the construction industry, the 1600 joint apprenticeship programs operated by North America's Building Trades Unions (NABTU) and their construction firms have played a key role in providing new technology training in the energy sector. Recently, there has been an increase in the blended classroom model that both incorporates in-person instruction and on-line computer course modules to supplement learning. This has sped up training and made it possible to have students do initial training preparation outside of the classroom which is especially beneficial to those that live in more remote areas.

Another growing interest within the industry is to integrate augmented (AR) and virtual reality (VR) during the job training process (Infosys, 2018). AR and VR are also used to support construction workers while on the job. Trimble Connect for Halolens is an example of a mixed reality headset that can serve as a two-way communication tool for more experienced workers to train new hires in the field as well as visualize and reference structural data. AR and VR more easily train workers in the field which is especially useful in rural construction sites. IBEW, SMART and UA are some of the unions with apprenticeship training programs that are exploring these learning technologies and planning to integrate them into their programs. They hope that as the industry increases the adoption of these technologies that it will also help to attract and recruit students to their apprenticeship programs.

Figure 16: Depiction of Microsoft Halolens used in the construction sector (Trimble, n.d.)

Construction firms and unions are aware of automation, artificial intelligence and other technological shifts but unsure how it will ultimately affect their workforce. Research and discussion on these issues are increasing within firms and labor-management organizations like the National Energy Management Institute which is working to more accurately project the rate of automation and identify how it will affect workers in the next 5 years. While there is still concern about negative impacts on workers, as a representative from the IBEW best put it, "We have no choice but to change with technology."

5.4 *Renewable Energy Developers*

Energy management will be vital as the US decarbonizes its electricity generation through increased deployment of distributed energy sources and electrical vehicles. A study on artificial intelligence and big data by IRENA estimates that 50 billion devices will be added to the electric system by 2025 compared to 2018 when there were 25 billion devices (IRENA, 2019). These changes in grid architecture and generation are also changing the skills' needs of the workforce in this area. Examples of current efforts include EWeLiNE and Gridcast that use artificial intelligence to predict wind and solar energy resources and potential generation rates. These models also account for electricity prices and market trends to help operators achieve greater efficiency. Additionally, startups like BeeBryte, are utilizing artificial intelligence in commercial thermal energy usage and have shown that by heating and cooling buildings based on customer preferences, they can save 40 percent on utility bills.

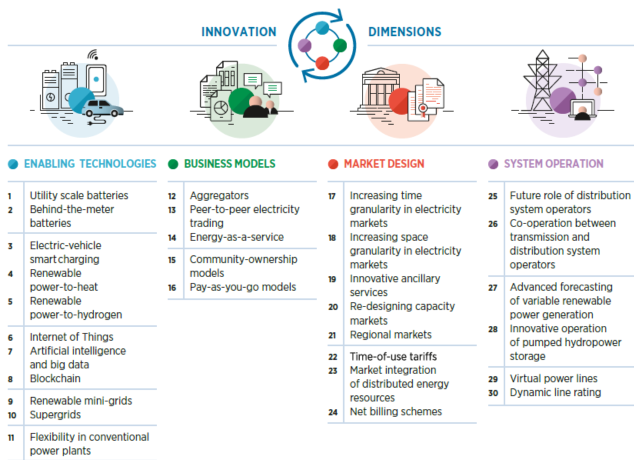


Table 12: Renewable energy technology and potential future impact (IRENA, 2019)

The added complexity of distributed solar, IoT and other products like electric vehicles, requires that renewable energy developers hire workers who are able to address data management and system operation. However, it is expected that developers' business models and the overall market design may change even more in the future. New operations may include peer-to-peer electricity trading, community ownership, and pay-as-you-go models. This will further require a demand for workers with communication, leadership and software skills that are not easily automatable or at risk of being displaced.

5.5 *Energy Efficiency*

Residential and commercial buildings in the United States consume 40 percent of total energy in the country, 70 percent of which is electrical energy (DOE EERE, n.d.). Although total energy use grew 37 percent in the past 40 years, homes use 10 percent less energy (DOE, 2015). Technological advancement has created more energy efficient home devices such as refrigerators, thermostats and HVAC systems. The US DOE Building Technologies Office aims to reduce energy use in buildings by 30 percent by 2030 compared to 2010 levels (DOE EERE, n.d.). Now, through integration with the internet, sensors and controls regulate heating and cooling, optimizing for user preferences while reducing energy usage. Other energy efficiency technologies include heat pumps and advanced window controls. With the rise of internet connected devices, US national energy laboratories around the country are developing standards and regulations on how such devices interact with one another and the grid.

A recent collaboration by the Department of Energy with Georgia Power developed Atlanta's first "smart neighborhood" where 46 homes were integrated with solar photovoltaics, batteries, and grid-connective, energy-efficient building devices to learn about homeowner behaviors and energy management (DOE EERE, 2019). The project's initial findings found that these homes use almost 40 percent less energy than newly built homes in Birmingham. And while this surpassed expectations, another study further proved the power of energy efficiency technology.

Reynolds Landing, a smart neighborhood in Alabama that has been running since 2017, found that electricity demand decreased by 70 percent from traditional homes during colder temperatures (DOE EERE, 2019). Both Georgia Power and Reynolds Landing, have provided opportunities for researchers and planners to get an understanding of how distributed energy systems, smart devices and battery storage work in real-life scenarios in order to plan for the future. They have also provided the opportunity for cross-institutional collaboration between government energy research agencies, Southern Company, Georgia Power, the Electric Power Institute and a homebuilder association. These pilots have also demonstrated the skills' needs in data management and AI needed by the energy workforce of the future.

5.6 Section Summary

In summary, technological advancement will have cross-cutting impacts across the energy sector. Despite the varying predictions of worker displacement from artificial intelligence and automation overall, there is a clear consensus from experts within the energy and energy efficiency sectors that most workers will not be at high risk from automation and AI. The greater challenge will be in developing internal training programs that can support existing employees in acquiring new skills. The exceptions are among some of the mining and extraction and manufacturing sectors where some less skilled occupations are still vulnerable to automation.

Overall, in the energy and energy efficiency sectors, there is already a demand for individuals to fill more technical, computer, and data focused roles. This will not happen overnight and will require thoughtful planning in how to support workers in terms of education, adaptability and financial need. In such planning, careful consideration should be given to those who will be most affected by technological change – men and underrepresented minorities from low education backgrounds. Actions on how to address this will be further discussed in Section 6: Policy Recommendations.

6 Policy Recommendations

The adoption of an aggressive suite of climate solutions' as modeled in Section 3 will create two major workforce issues that will need to be addressed. First is the response to the decline in fossil fuel jobs in production, generation, transmission, distribution and storage which currently employ 1.6 million Americans (see page 12). Second is the issue of scaling up and training the additional workforce needed to deploy the new energy systems in a way that maximizes social equity. This new workforce could require as many as 1.4 million new employees.

Unfortunately, the lack of geographical symmetry makes the transition from one set of jobs to the other somewhat challenging. This section will focus on the two sets of workforce policies confronting communities-- transition for those whose jobs are disappearing and equitable growth for those areas facing expansion. Luckily, there is at least some potential for overlap—if the problem is well planned and managed.

Transition. As described in Section 2, 10 states contain 73% of oil, coal, and natural gas production jobs (see page 12).

State	Coal	Oil	Gas	Total
Texas	5,205	208,268	116,803	330,276
Louisiana	1,142	51,092	23,963	76,197
California	1,843	56,424	7,847	66,114
Oklahoma	450	39,325	25843	65,618
Pennsylvania	6,241	17,984	14,146	38,371
Colorado	1,899	16,458	10,735	29,092
Illinois	3,785	21,173	1,416	26,374
West Virginia	14,359	4,647	5,816	24,822
New Mexico	1,161	14,601	6,338	22,100
Wyoming	5,964	8,654	6,682	21,300
Total	42,049	438,626	219,589	700,264

Table 13: Top fossil fuel state employment (USEER, 2019, State Fact Sheets)

Two states, Texas and Pennsylvania, are among the top 10 in all three fuels while six states are in the top 10 in two. As described in Section 2, 88% of the mining and extraction jobs in fuels are in just 10 states. The geographic concentration of fossil fuel production makes the transition more difficult, as does the isolation of many of these rural counties. Finally, within the fuels sector, where mining and extraction make up almost 50% of employment, there is relatively less skills' transferability. In the rest of the fuels sector's jobs—construction, manufacturing, professional services, and wholesale trade—transferability should be greater, resulting in a smoother transition (EFI, NASEO, & BW Research Partnership, 2019).

Section 1 summarized the development of the modern workforce training system and how some of its response mechanisms, such as TAA, have a mixed track record. In general, most contemporary workforce responses to worker dislocation events have focused on individual solutions and "retraining" the affected employee to re-enter the workforce in a different position or through a lateral move in their current "career ladder". Since the late 1970's and early 1980's almost no attention has been given to government's potential role as being the employer of last resort in such situations, as with the WPA during the Depression or as proposed periodically by some states.

Occasionally, states or communities have focused on repurposing dislocation sites to create replacement jobs, but the timelines for winding down one business and the start-up of another are almost always too disjointed to provide a smooth transition. One possibility, discussed briefly in section 4, would be to assess the viability of low carbon electricity production on each shuttered power plant site, both renewables and SMR's.

In a few cases, such as the nuclear production sites operated in the U.S. during the Cold War, the clean-up of environmental contamination has provided long-term meaningful employment for dislocated workers after production was discontinued (US DOE, Office of Environmental Management, n.d.). As described in section 3, this may have some relevance to former mining and extraction sites today.

One thing that is very clear, however, is that an individual retraining program alone, particularly within isolated or rural communities, is insufficient to help either the community or the individuals to recover from systemic shifts in the economy. Consequently, Section 6 will suggest several approaches that combine individual retraining programs with focused efforts to use government supported climate investments as an economic development tool in prioritized communities.

Energy Efficiency as an Economic Development Tool. Described below is an approach which integrates retraining with a federally supported, local economic development program, focused on investments in energy efficiency and energy infrastructure, two critical components of any successful climate plan. Testimony provided recently to the House Select Committee on the Climate Crisis stated:

> *"There are four ways that energy efficiency investments can benefit these highly impacted [Appalachian] communities.*
>
> *"The four response areas are energy infrastructure, the industrial sector, commercial buildings, and residential buildings. Energy efficiency investments are needed to meet carbon emissions reduction targets in every part of the country and in each of these sectors. However, by targeting those communities whose employment has been adversely impacted by the decline in coal production first, jobs can be provided in labor markets already suffering from higher than average unemployment. Given the demonstrated hiring crisis in energy efficiency (especially in its largest sector—construction—where a majority of employers reported that it was very difficult to hire new employees in 2018), a focus on introducing energy efficiency technologies into these communities is a sensible response to worker dislocation.*

"A four-pronged energy efficiency initiative in these communities and regions provides the added benefit of reducing residential consumer energy costs and making businesses and real estate more economically competitive.

"In the first edition of the Quadrennial Energy Review focused on Transmission, Storage and Distribution and released in April, 2015, the Department of Energy recommended that DOE should,

> **"Provide state financial assistance to promote and integrate TS&D infrastructure investment plans for electricity reliability, affordability, efficiency, lower carbon generation, and environmental protection.** In making awards under this program, DOE should require cooperation within the planning process of energy offices, public utility commissions, and environmental regulators within each state; with their counterparts in other states; and with infrastructure owners and operators and other entities responsible for maintaining the reliability of the bulk power system.

"Implementation of such a program, focusing first on Appalachia and other coal-impacted communities, would provide immediate economic support, job creation, and greater efficiency and resilience.

"In many of the communities that were originally built around the availability of coal resources, manufacturing also plays a more significant role in local economies. A focus on industrial energy efficiency would preserve the competitiveness of the existing manufacturing ecosystem while also creating demand for energy efficiency industrial products, particularly electrical motors, one of the largest consumers of energy in manufacturing. Many of the top 10 coal producing states—PA, OH, IL, IN, KY, and WV—have significant manufacturing employment in both energy intensive industries such as steel and aluminum, but also in the production of energy efficiency products. These kinds of industrial energy efficiency investments, thus, have the twin benefit of reducing costs while increasing product demand. Programs such as DOE's Industrial Assessment Centers which provide energy efficiency assessments to small and medium sized manufacturers could be expanded in these communities.

"Commercial and residential energy efficiency building retrofit programs could also be significantly expanded in the target areas, financed through federally guaranteed revolving loan programs with the loans paid back through energy savings.

"This kind of focused investment on energy efficiency in multiple sectors of the economy provides affected communities with the skills training needed for the jobs of the future. Increased deployment of energy efficiency technologies is going to be needed for at least the next 30 years to meet carbon reduction targets. Perfecting the model for concentrated investment in energy efficiency in coal communities today will provide a model for similar investments in other geographies where unemployment levels are endemically high." (Foster, 2019)

Modelling Energy Efficiency Investments in Appalachia. As laid out in the preceding testimony, a model program could be developed in Appalachia, creating federally supported financing mechanisms to fund commercial and residential energy efficiency programs. These projects would, in turn, create demand across the entire spectrum of energy efficiency employment, including especially construction and professional services. Utilizing the existing apprenticeship infrastructure with the construction unions to expand "earn while you learn" programs is the most effective way to expand the workforce while training new entrants in a broad range of construction skills as opposed to focusing solely on the more limited skills attached to single family residential efficiency programs.

In addition, a DOE-administered, federal energy infrastructure modernization program as proposed in the QER could also be modeled in Appalachia to demonstrate the overall economic benefits of an efficient, resilient, 21st Century grid. Existing industrial energy efficiency programs, such as the Industrial Assessment Centers (IAC's), could be expanded and the DOE Loan Program given a broader authority to target industrial energy efficiency programs. (U.S. Department of Energy, 2020) Collectively, these programs could then be applied over a longer time horizon as declining use of other fossil fuels might have similar disproportionate effects on other rural communities.

Energy Transition Adjustment Assistance. In spite of the limitations noted earlier in the performance of the TAA program responding to the loss of manufacturing jobs, Congress should consider the establishment of a Energy Transition Adjustment Assistance (ETAA) program to provide retraining opportunities and support to workers whose employment was lost as a result of climate policies, specifically the decline in fossil fuel production, use, transmission, distribution, and storage. Among the short comings of TAA are its benefit limitations, relocation benefits, and insufficient counselling and support services, all of which could be addressed to give participants a higher rate of success.

Nonetheless, establishing an ETAA program with clear eligibility rules and broad applicability would be an important statement of intent on how climate-related economic dislocation will be handled. Unlike trade-related dislocation, however, climate dislocation may also signal new employment opportunities with existing employers, needing employees with new or additional skills. For instance, an energy infrastructure company that today manages a portfolio of pipelines and generation projects may choose to shift focus and add additional electrical transmission assets for renewables, smart grids, storage or other distributive services, needing an evolving set of skills. Consequently, the ETAA program should include strong incentives for employers to provide training to existing employees as businesses shift to producing or managing low carbon energy, assets, and systems.

Another issue that the ETAA program should address is the increasing lack of mobility in the American workforce. As noted in the recent McKenzie report, "The Future of Work", mobility has declined significantly in the US over the last thirty years. While many factors contribute to this lack of mobility, some are clearly economic and include "under water" mortgage debt in declining communities, unaffordable housing costs in many urban areas, relocation costs, and declining urban wage differentials. Some or all of these factors could be addressed in an ETAA program to facilitate relocation.

Role of Construction Unions and Apprenticeship Programs. One of the key institutional networks for supporting the scale up of the workforce necessary to implement the transition to a low carbon economy is the joint apprenticeship system managed by the North American Building Trades Unions (NABTU) and their participating employers. This system, funded by more than $1 billion each year of labor-management negotiated contributions in 1600 training centers, has provided the skills necessary for much of our current energy infrastructure to be built, maintained, updated, and operated (NABTU, 2020). Expanding that workforce under either the two degree or 1.5 degree scenarios will require adding from a quarter million to 700,000 additional apprentices into the system during a multi-year ramp up period. A recent study from the U.S. Bureau of Labor Statistics predicted 13% growth for HVAC technicians, 2 ½ times the national average over the next decade (BLS, Sept., 2019), while David Dias, business agent for the SMART LU #104 in San Francisco, observed that, "80% of the hours our members work are in energy efficiency and 40% of those members will be eligible to retire in five years."

Data from multiple sources has validated that a unionized construction work force is paid better, enjoys better benefits, is more productive, and experiences fewer on-the-job injuries than their non-union counterparts. In 2018, the US BLS reported that average weekly wages in the construction industry were 49% higher for those who belonged to unions. (US BLS, 2019) Currently, both the energy infrastructure (TDS) and energy efficiency workforces are significantly more unionized than the U.S. private sector workforce as a whole, 16% and 11% (USEER, 2019) respectively, as compared to 6.4%. Thus, one of the most important ways to improve the job quality and the social equity outcomes of investments in climate solutions is to encourage higher rates of unionization.

There are multiple ways to accomplish this, including:

- Incentives to utilize registered joint apprenticeship programs with federally funded projects or programs.
- Expansion of Davis-Bacon "prevailing wage" requirements to cover projects receiving federal tax credits.
- Requirement for the use of project labor agreements on all federally funded climate investments.
- Requirement for the use of community benefits' agreements to establish local hire and diversity targets on federally funded projects.

Pre-apprenticeship Training. Another important way in which to expand the opportunities provided by investments in energy efficiency and energy infrastructure would be through expanding and formalizing the use of pre-apprenticeship training with existing apprenticeship programs that are providing employees for climate-related projects. Pre-apprenticeship programs, boot camps, and various other introductory training programs are currently offered by a range of employers, community colleges, and unions to introduce the work skills, environment, and social behaviors necessary to succeed. Such programs can last for as short as two weeks or as long as several months and are especially helpful for those who have been out of the workforce for lengthy periods of time. The Multi-Craft Core Curriculum (MC3) run by North America's Building Trades Unions (NABTU) is one such example. (NABTU, n.d.) The role of the current U.S. Department of Labor Advisory Committee on Apprenticeship should be expanded to provide explicit oversight and guidance to the extension of pre-apprenticeship programs to high unemployment communities and should be closely aligned to federally funded climate projects and involve local unions.

Energy Infrastructure Build Out and Repurposing. The energy infrastructure goals spelled out in the 2015 QER above serve as a reminder of the scope of work that will be necessary to modernize and decarbonize our energy systems. ASCE estimates that an additional $177 billion dollars will need to be spent on electrical transmission alone in the next decade to improve the reliability and functionality of that system. (ASCE, 2017) In 2019, 80% of construction employers in the TDS sector report difficulty in hiring new employees, with 27% saying that it was very difficult. (USEER, 2020) .

When discussing the issue of hiring difficulty with TransCanada Energy in a recent interview, an HR manager said, "We wouldn't anticipate any trouble hiring for new infrastructure projects because the permitting timeline is so long, frequently 10 years. Where we have difficulty is in those white-hot locations like Texas, Louisiana and West Virginia with so many projects simultaneously." Thus, the workforce challenges mounted by a significant increase in energy infrastructure investments over a 30-year time horizon, adding some hundreds of thousands of construction workers, seem eminently manageable to a large energy infrastructure company like TCE with over $99 billion of infrastructure assets.

Federal Reform. Three specific areas of reform should be addressed by the US Government to facilitate effective use of federal workforce development funding as it relates to climate solutions. These include energy workforce data collection and reporting, interagency workforce training and curricula development, and coordination of federal energy workforce and economic development resources.

Energy Workforce Data. As Section 2 lays out, energy workforce data as provided by the BLS-QCEW has many gaps that evolved over the years as both technologies and business models changed. As a result, current data is incomplete unless it is supplemented through additional employer surveys. In 2015 the U.S. DOE started the collection of additional energy data and the issuing of the annual U.S. Energy and Employment Report (USEER). That report was produced twice by the Department in 2016 and 2017 and three times subsequently, using the same methodology, by the non-profit Energy Futures Initiative and NASEO. Congress should mandate and provide funding for an annual data collection on energy and energy efficiency jobs in the U.S., as it did for one year in the FY 2020 omnibus spending bill, to provide the public with readily accessible data on how the implementation of climate policies is affecting the labor market, what and where jobs are being eliminated and created, and where and how employers are facing difficulty in hiring. This invaluable data is necessary at the state and local level to engage in thoughtful planning and effective response to worker dislocation.

Interagency Coordination. Currently six federal agencies play a role in helping to shape workforce activities in the energy field and related manufacturing sectors—the Departments of Energy, Labor, Education, Commerce, Defense, and the National Science Foundation. During the Obama Administration an interagency task force was established, including all cabinet-level agencies, to manage the implementation of the WIOA. Called the Skills Working Group, it initiated a subcommittee of the six agencies listed above, the Energy and Advanced Manufacturing Workforce Initiative (EAMWI, 2016) to coordinate the delivery of energy-related workforce training to the public. EAMWI was chartered to meet quarterly and make annual workforce plans that would enhance the effectiveness of the federal government in delivering energy workforce curricula and programs to the public, state, and local governments. EAMWI should be mandated and funded by Congress through the Department of Energy.

Energy Workforce and Economic Development Extension Program. The U.S. Department of Energy operates 35 technical assistance programs, ranging from its Industrial Assessment Centers promoting industrial energy efficiency to its wind and solar programs to grid modernization. Each of these programs has a workforce component in addition to their roles supporting technology deployment and economic development. One of the most important outward facing contributions that the federal government could offer to states and local communities as they implement far reaching climate policies would be easy access to these technical assistance programs and their workforce components. Congress should mandate and fund the establishment of an Energy Workforce and Economic Development Extension Program to coordinate the delivery of DOE technical and workforce services to state and local officials and the public and private sectors. Such a service would be in the long tradition of the extension services provided by the Department of Agriculture to modernize farming and improve the application of science to agriculture.

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