AMERICAN CLEAN POWER

2021 CLEAN ENERGY LABOR SUPPLY

[bw] RESEARCH PARTNERSHIP

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Introduction

The American Clean Power Association commissioned BW Research Partnership to conduct a clean energy labor supply study, identifying industry and occupational workforce demand for four specific clean energy technology sectors—solar, offshore wind, land-based wind, and battery storage. With estimated capacity additions through 2030 for each technology sector, the research team used economic models to project clean energy workforce demand under two different decarbonization policy scenarios; the research also includes a comprehensive and robust dataset of current clean energy employment in these sectors while the models included significant analysis and methodological validation to ensure conservative and reasonable estimations.

The purpose of this report is to identify the estimated nationwide job growth that would result from accelerating the rate of clean energy deployment to account for 50 percent (scenario #1) or 70 percent (scenario #2) of electricity generation by 2030. In addition to determining the overall job creation potential, the report details current employment levels as of the last quarter of 2020 for each of the technology sectors as a baseline of supply from the current labor market.

The report also provides the most recent union membership and coverage rates for each clean energy technology sector, as well as overall national industry and occupational unionization for key sectors such as manufacturing and construction. Unions are important in preparing the high-skilled labor force needed to deploy renewable and battery storage capacity across the nation as well as ensuring high job quality for these new positions.

For both policy scenarios, overall projected workforce demand is delineated by technology sector and industry sector, including utilities, manufacturing, construction, wholesale trade, and project development and operations. A final gap analysis assessment identifies overall expected occupational demand compared to current occupational supply and the Bureau of Labor Statistics' 10-year projections, which assume baseline economic activity without additional policy interventions. The employment growth resulting from decarbonization policies are in addition to the federally-projected baseline occupational growth over the next ten years.

For the purposes of this report, only direct and indirect employment estimates are included in the outputs; the induced employment resulting from direct and indirect job creation is not included in this analysis.

For more detail on the research methodology and model assumptions for this report, please refer to Appendix A.

Executive Summary

Increasing renewable and battery storage capacity to account for 50 or 70 percent of electricity generation over the next decade would create 5 to 6 million job-years[1] across multiple industry sectors and occupational groups. Not surprisingly, to meet both the product and labor demand for this infrastructure buildout, many of the jobs created would be in the construction and manufacturing industries, with additional support from project development and operations sectors such as finance, legal, consulting, architecture, engineering, and to a lesser extent, wholesale trade, utilities, and other industries. In particular, wind turbine technicians, solar photovoltaic installers, semiconductor processing technicians, metal fabricators, and electricians will be in high demand to produce and install the renewable energy and storage capacities required to reach a 50 or 70 percent standard. Many of these jobs are spread across the country and support above-average wages compared to the national average.

Employment growth generated through legislative action and decarbonization policies can also provide opportunities for increasing union labor and partnerships. Many of the jobs created would be concentrated across construction and installation positions, which are all fairly unionized jobs compared to the national private sector average and other occupational groups. Indeed, unions are key to supplying the labor market with skilled trades workers.

Overall, however, the increased economic activity under decarbonization policy scenarios would require significant additional job growth over the Bureau of Labor Statistics' 10-year occupational projections. These levels of projected job creation could result in labor constraints that would inhibit decarbonization efforts and the buildout of renewable and storage technologies. Expanding the talent pipeline through increased access, training program development, and active partnerships across all key actors in the workforce development system, including community colleges, labor unions, non-profits, and other training providers, will be required in order to meet the projected labor market demand over the next 10 years.

Key Findings

CURRENT EMPLOYMENT & REGIONAL DISTRIBUTION

In the last quarter of 2020, there were a total of 415,024 solar[2], wind, and battery storage workers across the United States. The majority of these jobs are found in the solar sector. In

[1] A job-year represents one year of work for one person. In other words, a construction job that lasts five years would be considered five job-years.

[2] This total only includes majority-time solar workers (those that spend 50 percent or more of their labor hours on solar-related work). There were an additional 85,201 solar workers at the end of 2020, for a total of 316,675 solar jobs as of Q4 2020.

total, there were 316,675 solar workers at the end of 2020. This number accounts for *all* solar workers in the U.S., regardless of the amount of time they spend working on solar-related projects and installs; for example, an employee who spends only 10 percent of their labor hours or work week on solar projects would be counted. Accounting for only *majority-time* solar employees, there were 231,474 solar workers in 2020; these are individuals who spend at least 50 percent to all of their labor hours on solar-specific activities.[3] The wind sector supported 116,801 jobs in 2020 while battery storage firms employed 66,749 individuals across the nation. By comparison, there were 131,841 coal industry workers across both coal electric power generation and coal fuels extraction, processing, and distribution; 251,402 natural gas industry workers; and 11,685 jobs in oil and other petroleum electric power generation.[4]

Resource-rich states with large populations have the largest number of clean energy jobs, but on a per capita basis, the sector has fairly even distribution across different states. More than a third (36 percent) of solar industry employment is found in California—roughly 113,000 jobs. A per capita analysis that examines solar jobs as a proportion of total employment in a state indicates that per capita solar employment in California is comparable to many other states, including Hawaii, Nevada, Vermont, Utah, Massachusetts, and New Mexico. Per capita solar employment indicates a more even distribution of solar jobs across the Western, Southwestern, and Northeastern parts of the U.S. Similarly, while California accounts for the largest total amount of battery storage jobs in the nation, on a per capita basis, Nevada, Vermont, Massachusetts, and Idaho have more storage jobs. For the wind sector, Texas is the top state with wind jobs, representing 22 percent of total wind energy employment, or more than 25,400 jobs. However, per capita, South Dakota, North Dakota, Colorado, Iowa, and Indiana have a greater share of wind energy jobs compared to total employment; on a per capita basis, wind jobs are fairly evenly distributed across the Midwestern, Western, and Southwestern portions of the U.S. For more information, please see the heat maps found on page 11.

OVERALL JOB CREATION

An aggressive decarbonization policy has the potential to create roughly five to six million job-years across solar, wind, and battery storage technologies. Increasing renewable and battery storage capacity to account for 50 or 70 percent of electricity generation over the next 10 years would result in the creation of many new jobs in construction, manufacturing, wholesale trade, project development and operations, and utilities. In other words, a decarbonization policy

[3] The solar jobs estimate includes all photovoltaic and concentrated solar employment, including residential solar and any other distributed applications; concentrated solar was a small proportion of total solar jobs in 2020—roughly seven percent of the solar labor market.

[4] The coal and natural gas employment estimates include both electric power generation and fuels extraction, processing, and distribution jobs. The 11,685 petroleum workers are exclusive of only electric power generation workers and do not include the petroleum fuels workforce, which totaled 495,210 workers at the end of 2020. All employment data is from the 2021 United States Energy and Employment Report (USEER), which can be found at: https://www.usenergyjobs.org/.

scenario that ramps up renewable and battery storage deployment to account for 50 percent of electricity generation over the next decade would create 4.94 million job-years through 2030; a decarbonization policy that increases deployment of these technologies to account for 70 percent of net generation over the next 10 years would result in 6.01 million job-years.

JOB CREATION BY TECHNOLOGY & INDUSTRY

The wind industry has the greatest job growth potential under each decarbonization policy scenario. Together, over the next decade, land-based and offshore wind deployment are projected to create 2.5 million job-years under scenario 1 and about three million job-years under scenario 2. With roughly 1.74 to 2.09 million job-years, land-based wind will account for the majority—about 70 percent—of employment growth in the wind sector. In addition to the job-years created throughout construction and project development, an additional 362,825 operations and maintenance job-years for land-based and offshore wind would be created under scenario 1 for the next 25 years; under scenario 2, this would increase to 436,675 job-years in operations and maintenance for 25 years.

Utility-scale solar will account for the majority of job growth in the solar sector. Under policy scenario 1, the deployment of distributed and utility-scale solar will generate 2.11 million job-years through 2030. Accounting for 70 percent of electricity generation (scenario 2) will result in the creation of 2.54 million job-years over the next decade. Almost 60 percent of this employment growth—roughly 867,000 to 1.04 million job-years—will be concentrated across utility-scale solar projects.

Battery storage deployment would account for about eight percent of all job-years created. Policy scenario 1 would result in about 373,000 job-years through 2030. Under policy scenario 2, increased battery storage deployment would create almost 448,000 job-years over the next decade. This represents 7.5 percent of job-years generated across all technology sectors.

The majority of jobs created would be found in the manufacturing, project development and operations, and construction industries. On average, about four in ten job-years created would be concentrated in manufacturing with another quarter found in the project development and operations industry; much of the manufacturing work will be found in the wind industry, explained further in the following paragraphs. Under policy scenario 1, this represents about 1.86 million job-years in the manufacturing sector and 1.25 million project development and operations job-years over the next 10 years. Construction represents about 21 percent of job growth, followed by utilities with four percent of total jobs created and wholesale trade at just under two percent of all jobs created. The remaining 10 percent of job growth is found across other industries such as agriculture, mining, retail trade, transportation, educational services, healthcare, arts, entertainment, and recreation, accommodation and food services, public administration, and other services such as repair and maintenance.

Increasing both distributed and utility-scale solar capacity would largely result in project development and operations growth. On average, half of all jobs created in the distributed solar sector would be found in the project development and operations industry—roughly 436,000 to 524,000 job-years over the next decade; these are largely professional, scientific, and technical jobs such as architecture, engineering, and specialized design services. Construction job growth accounts for 16 percent of all jobs created in the distributed solar sector, followed by manufacturing at 12 percent. For utility-scale solar, employment growth in the project development and operations industry represents about 47 percent of jobs created, followed by manufacturing at 23 percent and construction at 17 percent. In total, under policy scenario 1 or policy scenario 2, utility-scale deployment would support roughly 1.25 to 1.5 million job-years through 2030, respectively.

Growth in the offshore wind industry would create mostly manufacturing jobs, while increased land-based wind capacity would generate both construction and manufacturing jobs. Eight in ten jobs created in the offshore wind industry would be found in manufacturing.[5] Over the next 10 years, the offshore wind manufacturing sector would see an increase of about 560,000 to 743,000 job-years due to domestic production of towers, blades, array and export cables, nacelles, rotors, drivetrains, and other wind turbine components. Construction jobs represent nine percent of total jobs created in offshore wind. By contrast, about three in ten jobs created in the land-based wind sector would be found in construction with another five in ten in found in the manufacturing industry. Through 2030, this would entail 556,000 to 669,000 job-years in the construction industry and roughly 830,000 to 997,000 job-years in the manufacturing industry. The remaining jobs created in the land-based wind sector are found in the utilities industry (10 percent), all other sectors (eight percent), and project development and operations (two percent).

Battery storage employment growth would be concentrated in project development and operations and manufacturing. Forty-two percent of jobs created in the battery storage sector would be in the project development and operations industry, followed by manufacturing at 24 percent. Over the next decade, this represents an increase of 157,000 project development and operations job-years under policy scenario 1 and 189,000 project development and operations job-years under policy scenario 2. As with the solar sector, project development and operations job growth is concentrated in scientific and technical services which includes architecture, engineering, and specialized design services as well as consulting, legal, financial, and research support.

[5] Offshore wind manufacturing and assembly will involve the use of many skilled trades workers. As such, these jobs encompass more than traditional factory manufacturing. For example, foundation construction requires significant welding, metal and concrete work, and other civil construction work.

OCCUPATIONAL DEMAND & SUPPLY GAPS

Almost half of all job-years created will be found across a variety of occupations. On average, 48 percent of job-years created under these decarbonization scenarios would be found across 35 specific occupations. Of these, 24 percent would be construction jobs and 18 percent would be production positions. Architecture and engineering occupations comprise 14 percent of the top 35 in-demand occupations, followed by legal positions (10 percent), installation, maintenance, and repair (10 percent), management (seven percent), office and administrative (seven percent), business and financial operations (five percent), computer and information technology (three percent), and transportation and material moving (two percent).

The majority of jobs generated support above-average annual wages. Of the total jobs generated across the top 35 in-demand occupations, 65 percent of jobs support an average annual wage that is higher than the national average wage of $56,310. Wind turbine technicians—an occupation that will see the greatest gap in supply—made an average of $59,340 in 2020; this is five percent higher than the national average. Similarly in 2020, the average annual wage for electricians was $61,550, or nine percent higher than the national average. Other in-demand occupations including supervisors of production and construction workers or mechanics earn roughly 16 to 23 percent above the national average. Demand for electrical and civil engineers will also be high under decarbonization policies; these individuals earn roughly 41 to 47 percent more than the national average. For more information on occupational wages, see Table 3.

Wind turbine service technicians, solar photovoltaic installers, semiconductor processing technicians, structural metal fabricators and fitters, electricians, and electrician helpers will have significant supply gaps over the next 10 years. On average, roughly 70,200 jobs created for the next 10 years will be across these occupations.[6] In 2020, there were roughly 848,400 workers across these six occupations. Assuming baseline economic activity, and not including decarbonization policies, the Bureau of Labor Statistics projects that these jobs will grow by an additional 161,700 jobs through 2029. In order to meet baseline economic demand in addition to expanded economic activity under decarbonization scenarios, the labor market must supply more than 231,850 wind turbine service technicians, solar photovoltaic installers, semiconductor processing technicians, structural metal fabricators and fitters, and electrician helpers, and electricians over the next 10 years.

Wind turbine technicians in particular will experience the greatest labor supply gap over the next decade under accelerated decarbonization policies. At the end of 2020, there were 5,860 wind turbine service technicians. Under baseline economic conditions, the Bureau of Labor Statistics predicts that there will be 5,440 new wind technician jobs by 2029, while the ramping up of wind capacity across the nation would produce an additional 6,769 wind technicians over

[6] For this analysis, job-years are divided by 10 in order to provide comparisons to the BLS occupational projections.

the next ten years. In order to support baseline economic growth and the increased economic activity under decarbonization policy scenarios, the labor market would have to produce 12,209 wind turbine service technicians over the next ten years. These are jobs that support above-average wages. In 2020, the average annual wage for a wind turbine service technician was $59,340—five percent higher than the national average.

For more detailed information on projected job growth by occupation, please see Table 3 under the Occupational Demand & Gap Analysis section.

UNIONIZATION

Unionization rates for solar, wind, and battery storage are higher than the national private-sector average. Union membership rates for solar, wind, and battery storage sit at around 9.5 percent each while union coverage or representation is just above 10 percent for each sector. By comparison, the national private-sector union membership rate was 6.3 percent in 2020 while the union representation rate was 7.2 percent.[7]

Many of the jobs created will be in the manufacturing and construction industries; these industries have above-average unionization rates. In the solar sector, roughly 16 percent of jobs created are in construction. The majority of wind industry jobs created—roughly 80 to 90 percent—will be found in construction or manufacturing. For battery storage, roughly a quarter of jobs will be in manufacturing, with an additional 17 percent in construction. Union membership for construction and manufacturing are a respective 12.7 and 8.5 percent.

Across occupational groups examined, construction as well as installation, maintenance, and repair occupations have among the highest unionization rates. Union membership among construction occupations[8] was 17.1 percent in 2020, followed by installation, maintenance, and repair occupations at 14.5 percent. Production occupations also have an above-average union membership rate at 11.9 percent.

MANY OF THE JOBS CREATED FROM THE PROPOSED SCENARIOS WOULD BE ACROSS THESE MORE HIGHLY-UNIONIZED OCCUPATIONAL GROUPS. OF THE TOP 35 OCCUPATIONS THAT WOULD BE IMPACTED BY INCREASED DEPLOYMENT OF RENEWABLES AND BATTERY STORAGE IN TABLE 3

Table 3, 24 percent will be construction occupations and 18 percent will be production jobs. Installation, maintenance, and repair occupations will comprise roughly one in 10 jobs created.

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[7] Bureau of Labor Statistics. Union Membership Annual News Release. January 2021. https://www.bls.gov/news.release/union2.htm.

[8] This is based on the overall occupational group—construction and extraction. Though there are no mining and resource extraction-related occupations within the renewable and battery storage sectors, unionization data for these occupational groups is not delineated in publicly-available datasets and thus can only be provided for the full group—construction and extraction.

Projected Clean Energy Development

Clean Energy Capacity Additions

Projected capacity additions for this report are based on the *Renewable Energy and Infrastructure Policy Scenario Analysis* produced by Wood Mackenzie and the American Clean Power Association in December 2020.[9] Assuming legislative action incentivizing 50 percent renewables (scenario 1) by 2030, the report models employment growth based on the following gigawatt (GW) inputs: a 59 GW increase in distributed solar, 298 GW increase in utility-scale solar, 218 GW increase in land-based wind, 53 GW increase in offshore wind, and 188 GW increase in battery storage capacity.

The inputs for policy scenario 2 assume a 20-percentage point increase over the baseline in scenario 1, with the same proportional distribution of resources. These inputs are shown below in Figure 1 in orange.

2020 Deployment Metrics


In 2020, the United States installed 19.2 gigawatts of solar PV capacity, bringing the cumulative total to almost 98 GW. In Q3 of 2020, utility-scale solar accounted for about 70 percent of capacity installed. As of the third quarter of 2020, cumulative capacity for utility PV totaled 7.6 GW. Solar accounted for 43 percent of all new electricity-generating capacity added across the nation in 2020.[10]


Wind deployment hit a new record in 2020, with capacity additions totaling 14.2 GW. To date, total wind turbine capacity sits at 118 GW.[11]

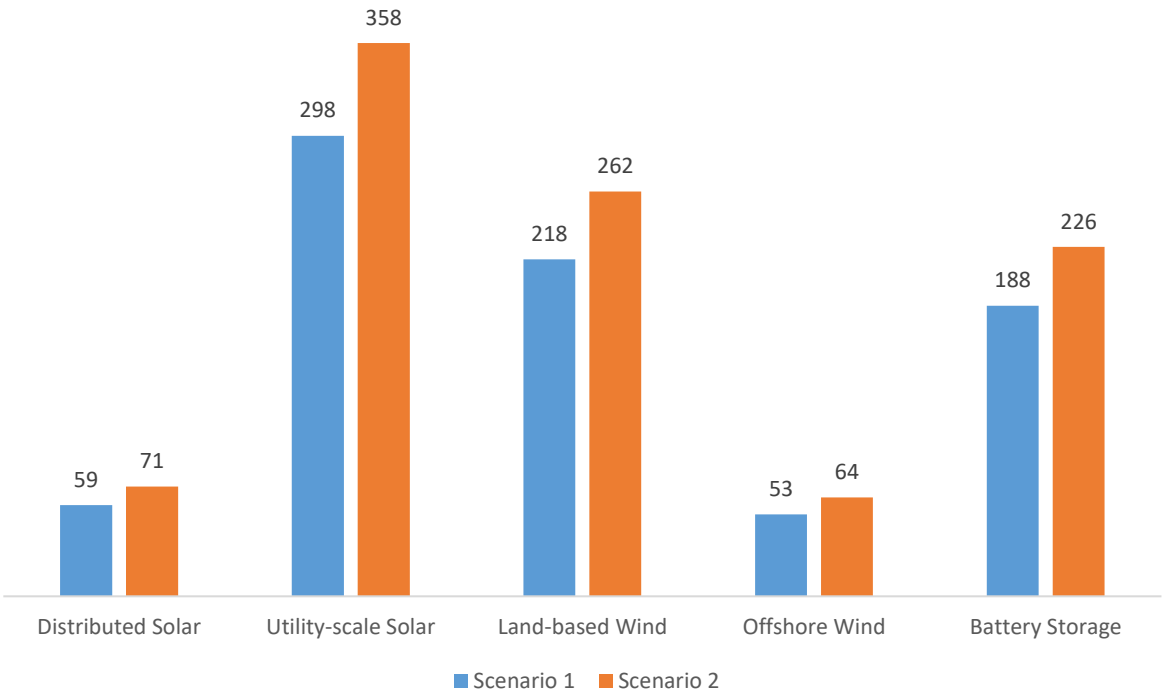
[9] https://cleanpower.org/wp-content/uploads/2021/02/american-clean-power-renewable-energy-and-infrastucture-policy-analysis.pdf

[10] *See generally:* Solar Energy Industries Association (SEIA). U.S. Solar Market Insight, March 2021. https://www.seia.org/us-solar-market-insight, and https://www.seia.org/research-resources/solar-market-insight-report-2020-q4.

[11] U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=46976#:~:text=According%20to%20data%20recently%20published,13.2%20GW%20added%20in%202012.

Also in 2020, battery storage capacity in the U.S. rose by just over one GW—1,464 MW or 3,487 MWh—bringing current storage capacity close to 3.5 GWh as of the last quarter of 2020.[12]

FIGURE 1. PROJECTED CLEAN ENERGY CAPACITY ADDITIONS, 2020 – 2030 (GW)



[12] https://www.energy-storage.news/news/in-2020-the-us-went-beyond-a-gigawatt-of-advanced-energy-storage-installati#:~:text=The%20US'%20installations%20of%20advanced,was%20close%20to%203.5GWh.

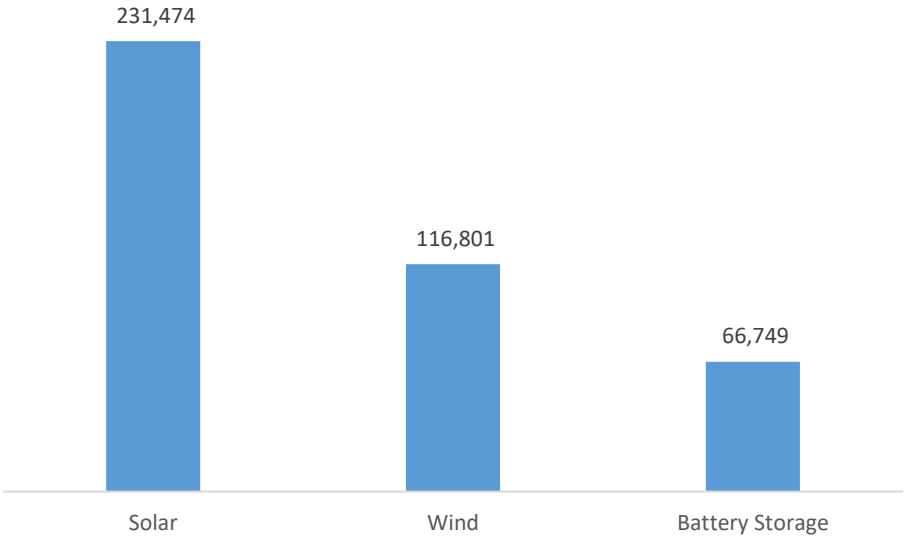
Clean Energy Workforce Supply

Current Clean Energy Employment

As of the end of 2020, there were 231,474 solar workers[13] across the United States. Across solar jobs within the construction industry, 118,250 workers (72 percent) are focused on residential, non-residential, and community solar; 28 percent of solar construction jobs—or 46,493 workers—are utility-scale installation employees. In the last quarter of 2020, the wind industry employed 116,801 workers and the battery storage sector accounted for 66,749 jobs (Figure 2).

By comparison, there were 131,841 coal industry workers across both coal electric power generation and coal fuels extraction, processing, and distribution; 251,402 natural gas industry workers; and 11,685 jobs in oil and other petroleum electric power generation.[14]

FIGURE 2. EMPLOYMENT BY TECHNOLOGY SECTOR, Q4 2020



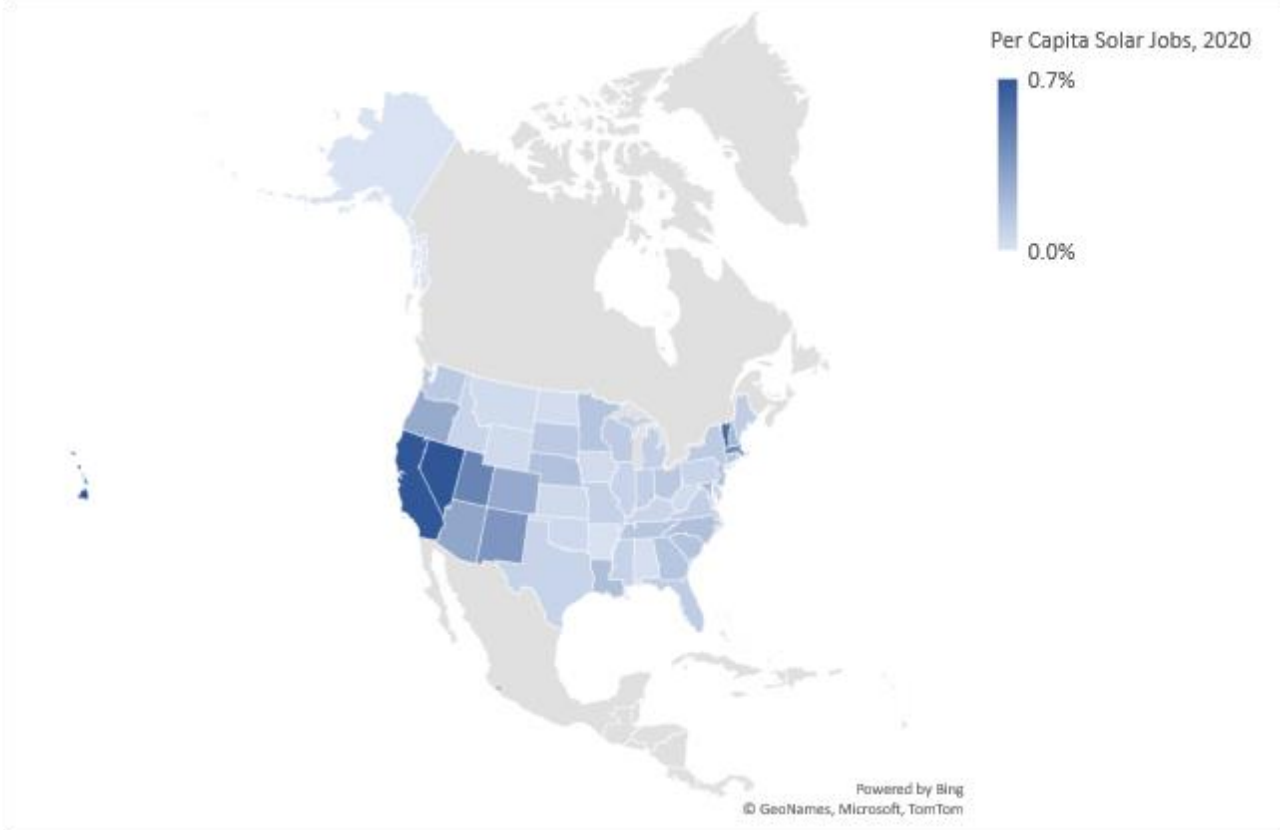
[13] This is the number of solar workers that spend the majority of their time working on solar-related installs and projects. In total, there were 316,675 solar jobs at the end of 2020; this includes all solar workers, regardless of the amount of labor hours dedicated to solar-specific activity. The solar jobs estimate includes all photovoltaic and concentrated solar employment, including residential solar and any other distributed applications; concentrated solar was a small proportion of total solar jobs in 2020—roughly seven percent of the solar labor market. All employment data is from the 2021 United States Energy and Employment Report, which can be found at: https://www.usenergyjobs.org/.

[14] The coal and natural gas employment estimates include both electric power generation and fuels extraction, processing, and distribution jobs. The 11,685 petroleum workers are exclusive of only electric power generation workers and do not include the petroleum fuels workforce, which totaled 495,210 workers at the end of 2020. All employment data is from the 2021 United States Energy and Employment Report, which can be found at: https://www.usenergyjobs.org/.

Geographic Distribution of Clean Energy Employment

Solar jobs are highly concentrated in California, where 36 percent of all solar employment was found at the end of 2020. The remaining top states with solar jobs include Massachusetts, New York, Texas, and Florida. On a per capita basis, however, solar employment is more evenly distributed across the Western, Southwestern, and Northeastern portions of the U.S.

FIGURE 3. PER CAPITA SOLAR EMPLOYMENT BY STATE, 2020[15]

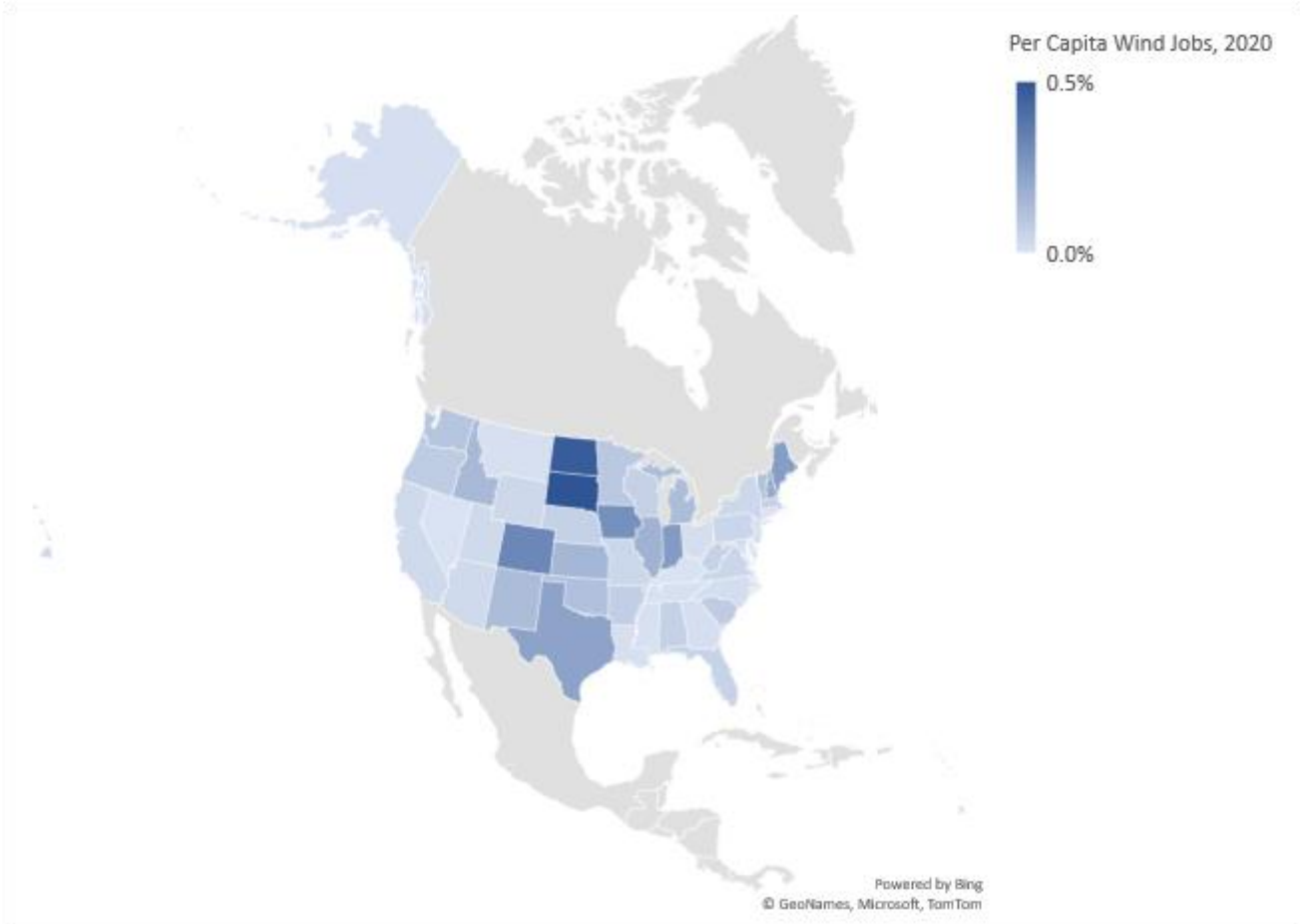


[15] Solar employment featured on this map includes all the 316,675 solar workers across the country as of the last quarter of 2020. The total solar jobs described in Figure 2 represent only those who spend the majority of their time dedicated to solar-related activity.

Texas is home to 22 percent of all wind energy jobs in the nation. Following Texas, Illinois accounts for eight percent of wind employment while Colorado comprises almost seven percent of wind jobs in the U.S. Indiana and California are also among the top five states with wind energy jobs. As of the last quarter of 2020, Indiana was home to more than 6,800 wind jobs, or roughly six percent of all wind employment in the U.S.; California supported 6,300 wind energy jobs, or just over five percent of all wind energy employment.

Removing outlier states, such as Texas, wind employment is more evenly distributed across Midwestern, Western, and Southwestern portions of United States, with South Dakota, North Dakota, Colorado, Iowa, and Indiana indicating a greater share of wind energy jobs compared to total employment.

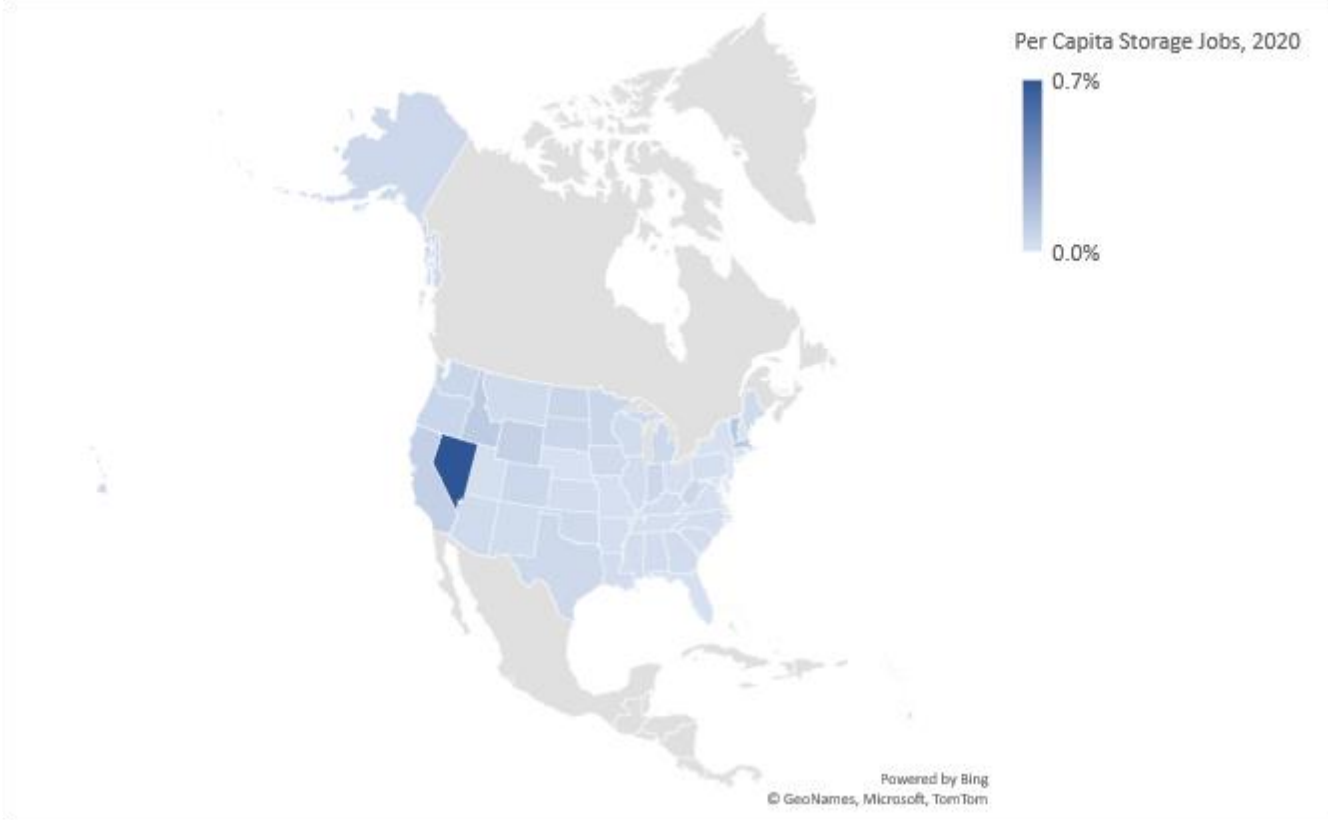
FIGURE 4. PER CAPITA WIND EMPLOYMENT BY STATE, 2020



As with the solar industry, storage employment is also largely concentrated in California. The state represents 22 percent of all storage jobs in the U.S.—roughly 16,800 workers. Nevada accounts for 11 percent of total storage employment, followed by Texas nine percent, Massachusetts with six percent of jobs, and Washington with three percent of total storage jobs in the United States.

On a per capita basis, Nevada, Vermont, Massachusetts, Idaho, and California are the top states with storage employment compared to overall total employment.

FIGURE 5. PER CAPITA STORAGE EMPLOYMENT BY STATE, 2020[16]



[16] The employment distribution in this map includes all clean storage jobs; in addition to battery storage, the clean storage sector also includes pumped hydropower storage, mechanical storage, thermal storage, biofuels storage, and nuclear fuels storage. Though the research team cannot extrapolate battery storage by state due to the level of granularity required, the majority of employment—roughly 85 percent—featured in the clean storage sector are battery storage jobs. As a result, this map may be used a proxy for understanding the distribution of battery storage employment across the United States.

Clean Energy Workforce Demand

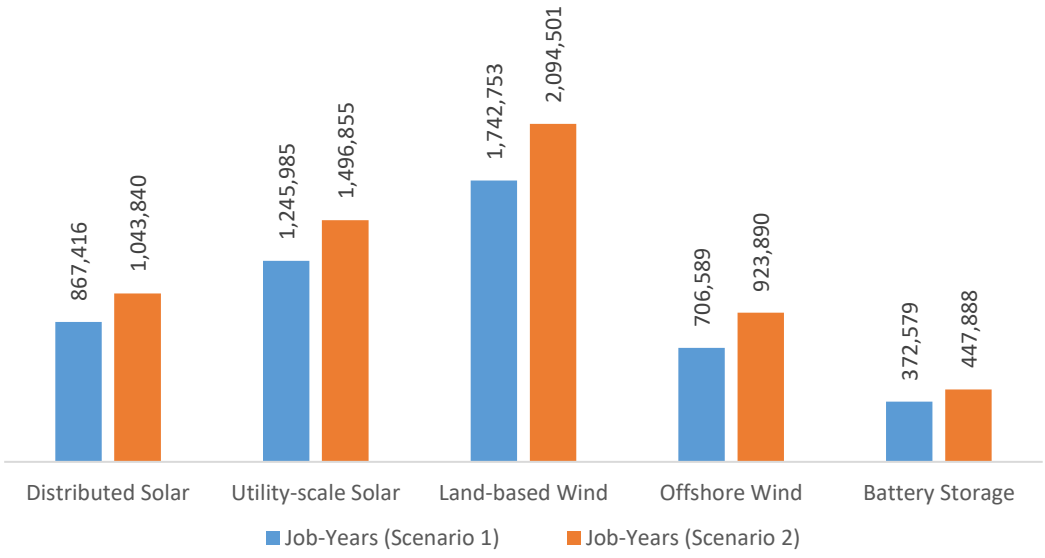
Overall Projected Clean Energy Job Creation

Under policy scenario 1—where renewables and storage account for 50 percent of electricity generation—an estimated 4.94 million job-years will be created across the distributed solar, utility-scale solar, land-based wind, offshore wind, and battery storage sectors over the next 10 years.

If renewables and battery storage capacity were to comprise 70 percent of electricity generation under policy scenario 2, this would result in an additional 1.07 million job-years for a total of 6.01 million job-years through 2030 across construction, manufacturing, wholesale trade, project development and operations, utilities, and other industry sectors.[17]

Job-years are useful in calculating the amount of work required to complete a project. A job-year represents one year of work for one person. In other words, a new construction job that lasts five years would be considered five job-years. Job-years are especially useful in representing employment in the trades, given that workers frequently move from project to project. Thus, taking the projected job-years in Figure 6 as an example, the 867,416 job-years under scenario 1 for the distributed solar sector translates to 86,742 distributed solar jobs for the next 10 years.

FIGURE 6. TOTAL PROJECTED JOB-YEARS BY TECHNOLOGY SECTOR & SCENARIO



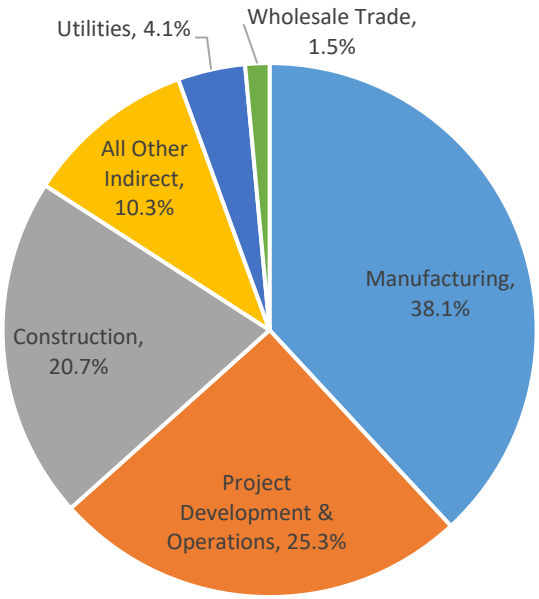
[17] Other industries include agriculture, mining, retail trade, transportation, educational services, healthcare, arts, entertainment, and recreation, accommodation and food services, public administration, and other services such as repair and maintenance.

Clean Energy Job Creation by Industry & Technology

Figure 7 provides an overview of the jobs created by industry by taking the average of employment growth across scenario 1 and scenario 2 to identify which industries, on average, would experience the most significant job growth under a decarbonization policy. Overall, the manufacturing and project development and operations sectors would see the majority of employment growth with increased solar, wind, and battery storage capacity. Manufacturing would account for 38 percent of job-years created over the next 10 years, while project development and operations represent 25 percent of job-years created, followed by construction at 21 percent, utilities at four percent, and wholesale trade at two percent.

All other indirect employment includes any additional jobs created across agriculture, mining, retail trade, transportation, educational services, healthcare, arts, entertainment, and recreation, accommodations and food services, public administration, and other services such as repair and maintenance; these sectors would comprise about 10 percent of total job-years created through 2030.

FIGURE 7. AVERAGE DISTRIBUTION OF JOB CREATION BY INDUSTRY ACROSS BOTH SCENARIOS



Under policy scenario 1, expanded capacity additions of solar, wind, and battery storage would result in a total of just over 1.86 million job-years in the manufacturing industry and more than 1.25 million job-years in the project development and operations industry over the next 10 years. Offshore wind manufacturing and assembly, in particular, will involve the use of many skilled trades workers. As such, these jobs encompass more than traditional factory manufacturing; foundation and tower construction includes significant welding, metal work, and concrete work. Tower, monopile foundation, and gravity-based foundation assembly also employs welders and other metalworking occupations, concrete laborers, and other skilled trades.

The construction sector would grow by roughly 1.03 million job-years through 2030, followed by utilities with about 203,000 job-years and wholesale trade with 73,000 job-years over the next decade. The increased activity in these sectors would also create an additional roughly 513,000 job-years across other industry sectors in the U.S. economy through 2030.

Table 2 highlights total projected job creation by industry and technology for scenario 2.

TABLE 1. TOTAL PROJECTED JOB-YEARS BY INDUSTRY & TECHNOLOGY UNDER SCENARIO 1

	Distributed Solar	Utility-scale Solar	Land-based Wind	Offshore Wind	Battery Storage	TOTAL	% of Jobs Created
Construction	136,520	205,803	556,451	69,723	62,139	**1,030,636**	**20.9%**
Manufacturing	100,562	283,251	829,685	560,146	88,889	**1,862,533**	**37.7%**
Wholesale Trade[18]	11,833	45,793	-	-	15,328	**72,955**	**1.5%**
Project Development & Operations[19]	435,644	583,315	40,971	35,895	157,288	**1,253,112**	**25.4%**
Utilities	614	3,207	170,388	24,146	4,942	**203,298**	**4.1%**
All Other Sectors[20]	182,243	124,615	145,258	16,680	43,993	**512,788**	**10.4%**
TOTAL	**867,416**	**1,245,985**	**1,742,753**	**706,589**	**372,579**	**4,935,323**	

[18] Under the JEDI model used for land-based and offshore wind, 100 percent of expenditures go to companies that produce, transport, operate, and build projects. As such, there is no wholesale trade employment output for the wind sector, whereas the solar and battery storage models from IMPLAN include trade as the wholesaler's margin.
[19] This includes professional and business services such as consulting, finance, research, and legal support as well as other professional, scientific, and technical jobs such as architecture, engineering, and specialized design services.
[20] This includes indirect jobs created across agriculture, mining, retail trade, transportation, educational services, healthcare, arts, entertainment, and recreation, accommodation and food services, public administration, and other services such as repair and maintenance.

TABLE 2. TOTAL PROJECTED JOB-YEARS BY INDUSTRY & TECHNOLOGY UNDER SCENARIO 2

	Distributed Solar	Utility-scale Solar	Land-based Wind	Offshore Wind	Battery Storage	TOTAL	% of Jobs Created
Construction	164,287	247,240	668,762	83,699	74,698	**1,238,687**	**20.6%**
Manufacturing	121,015	340,282	997,144	743,131	106,856	**2,308,429**	**38.4%**
Wholesale Trade[21]	14,240	55,013	-	-	18,426	**87,680**	**1.5%**
Project Development & Operations[22]	524,249	700,761	49,240	47,046	189,080	**1,510,376**	**25.1%**
Utilities	739	3,853	204,778	28,957	5,941	**244,269**	**4.1%**
All Other Sectors[23]	219,309	149,705	174,576	21,057	52,885	**617,532**	**10.3%**
TOTAL	**1,043,840**	**1,496,855**	**2,094,501**	**923,890**	**447,888**	**6,006,974**	

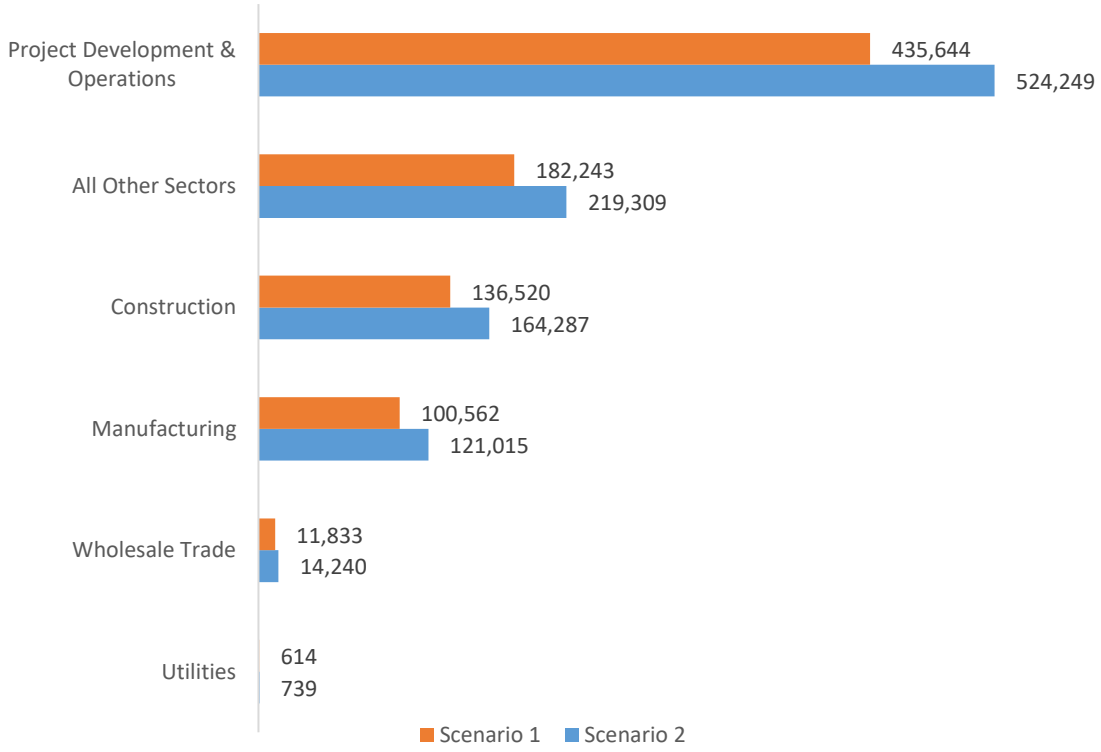
[21] Under the JEDI model used for land-based and offshore wind, 100 percent of expenditures go to companies that produce, transport, operate, and build projects. As such, there is no wholesale trade employment output for the wind sector, whereas the solar and battery storage models from IMPLAN include trade as the wholesaler's margin.
[22] This includes professional and business services such as consulting, finance, research, and legal support as well as other professional, scientific, and technical jobs such as architecture, engineering, and specialized design services.
[23] This includes indirect jobs created across agriculture, mining, retail trade, transportation, educational services, healthcare, arts, entertainment, and recreation, accommodation and food services, public administration, and other services such as repair and maintenance.

SOLAR

Under policy scenario 1, a 59 GW addition to distributed solar capacity, representing roughly $123.8 billion in domestic investments[24] over the next ten years, would result in the creation of 867,416 job-years through 2030. A 71 GW addition in distributed solar capacity, representing $149 billion in domestic investments, would create 1.04 million job-years through 2030.

The majority of employment growth for distributed solar would be found in the project development and operations sector, which includes legal services, accounting, architecture and engineering, information technology, management and consulting services, scientific research, or marketing and advertising services. On average, job creation within the project development and operations sector represents 50 percent of total job-years created for distributed solar, followed by all other sectors at 21 percent, construction (16 percent), manufacturing (12 percent), wholesale trade (one percent), and utilities (less than one percent).

FIGURE 8. DISTRIBUTED SOLAR JOB CREATION THROUGH 2030 BY INDUSTRY & SCENARIO

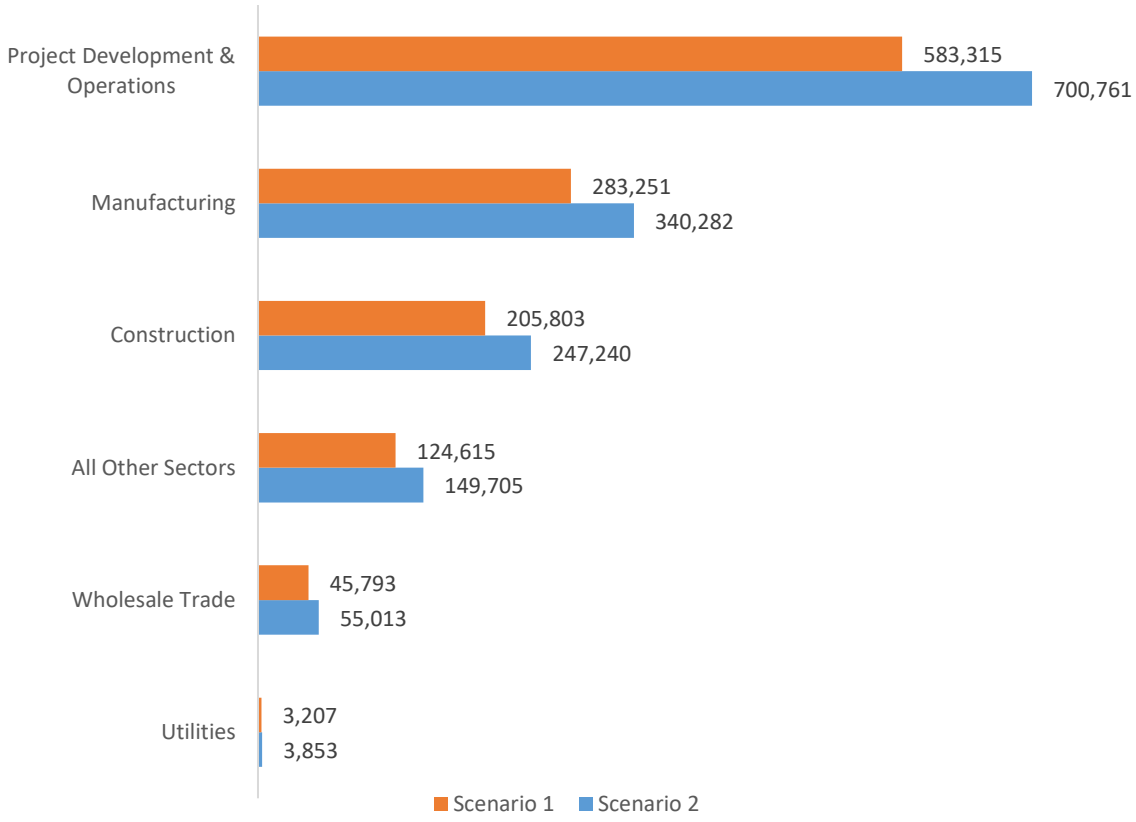


[24] See the methodology section of this report for more information on total project costs and domestic spending for each technology.

Under policy scenario 1, a 298 GW increase in utility-scale solar which represents more than $177.3 billion in domestic investments would create 832,582 job-years over the next 10 years while a 70 percent—358 GW representing $213 billion in domestic investments—increase under scenario 2 creates more than one million job-years in the utility-scale solar sector through 2030.

Unlike distributed solar, employment growth for utility-scale solar is concentrated in the construction industry. On average, construction industry job growth represents roughly four in ten job-years created (40 percent), followed by project development and operations at about three in ten job-years (27 percent), manufacturing (18 percent), all other sectors (11 percent), wholesale trade (four percent), and utilities (less than one percent).[25]

FIGURE 9. UTILITY-SCALE SOLAR JOB CREATION THROUGH 2030 BY INDUSTRY & SCENARIO



[25] It is also important to note that there will be additional operations and maintenance (O&M) jobs created in the solar sector following project construction, though these jobs are not included in the above calculations given recent and forecasted O&M cost reductions due to semi- and fully-automated O&M processes; the research team chose to be conservative in its estimation of future O&M impacts in the solar industry. For more information on O&M costs, please see the National Renewable Energy Laboratory's (NREL) U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018 Report.

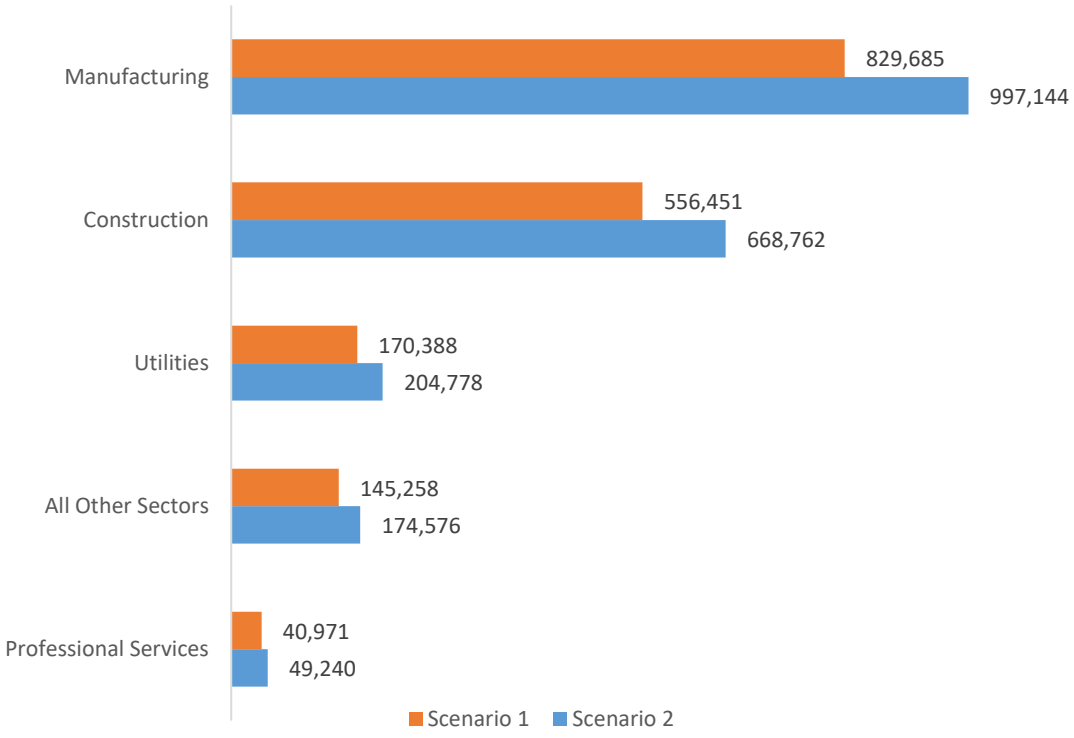
WIND

Overall, an increase of 218 GW of land-based wind capacity—representing more than $242.7 billion in domestic spending—under policy scenario 1 would result in the creation of 1.74 million job-years over the next decade; policy scenario 2, which calls for 262 GW of land-based wind capacity, representing $291.7 billion in domestic investments, would create an additional 351,748 job-years for a total of 2.09 million job-years through 2030.

Increased land-based wind capacity would create jobs largely in the manufacturing and construction industries. Growth in employment for the manufacturing and construction sectors each account for a respective 48 and 32 percent of job-years created. Manufacturing workers are required to produce the wind turbine components and parts, such as towers, blades, array and export cables, nacelles, rotors, drivetrains, and other wind turbine components.

Job growth in the utilities sector represents almost 10 percent of total job-years created, followed by all other sectors (eight percent) and project development and operations (two percent).

FIGURE 10. LAND-BASED WIND JOB CREATION THROUGH 2030 BY INDUSTRY & SCENARIO



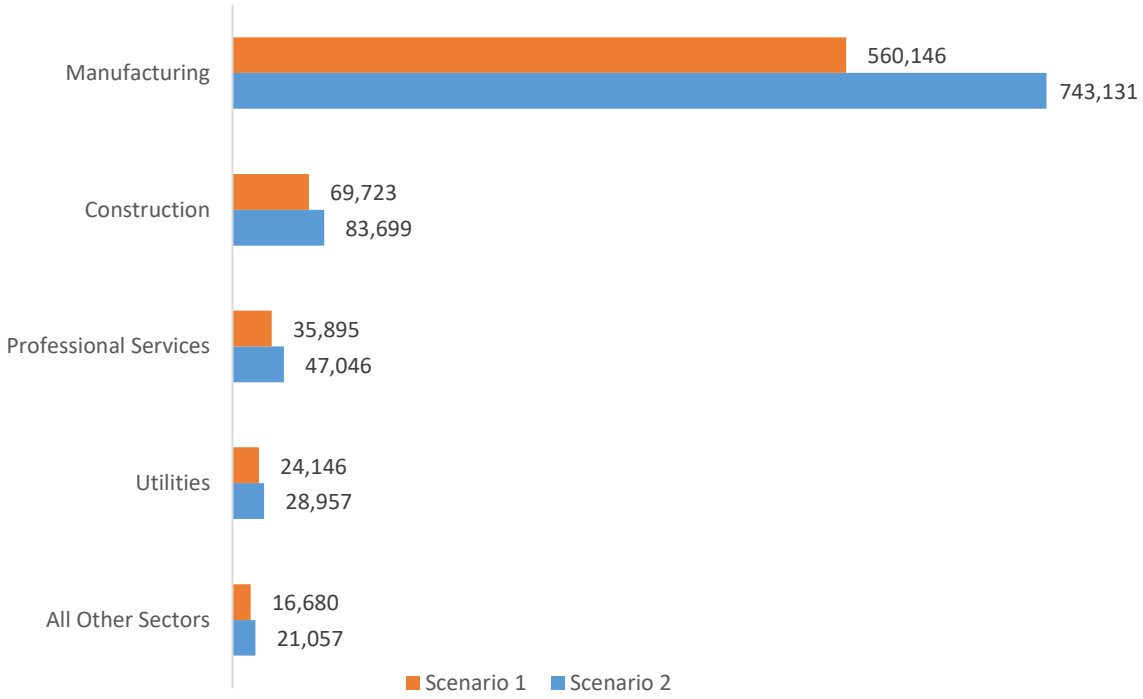
Assuming a 53 GW increase in offshore wind capacity under policy scenario 1, a total of 706,589 job-years would be created through 2030. Adding 64 GW of offshore wind capacity would result in the creation of 923,890 job-years over the next 10 years.

For the offshore wind industry, the majority of employment growth would be concentrated in the manufacturing sector. On average, manufacturing job growth accounts for about eight in ten job-years created, followed by construction at nine percent, project development and operations at five percent, utilities at three percent, and all other sectors at two percent.

Operations & Maintenance (O&M)

Job creation discussed thus far describes work generated during the construction and buildout of land-based and offshore wind projects over the next 10 years. In addition to these job-years, workers will be required to operate, maintain, inspect, and provide technical support throughout the lifespan of these projects. Assuming a 25-year operation period[26], an additional 362,825 direct O&M job-years for land-based and offshore wind would be created under scenario 1 and an additional 3.5 million supply chain, or indirect, O&M job-years. Under scenario 2, this would increase to 436,675 direct job-years in operations and maintenance for 25 years and 4.3 million indirect job-years.

FIGURE 11. OFFSHORE WIND JOB CREATION THROUGH 2030 BY INDUSTRY & SCENARIO



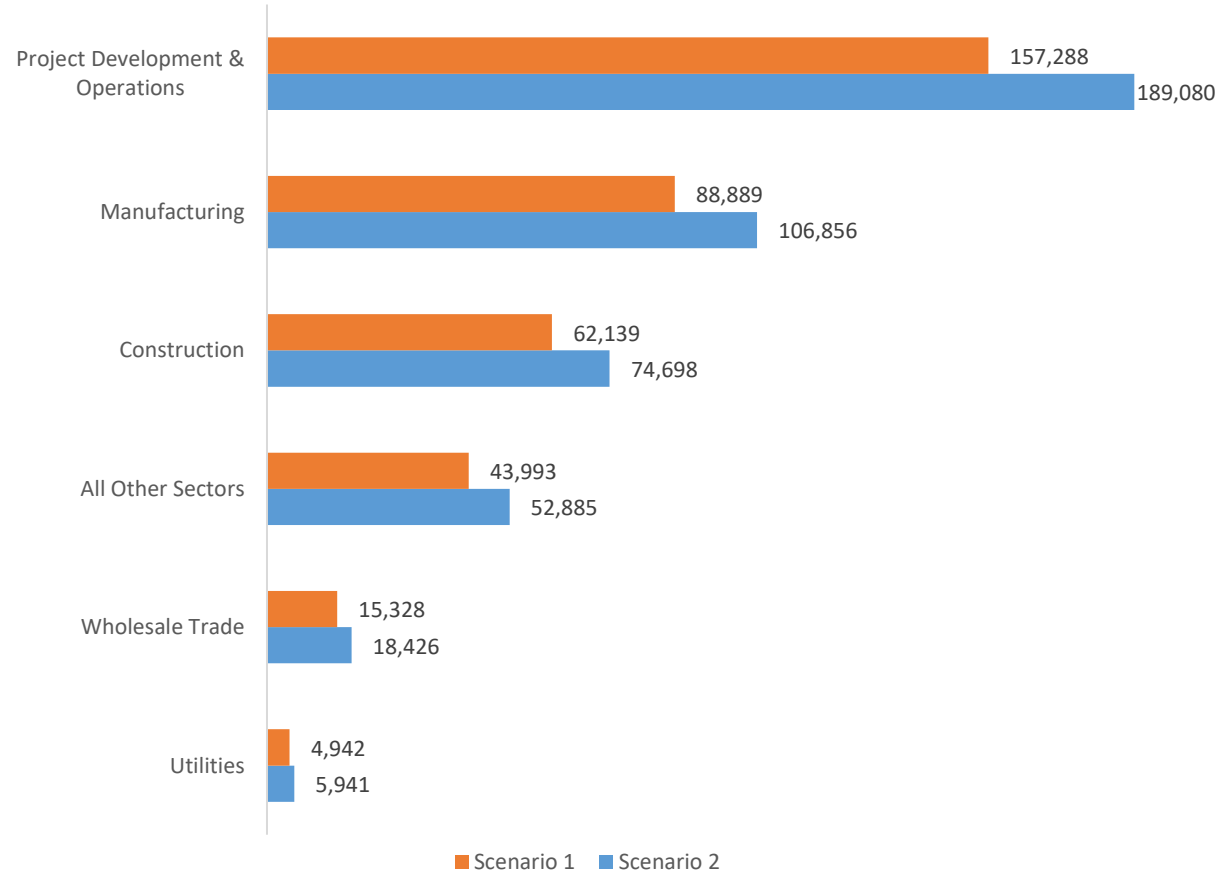
[26] Most projects forecast a 30-year operational life, but the research team chose 25 years as a conservative estimate.

BATTERY STORAGE

A nationwide increase of 188 GW in battery storage capacity (scenario 1), which represents $61.5 billion in domestic spending, would result in the creation of 372,579 million job-years through 2030, while an increase of 226 GW, representing $73.9 billion in domestic spending under policy scenario 2, would create 447,888 job-years over the next decade.

On average, 42 percent of job-years created in battery storage are found in the project development and operations industry, followed by manufacturing (24 percent), construction (17 percent), all other sectors (12 percent), wholesale trade (four percent), and utilities (one percent).

FIGURE 12. BATTERY STORAGE JOB CREATION THROUGH 2030 BY INDUSTRY & SCENARIO

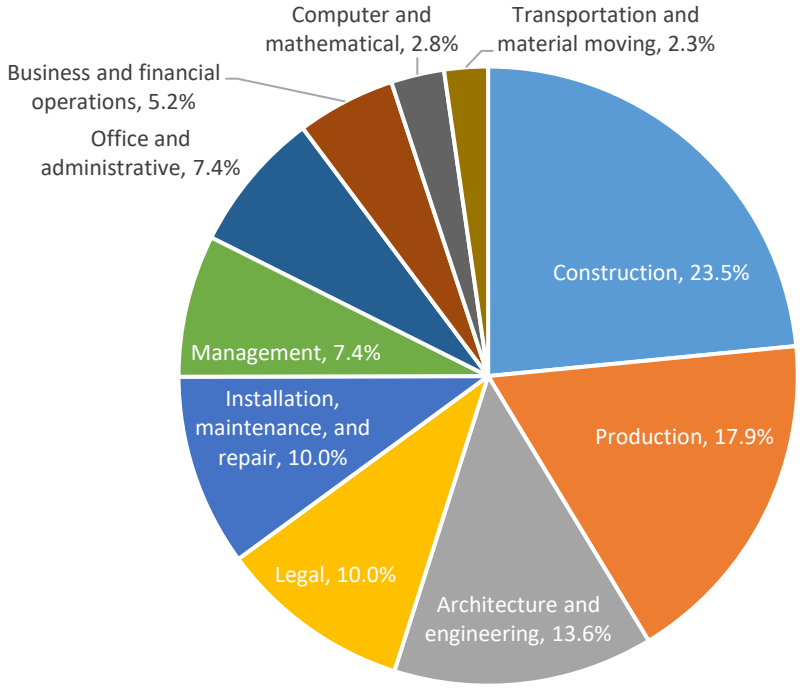


Occupational Demand & Gap Analysis

Table 3 below highlights the top 35 in-demand occupations that will be impacted when increasing nationwide solar, wind, and battery storage capacity. Policy scenarios that increase deployment of these technologies to account for 50 or 70 percent of electricity generation will result in the highest number of jobs created across the occupations in Table 3. In fact, almost half of all job-years created (48 percent) from the decarbonization policy scenarios will be found across this wide range of occupations. On average, a quarter of the top in-demand occupations are construction jobs, followed by production jobs at 18 percent. Architecture and engineering occupations represent 14 percent of in-demand jobs, followed by legal and installation, maintenance, and repair occupations at 10 percent each. The remaining occupational groups—management, office and administrative, business and financial, computer and mathematical, and transportation and material moving—all comprise under 10 percent each.

On average, 65 percent of job-years created across these in-demand occupations will support an average annual wage that is higher than the national average of $56,310. In particular, wind turbine service technicians, electricians, supervisors of production and construction workers or mechanics, and civil and electrical engineers are in-demand occupations that earn more than the national average.

FIGURE 13. AVERAGE DISTRIBUTION OF JOB CREATION IN TOP 35 OCCUPATIONS



The Bureau of Labor Statistics predicts baseline employment growth through 2029, assuming standard economic conditions and without additional climate and decarbonization policies that would accelerate the development of renewables and battery storage capacity. This analysis finds that decarbonization policy and administrative action would result in additional job growth beyond the BLS projections, ultimately producing significant labor supply gaps for the following occupations: wind turbine service technicians, solar photovoltaic installers, semiconductor processing technicians, structural metal fabricators and fitters, electrician helpers, and electricians. The high demand for these jobs resulting from decarbonization policies, plus standard baseline economic growth, could result in labor supply gaps that could stall project development. Though there are additional occupations with projected employment gaps featured in Table 3, the aforementioned occupations are those which are likely to experience the most significant gaps over the next ten years.

Wind Turbine Service Technicians

Wind turbine service technicians will experience the greatest occupational gap assuming a 50 or 70 percent renewable standard.[27] In 2020, there were 5,860 wind turbine service technicians across the U.S. The BLS projects this occupation to grow by 93 percent through 2029, an addition of more than 5,400 jobs. However, under a decarbonization policy scenario, the demand for wind turbine service technicians will be 60 percent higher than the BLS-projected growth for 2029. The analysis finds that an average of 6,769 wind turbine service technicians will be needed each year for the next ten years to support the project development buildout of land-based and offshore wind technologies. In total, just over 12,200 wind turbine service technicians must be trained through 2030 in order to support both baseline economic conditions and a ramping up of renewable deployment through decarbonization policy action.

Solar Photovoltaic (PV) Installers

The demand for solar photovoltaic installers over the next decade is 21 percent higher than the BLS projections under standard economic conditions. To date, there are almost 11,500 solar photovoltaic installers as of 2020. Through 2029, the BLS projects that these jobs will grow by 58 percent, resulting in an additional roughly 6,600 new solar installer positions. However, including a decarbonization policy scenario would require yet another 3,735 solar PV installers each year for the next decade. In total, in order to support baseline growth and accelerated renewable capacity buildout, the labor market must supply 10,345 solar PV installers through 2030.

[27] It should be noted that the wind turbine service technician jobs modeled in the gap analysis support the construction and installation phase. O&M jobs are not modeled in the gap analysis.

Semiconductor Processing Technicians

Semiconductor processing technicians are vital to the acceleration of solar deployment. These individuals support the manufacture of electronic semiconductors through a variety of tasks. At the end of 2020, there were just over 31,000 semiconductor processing technicians across the U.S. Through 2029, the Bureau of Labor Statistics actually projected a slight decline in these positions, by less than a percent or about 80 jobs. However, under accelerated decarbonization and renewable capacity deployment, semiconductor processing technician positions will grow by roughly 5,600 jobs over the next decade.[28]

Structural Metal Fabricators and Fitters

On average, decarbonization policy action would result in the creation of just over 8,600 new positions for structural metal fabricators and fitters. The Bureau of Labor Statistics projects that these occupations would decline through 2029, by five percent or almost 3,600 positions. However, a 50 or 70 percent renewable standard, and with the significant increase in domestic manufacturing for wind turbine components and electrical wiring and power distributor and transformer manufacturing for solar panels, these jobs are expected to see significant growth over the next decade. By 2030, the labor market will have to supply just over 5,000 structural metal fabricators and fitters in order to achieve renewable and storage capacity goals.

Electricians and Electrician Helpers

On average, additional employment growth resulting from decarbonization policies would support the creation of 40,891 electrician jobs for 10 years. There are currently 656,510 electricians across the United States and the Bureau of Labor Statistics projects that figure to grow by 22 percent through 2029, an increase of about 145,000 jobs. However, in order to meet projections for baseline economic conditions as well as the additional economic activity and labor market growth generated under decarbonization policy scenarios, the labor market will need to meet the demand for roughly 185,781 electricians from now through 2030. The demand for electricians under a 50 or 70 percent renewable standard is five percent higher than the overall BLS projection. As of 2020, 31 percent of electricians—or 204,175 electricians—are union members (see Table 5).

Electrician helpers support duties that require less skill or certification compared to licensed electricians. These individuals support projects by supplying materials, cleaning work areas and equipment, breaking up concrete, digging trenches, or bolting component parts together. Under a decarbonization policy scenario, an average of 4,511 electrician helper positions will be created over 10 years. The BLS already projects this occupation to grow by 11 percent, or almost

[28] This takes into account both the projected growth under decarbonization and the BLS projected decline over the next decade.

8,400 jobs through 2029. In order to meet general economic growth demands and the additional growth under decarbonization policies, the labor market must generate almost 12,900 electrician helpers over the next decade.

TABLE 3. TOP 35 OCCUPATIONS WITH PROJECTED JOB GROWTH[29]

Occupation	Job Creation (Scenario 1)	Job Creation (Scenario 2)	Average Across Both Scenarios	Total Employment, 2020[30]	BLS 2029 Projection[31]	% Growth Above BLS Projection	Total Projected Need by 2030	Average Wage, 2020[32]
Wind Turbine Service Technicians	6,149	7,388	6,769	5,860	11,300	59.9%	18,069	$59,340
Solar Photovoltaic Installers	3,390	4,079	3,735	11,490	18,100	20.6%	21,835	$48,020
Semiconductor Processing Technicians	5,112	6,144	5,628	31,080	31,000	18.2%	36,628	$45,210
Structural Metal Fabricators and Fitters	7,541	9,711	8,626	69,550	66,000	13.1%	74,626	$44,750
Helpers--Electricians	4,098	4,925	4,511	73,920	82,300	5.5%	86,811	$35,440
Electricians	36,954	44,827	40,891	656,510	801,400	5.1%	842,291	$61,550
Helpers--Installation, Maintenance, and Repair Workers	3,961	5,177	4,569	91,430	105,500	4.3%	110,069	$33,960
Electrical, Electronic, and Electromechanical Assemblers, Except Coil Winders, Tapers, and Finishers	11,589	13,929	12,759	283,800	295,900	4.3%	308,659	$38,750
Electronics Engineers, Except Computer	4,910	5,954	5,432	122,320	136,800	4.0%	142,232	$112,320
Electrical and Electronic Engineering Technologists and Technicians	4,067	4,898	4,483	115,270	127,800	3.5%	132,283	$68,310
Electrical Engineers	5,050	6,073	5,561	185,220	202,100	2.8%	207,661	$105,990
Architectural and Engineering Managers	4,916	5,988	5,452	195,900	203,200	2.7%	208,652	$158,100
Civil Engineers	7,765	9,339	8,552	300,850	334,700	2.6%	343,252	$95,440
Paralegals and Legal Assistants	8,226	9,900	9,063	332,720	373,100	2.4%	382,163	$56,610

[29] For this analysis, job-years are divided by 10 in order to provide comparisons to the BLS occupational projections.
[30] Bureau of Labor Statistics, Occupational Employment and Wage Statistics. May 2020. https://www.bls.gov/oes/home.htm.
[31] Bureau of Labor Statistics, Employment Projections. https://www.bls.gov/emp/.
[32] Bureau of Labor Statistics, Occupational Employment and Wage Statistics. May 2020. https://www.bls.gov/oes/home.htm.

Welders, Cutters, Solderers, and Brazers	9,360	11,538	10,449	397,550	452,500	2.3%	462,949	$46,690
Lawyers	15,889	19,112	17,500	658,120	846,300	2.1%	863,800	$148,910
Industrial Engineers	5,356	6,480	5,918	290,190	325,800	1.8%	331,718	$93,610
Mechanical Engineers	5,411	6,515	5,963	293,960	328,700	1.8%	334,663	$95,560
Industrial Machinery Mechanics	4,243	5,424	4,833	385,980	461,700	1.0%	466,533	$57,350
Machinists	3,514	4,293	3,903	360,340	404,400	1.0%	408,303	$47,800
First-Line Supervisors of Production and Operating Workers	5,326	6,480	5,903	599,900	646,900	0.9%	652,803	$66,800
First-Line Supervisors of Construction Trades and Extraction Workers	5,282	6,348	5,815	614,080	718,000	0.8%	723,815	$72,990
First-Line Supervisors of Mechanics, Installers, and Repairers	3,580	4,465	4,022	475,000	512,400	0.8%	516,422	$73,100
Construction Laborers	6,435	7,733	7,084	971,330	1,473,400	0.5%	1,480,484	$43,000
Management Analysts	4,113	4,944	4,528	734,000	970,200	0.5%	974,728	$97,580
Software Developers and Software Quality Assurance Analysts and Testers	6,674	8,022	7,348	1,476,800	1,785,200	0.4%	1,792,548	$114,270
Maintenance and Repair Workers, General	5,564	7,103	6,334	1,357,630	1,579,400	0.4%	1,585,734	$43,790
General and Operations Managers	9,165	11,157	10,161	2,347,420	2,630,200	0.4%	2,640,361	$125,740
Project Management Specialists and Business Operations Specialists, All Other	4,616	5,549	5,083	1,444,420	1,441,600	0.4%	1,446,683	$84,290
Personal Service Managers, All Other; Entertainment and Recreation Managers, Except Gambling; and Managers, All Other[33]	3,661	4,401	4,031	469,160	1,167,500	0.3%	1,171,531	$123,980

[33] Personal service managers are largely employed in the following industries: management, scientific, and technical consulting services; office administrative service; residential building construction; management of companies and enterprises; building equipment contractors; and executive, legislative, and other government support.

Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	5,960	7,179	6,569	1,850,360	2,022,600	0.3%	2,029,169	$40,420
Bookkeeping, Accounting, and Auditing Clerks	4,103	4,942	4,522	1,443,940	1,578,200	0.3%	1,582,722	$44,100
Office Clerks, General	7,665	9,235	8,450	2,788,090	2,970,400	0.3%	2,978,850	$37,770
Accountants and Auditors	3,656	4,398	4,027	1,274,620	1,497,900	0.3%	1,501,927	$81,660
Laborers and Freight, Stock, and Material Movers, Hand	5,412	6,667	6,040	2,805,200	3,111,700	0.2%	3,117,740	$33,710

Labor Unionization Rates

This year's United States Energy and Employment Report (USEER) includes a methodology revision for union membership and union coverage rates. These data have been revised due to feedback from industry and concerns over non-response bias. As a result, the data on union membership are not comparable to previous USEER reports. The updated methodology includes Current Population Statistics (CPS), CIC-NAICS crosswalks, and data from the Bureau of Labor Statistics (BLS), in addition to USEER survey data.[34]

Union membership rates across the solar, wind, and battery storage sectors sit at around 9.5 percent while union coverage or representation rates are just above 10 percent across each sector. By comparison, the national private-sector union membership rate was 6.3 percent in 2020 while the union representation rate was 7.2 percent.[35]

Of the industries compared in Figure 14—those most commonly found in renewable energy technology sectors—utilities have the highest unionization rates, followed by construction, manufacturing, wholesale trade, and project development and operations. Both the solar and battery storage sector are mostly comprised of construction jobs. Roughly 53 percent of employment in the solar sector is found in construction, while 47 percent of jobs in the storage sector are also in the construction industry. Though not the majority of employment, the largest industry employer within the wind sector is also construction, comprising about a third of total wind jobs. In general, these three sectors are largely composed of construction, manufacturing, and project development and operations jobs.[36] Not surprisingly, because solar, wind, and battery storage have few utility jobs, these technology sectors are more likely to have unionization rates similar to those of the construction or manufacturing industries.

In terms of occupational groups, construction occupations[37] have the highest rates of unionization, with an almost 19 percent union representation rate and a 17 percent union membership rate. Just under 16 percent of workers in installation, maintenance, and repair occupations are covered by unions while 15 percent are union members. Architecture and engineering occupations are the least unionized by comparison in Figure 15.

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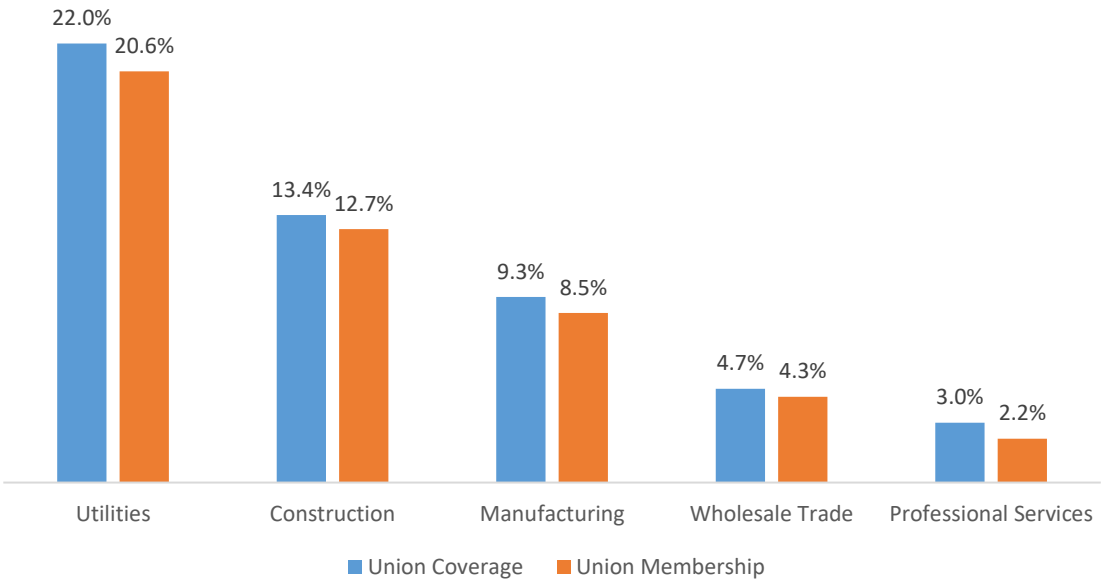
[34] For more information, see the methodology section of this report or visit: https://www.usenergyjobs.org/.
[35] Bureau of Labor Statistics. Union Membership Annual News Release. January 2021. https://www.bls.gov/news.release/union2.htm.
[36] Wages, Benefits, and Change: A Supplemental Report to the Annual U.S. Energy and Employment Report. https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/606d110dbef912521b0153b9/1617760533719/Wage+Reporrt.pdf
[37] This is based on the overall occupational group—construction and extraction. Though there are no mining and resource extraction-related occupations within the renewable and battery storage sectors, unionization data for these occupational groups is not delineated in publicly-available datasets and thus can only be provided for the full group—construction and extraction.

TABLE 4. UNIONIZATION RATES BY TECHNOLOGY SECTOR, Q4 2020[38]

	Union Coverage	Union Membership
Solar	10.3%	9.6%
Wind	10.2%	9.5%
Battery Storage	10.3%	9.6%

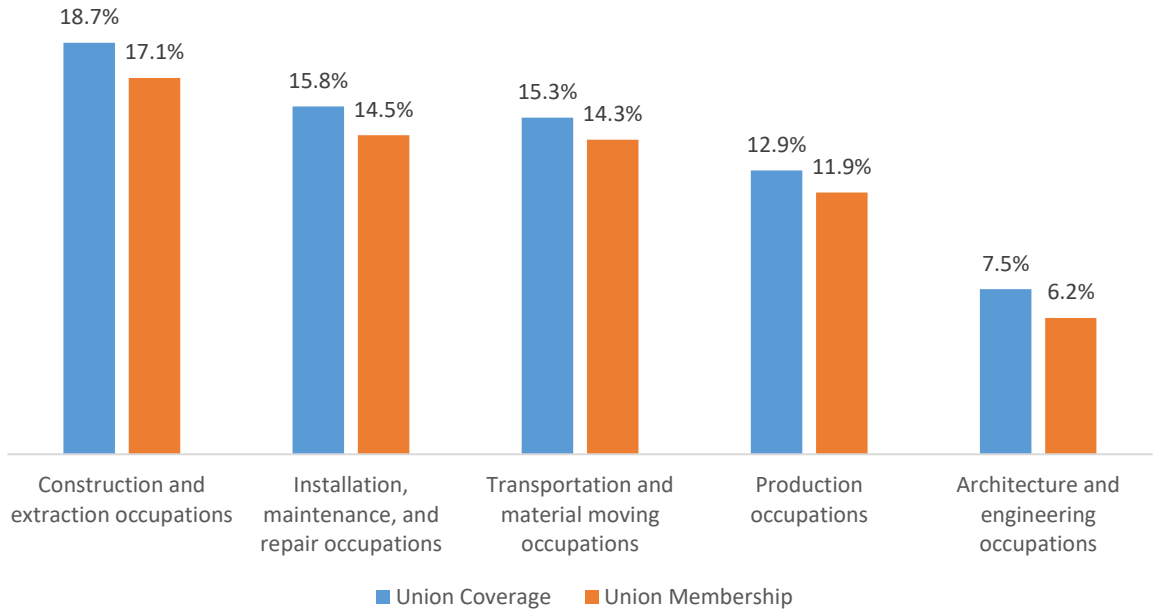
FIGURE 14. UNIONIZATION RATES BY INDUSTRY, 2020[39]



[38] Workers are counted as union *members* if they are a member of a labor union or of an employee association similar to a union. Workers are counted as *covered* by a collective bargaining agreement if they are union members or if they are not members but say they are covered by a union contract." Definitions are from Barry T. Hirsch and David A. Macpherson, "Union Membership and Coverage Database from the Current Population Survey: Note," *Industrial and Labor Relations Review*, 56, no. 2 (January 2003): 349-54, http://unionstats.gsu.edu/UnionStats.pdf.

[39] Bureau of Labor Statistics. Union Membership Annual News Release. January 2021. https://www.bls.gov/news.release/union2.htm.

FIGURE 15. UNIONIZATION RATES BY OCCUPATIONAL GROUP, 2020[40]



[40] Bureau of Labor Statistics. Union Membership Annual News Release. January 2021. https://www.bls.gov/news.release/union2.htm.

Of the top 35 in-demand occupations for which data exists, electricians, structural metal fabricators, and construction trade supervisors have among the highest rates of union membership and coverage.

TABLE 5. UNIONIZATION RATES FOR SELECT OCCUPATIONS, 2020[41]

	Union Membership	Union Coverage
Electricians	31.1%	32.4%
Structural Metal Fabricators and Fitters	21.0%	21.0%
First-Line Supervisors of Construction Trades and Extraction Workers	19.7%	20.9%
Electrical and Electronic Engineering Technologists and Technicians	15.8%	17.6%
Laborers and Freight, Stock, and Material Movers, Hand	13.6%	14.4%
Maintenance and Repair Workers, General	12.7%	14.2%
Solar Photovoltaic Installers	13.8%	13.8%
Construction Laborers	11.8%	12.8%
Machinists	12.4%	12.7%
Civil Engineers	9.9%	11.3%
Office Clerks, General	10.3%	11.3%
First-Line Supervisors of Production and Operating Workers	8.7%	9.8%
Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	7.7%	8.5%
Lawyers	7.2%	8.3%
First-Line Supervisors of Mechanics, Installers, and Repairers	7.0%	7.2%
Mechanical Engineers	3.1%	6.0%
Paralegals and Legal Assistants	4.7%	5.6%
Accountants and Auditors	4.3%	5.4%
Architectural and Engineering Managers	4.0%	4.8%
General and Operations Managers	2.6%	3.9%
Bookkeeping, Accounting, and Auditing Clerks	3.4%	3.8%
Helpers--Installation, Maintenance, and Repair Workers	3.1%	3.1%
Management Analysts	1.8%	2.8%

[41] Occupational unionization data is from the Union Membership and Coverage Database, based on the Bureau of Labor Statistics Current Population Survey, which can be found at: http://www.unionstats.com/. The unionization rates featured in Table 5 are meant to describe unionization membership and coverage for the top 35 occupations in-demand occupations discussed in the Occupational Demand & Gap Analysis section. Unfortunately, 12 out of the 35 occupations do not have publicly-available unionization data. As such, Table 5 features those out of the top 35 for which data is available.

Appendix A: Research Methodology

EMPLOYMENT MODELING METHODOLOGY

Offshore Wind

The research team used NREL JEDI Offshore (OSW) v.10.24.17 to calculate both direct and indirect jobs impacts, splitting the total capacity additions for each scenario evenly between five two-year intervals. The research team ran the JEDI OSW model using United States region, 12,000 kW turbine size, and 2020 dollars under the "advanced" setting. For each interval, the research team adjusted the domestic installation labor requirements up 10 percentage points, starting at 50 percent domestic labor for the first interval and ending at 90 percent for the last interval. The total and local spending under the two scenarios is detailed in the table below.

	Scenario 1	Scenario 2
Total Project Cost	$178,974,992,281	$232,126,165,863
Local Spending	$141,718,168,403	$186,513,770,075

Land-based Wind

The research team used NREL JEDI LBW v.6.28.19 to calculate both direct and indirect impacts. The research team used adjusted local content data of equipment costs, increasing turbines from 20 to 50 percent, blades from 60 to 70 percent, and towers from 80 to 85 percent. The research team ran all capacity additions for each scenario under one project in the United States region, using 2,500 kW turbine size and 2020 dollars. The total and local spending under the two scenarios is detailed in the table below.

	Scenario 1	Scenario 2
Total Project Cost	$329,022,638,616	$395,430,877,603
Local Spending	$242,720,512,073	$291,709,973,225

Battery Storage

The battery storage model used an IMPLAN-by-parts analysis at the national level by assigning industry impacts by share of total project cost using the 60 MW 2-hour standalone Li-ion model from the NREL report, *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmark: Q1 2020*.[42] Cost per watt of $0.81 from the same report was used to calculate total costs of capacity additions under each scenario.[43] A domestic content requirement of 25 percent was used in the

[42] https://www.nrel.gov/docs/fy21osti/77324.pdf
[43] $0.81/Watt omits contingency cost.

calculation of IMPLAN inputs for manufacturing industries. Below is a table detailing the share of total project cost from the NREL study as well as the final input amounts by IMPLAN industry under each scenario. The input columns for each component are costs after adjusting for domestic content.

Code	Description	Impact	Share	Scenario 1 Inputs†	Scenario 2 Inputs†
455	Legal services	Output	1%	$925,238,867	$1,112,255,233
47	Electric power transmission and distribution	Output	4%	$5,795,021,667	$6,966,355,833
457	Architectural and engineering services	Output	10%	$15,514,721,933	$18,650,676,367
52	Construction of new power structures	Output	8%	$11,612,443,533	$13,959,639,567
336	Other energy wire manufacturing	Output	13%	$4,768,529,917	$5,732,381,708
236	Fabricated metal structure manufacturing	Output	4%	$1,451,685,867	$1,745,111,733
329	Power distribution and transformer manufacturing	Output	7%	$2,820,000,000	$3,390,000,000
333	Storage battery manufacturing	Output	49%	$18,612,000,000	$22,374,000,000
	Total Project Costs			**$151,463,490,933**	**$182,078,451,867**
	Total Domestic Costs			**$61,499,641,783**	**$73,930,420,442**

Distributed & Utility-scale Solar

The solar modeling used an IMPLAN-by-parts analysis at the national level using cost data from the same NREL technical paper referenced above, using the 100 MW utility model and a weighted average of the 7.0 kW residential and 200 kW commercial models for distributed.[44] Cost per watt of $0.98 for utility PV and $2.64 for distributed is used.[45] The research team assumed local manufacturing content of 25 percent for semiconductor manufacturing and power distribution and transformer manufacturing. Tables below detail the cost inputs by industry for both scenarios for both distributed and utility PV. The input columns for each component are costs after adjusting for domestic content. In order to correctly assign impacts by type and avoid double counting of impacts, the research team took the employment outputs from this IMPLAN analysis by industry and summed all indirect employment impacts with the direct employment impacts for the manufacturing, wholesale, and government industries that are part of the solar supply chain. The research team then summed the remaining direct jobs impacts in the construction and project development and operations industries.

Code	Description	Impact	Share	Utility PV Scenario 1 Input†	Utility PV Scenario 2 Input†
457	Architectural and engineering services	Output	13%	$38,740,000,000	$46,540,000,000
52	Construction of new power structures	Output	11%	$32,780,000,000	$39,380,000,000
455	Legal services	Output	5%	$14,900,000,000	$17,900,000,000

† Column does not sum to the total project cost listed due to domestic content requirements.

[44] https://www.nrel.gov/docs/fy21osti/77324.pdf

[45] $0.98/Watt and $2.64/Watt omit contingency cost.

336	Other energy wire manufacturing	Output	7%	$20,860,000,000	$25,060,000,000
236	Fabricated metal structure manufacturing	Output	12%	$35,760,000,000	$42,960,000,000
307	Semiconductor Manufacturing	Output	42%	$30,545,000,000	$36,695,000,000
329	Power distribution and transformer manufacturing	Output	5%	$3,725,000,000	$4,475,000,000
	Total Project Costs			**$292,040,000,000**	**$350,840,000,000**
	Total Domestic Costs			**$177,310,000,000**	**$213,010,000,000**

Code	Description	Impact	Share	Distributed PV Scenario 1 Input†	Distributed PV Scenario 2 Input†
457	Architectural and engineering services	Output	21%	$32,532,600,000	$39,149,400,000
52	Construction of new power structures	Output	7%	$10,962,200,000	$13,191,800,000
455	Legal services	Output	9%	$13,676,200,000	$16,457,800,000
465	Advertising and PR	Output	16%	$24,355,200,000	$29,308,800,000
395	Wholesale Equipment and Supplies	Output	9%	$14,726,400,000	$17,721,600,000
336	Other energy wire manufacturing	Output	9%	$13,404,800,000	$16,131,200,000
236	Fabricated metal structure manufacturing	Output	3%	$4,696,400,000	$5,651,600,000
307	Semiconductor Manufacturing	Output	15%	$5,926,550,000	$7,131,950,000
329	Power distribution and transformer manufacturing	Output	9%	$3,560,650,000	$4,284,850,000
	Total Project Costs			**$155,771,800,000**	**$187,454,200,000**
	Total Domestic Costs			**$123,841,000,000**	**$149,029,000,000**

UNIONIZATION RATES

Technology sector unionization rate data for solar, wind, and battery storage uses a revised extrapolation methodology from those reported in the 2020 U.S. Energy and Employment Report (USEER). The updated methodology uses national employment within each energy sub-technology sector broken out by industry and organized by North American Industry Classification System (NAICS) codes. These employment numbers are derived from the 2021 USEER, methodology for which can be found at https://www.usenergyjobs.org/. The 2020 union membership rates by industry are converted from their original Census Industry Code (CIC) organization to NAICS codes using a CIC-NAICS crosswalk.[46,47] The research team then weighted the union membership rate for each NAICS code on the corresponding employment within each sub-technology in order to calculate the final sub-technology unionization rate.

† Column does not sum to the total project cost listed due to domestic content requirements.

[46] Barry T. Hirsch and David A. Macpherson, "IV. Industry: Union Membership, Coverage, Density, and Employment by Industry, 2019." https://www.unionstats.com/

[47] Crosswalk found at https://www.census.gov/topics/employment/industry-occupation/guidance/code-lists.html