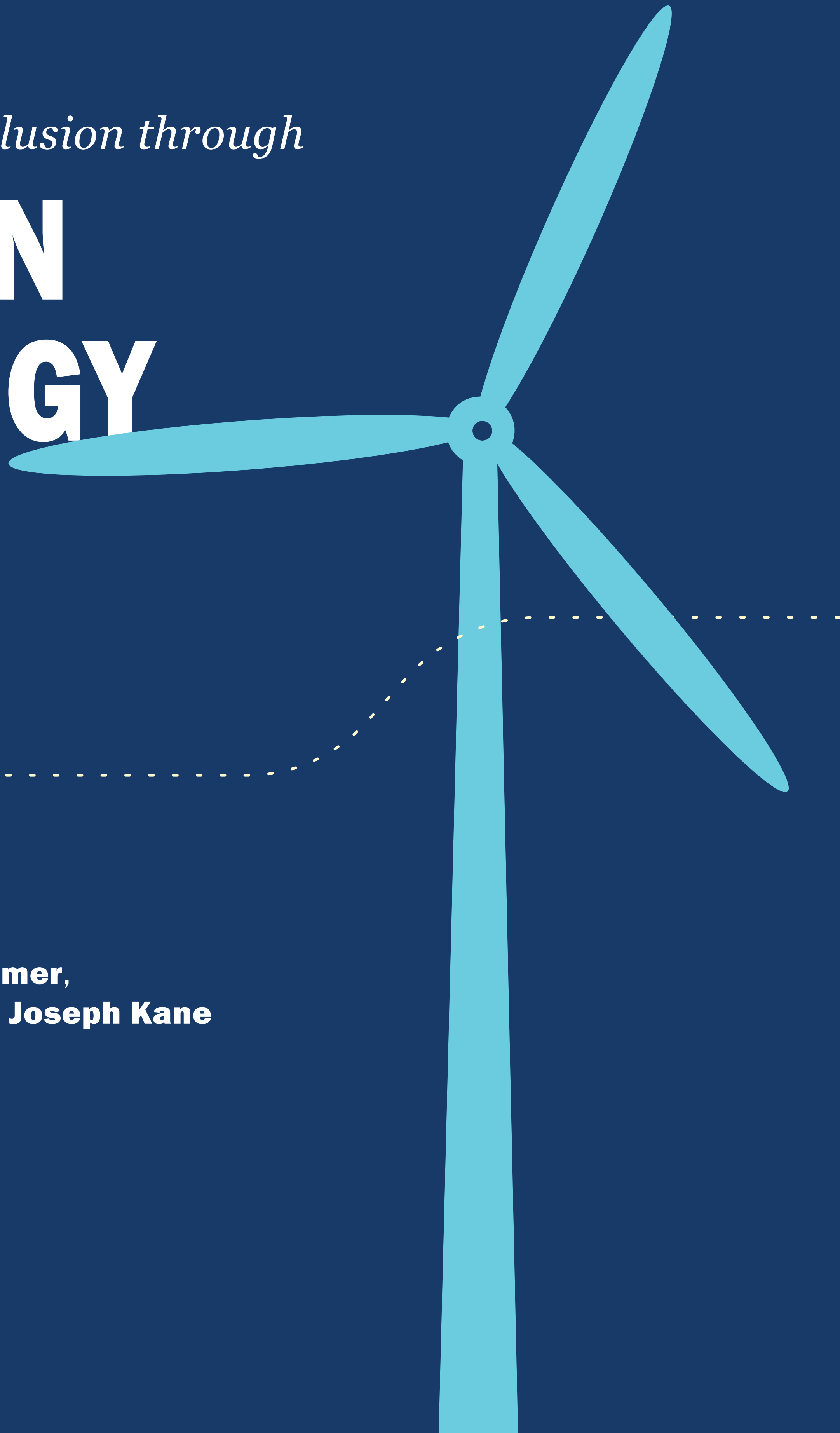
Advancing inclusion through

CLEAN ENERGY JOBS



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April 2019

Metropolitan Policy Program
at BROOKINGS

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Executive summary

The transition to a clean energy economy continues. Motivated by mounting scientific evidence, shifting market forces, and in some cases policy, U.S. industries have responded by installing more zero-carbon energy sources, developing more energy-efficient products, and adopting more environmentally-sensitive standards. More recently debates have broken out in Congress over the need for an ambitious Green New Deal centered on clean energy economy employment. As a result, shifts in "green jobs," carbon emissions, electricity consumption, and resilience to climate shocks have become some of the highest-profile, most-debated trends of the decade.

While much has been written about all of those topics, considerably less attention has been paid to how all this intersects with the workforce. Over the years, assessments of the "clean" or "green" economy have often focused on "sizing" the sector by counting associated jobs under various clean energy activities. These counts are vital, confirming the extent of the country's energy evolution. Yet they tell us little about the nature of work and the occupations necessary to deliver a functional clean energy economy moving forward.

Focused squarely on the workforce side of the clean energy transition, this analysis intends to help energy-sector professionals, state and local policymakers, regional education and training-sector leaders, and community organizations get a clearer look at the nature, needs, and opportunities associated with the future clean energy workforce. In particular, this analysis aims to explore the extent to which such occupations will offer inclusive pathways to economic opportunity.

Using federal datasets and industrial classifications from prior clean energy economy research, this report finds that:

- **The transition to the clean energy economy will primarily involve 320 unique occupations spread across three major industrial sectors:** *clean energy production*, *energy efficiency*, **and** *environmental management*. These occupations represent a range of workplace responsibilities, from jobs unique to the energy sector to support services found throughout the broader economy.

- **Workers in clean energy earn higher and more equitable wages when compared to all workers nationally.** Mean hourly wages exceed national averages by 8 to 19 percent. Clean energy economy wages are also more equitable; workers at lower ends of the income spectrum can earn $5 to $10 more per hour than other jobs.

- **Even when they have higher pay, many occupations within the clean energy economy tend to have lower educational requirements**. This is especially true within the ***clean energy production*** and ***energy efficiency*** *sectors*, which include sizable occupations like electricians, carpenters, and plumbers. Roughly 50 percent of workers attain no more than a high school diploma yet earn higher wages than similarly-educated peers in other industries.

- **Occupations within the *clean energy production* and *energy efficiency* sectors tend to require greater scientific knowledge and technical skills than the average American job.** Conversely, knowledge and skill requirements in *environmental management* occupations trend towards national averages.

- **The clean energy economy workforce is older, dominated by male workers, and lacks racial diversity when compared to all occupations nationally.** Fewer than 20 percent of workers in the ***clean energy production*** and ***energy efficiency*** sectors are women, while black workers fill less than ten percent of these sector's jobs.

These results confirm the transition to a clean energy economy could help address economic inclusion challenges from the national to the local level. However, the current roster of workers in related occupations is far from inclusive—suggesting the existence of distinct barriers to access that require additional attention and action.

I. Introduction

The U.S. economy is in the midst of a dramatic energy transition.

In the face of a changing climate, rising sea levels, and various national security concerns, market forces—assisted by public policy—continue to shift key portions of the American economy away from carbon-intensive, fossil fuel driven activities toward cleaner, more efficient, and higher-output ones, especially through greater energy efficiency and more use of renewable energy sources.

Consumers are changing their behavior and increasingly seeking greener alternatives as new products flood the marketplace. Businesses are launching new innovations, shifting production schedules, and bringing cleaner products and services to the market to serve them. And with the recent promotion by climate activists of an ambitious Green New Deal, fiery policy debates have broken out in Congress over the need for investments in clean-energy jobs and infrastructure.[1]

As a result, big changes in consumption patterns, manufacturing processes, the power sector, and regulatory affairs—all related to the shift to reduced carbon emissions—have become some of the highest-profile, most-debated trends of the decade.

While much has been written about all of those trends, less attention has been paid to how all this intersects with the American workforce—even though "green jobs" lie at the center of the Green New Deal vision. This is a gap in the debates, given that the clean-energy transition impacts and crucially depends on having an appropriately skilled workforce to carry out the wide range of activities associated with this economy-wide effort. These activities range from assembly-line laborers to manufacture energy-saving products, tradesman to construct energy-efficient buildings, or technicians to operate renewable energy facilities. The continued expansion of the American clean energy sector may well have significant implications for the American labor market, education and training institutions, and the need to locate more durable, family-supporting jobs with limited barriers to entry at a time of widening income inequality and a shrinking middle class.

Yet, it has been hard to get a clear sense of the labor market opportunities that are emerging during this transition. With more attention focused on demonstrating the size and growth of today's clean energy economy industries, much less research has drilled down on the characteristics of the occupations involved in the transition. And most research has not closely examined the skills required for such jobs or the demographic and educational profile of those who fill them; one notable exception is a recent UC Berkeley study examining diversity in California's clean energy workforce.[2]

Focused squarely on the workforce side of the clean energy transition, the following analysis is intended to help energy-sector professionals, state and local policymakers, regional education and training-sector leaders, and community organizations get a clearer look at the nature, needs, and opportunities associated with the future clean energy workforce.

Building on existing definitions of the clean energy sector, this report first moves to classify the broad range of occupations implicated in this economy-wide transition and employ a novel methodology using Bureau of Labor Statistics and O*NET data to characterize the individuals who currently fill those positions.[3] The analysis then uses the earnings, educational background, skills development, and demographics of this workforce to characterize how inclusive the future clean energy economy is likely to be. Finally, the report concludes with top-line implications for the businesses, workforce development organizations, and government actors who will help develop the clean energy economy workforce.

The resulting analysis projects great promise for the U.S. labor market and household opportunity as the clean energy economy transitions continues to push forward. Yet delivering economy-wide prosperity based on the inclusive nature of many clean energy economy occupations will require a more concerted effort to ensure all individuals can fill these jobs.

II. Defining occupations in the clean energy economy transition

The energy-related economy already leaves a sizable footprint on the labor market. More than 3.6 million workers are employed in traditional energy jobs—focused on energy production, transmission, distribution, and storage—but this is just one small slice of the millions of jobs in utilities, product manufacturing, construction, and environmental regulation that compose the full suite of energy-related activities.[4]

Staffing all these industries entails a broad assortment of occupations. Energy-related industries are typified by a need for skilled trades to help manufacture advanced products, execute large-scale construction projects, research and develop new technologies, and deliver other detailed STEM-related services.[5] At the same time, businesses within these industries rely on an expansive suite of support services—including business, financial, and customer management—to compete.[6] Likewise, government and nonprofit organizations rely on specially trained workers to execute their missions.[7]

Considering that many of today's industries that contribute to dirtier activities will become central to tomorrow's clean energy economy, defining clean energy economy occupations means looking much wider than just the newest green occupations. Solar photovoltaic installers and wind turbine service technicians are central to delivering an economy that runs on zero carbon fuels, but an economy-wide transition to a cleaner future must also include jobs like construction managers, electricians, office clerks, and agricultural inspectors.

The clean energy economy is about more than today's green workers; it's about the enormous range of occupations implicated in the long-run transition. Knowing more about these workers will help in supplying a capable workforce to support the shift.

Correctly identifying the scope of the clean energy economy also matters because it could help address some of the country's central economic challenges. Widening income inequality and a shrinking middle class pose an enormous macroeconomic challenge, particularly when it comes to identifying and supporting well-paid jobs available to all types of workers, including those without a four-year degree.[8] Furthermore, as many communities and local workers are struck by job losses from automation[9] and trade,[10] they increasingly need to retrain to gain new skills to stay competitive in the modern global marketplace.[11] This deep set of inclusion challenges leaves the country and its local economies eager to find careers that offer long-term durability, living wages, and limited barriers to entry.

This is where the relationship between macroeconomic prosperity challenges and the clean energy transition comes into focus. If the clean energy economy offers inclusive pathways to opportunity—meaning all segments of society can access jobs that enable upward economic mobility—then securing a more resilient planet will also help secure a more resilient economy. It also allows proponents of a more sustainable future to make economic arguments more forcefully.

To capture the full range of occupations involved in the clean energy economy transition, this report uses a new approach to judge the *nature*

and *quality* of clean energy economy occupations. It starts by using foundational research.

Following the Great Recession of 2008 and the remarkable growth in federal clean energy economy efforts, there was a flurry of national and regional research efforts to characterize the potential for employment in the "clean" or "green" economy. The primary objective of these early efforts was to *quantify the number of jobs* in the clean energy economy. At the national scale, path-breaking efforts included Pew's 2009 "Clean Energy Economy" report,[12] the 2010 Bureau of Labor Statistics' (BLS) Green Jobs Initiative,[13] Eurostat's 2009 environmental economy estimates,[14] and the 2011 Brookings report, "Sizing the Clean Economy."[15] The Department of Energy continued this effort by including clean energy economy measures within their broader 2016 and 2017 "U.S. Energy and Employment" reports.[16] More recent analyses from the National Association of State Energy Officials and the Energy Futures Initiative expanded on these earlier studies to examine employment trends in particular industries and occupations throughout the energy sector.[17]

Several other national-level reports quantified specific segments of the clean energy economy—for example, The Solar Foundation's annual "National Solar Jobs Census" and the American Wind Energy Association's "U.S. Wind Industry Annual Market Report"—and still more researchers attempted to characterize the national clean energy economy using survey methodologies. Within this flurry, numerous state-level efforts by business trade associations, state industry associations, utility entities, and public agencies sought to capture the clean labor market within their borders.

Given this rich body of past work, the present study adopts key definitions and sector segmentations found throughout the existing literature to structure a new look at clean energy occupations. The report then uses two critical definitions to capture the range of relevant industries and to delineate the occupations essential to them:

- **Clean energy** *is energy not derived from fossil fuels. Clean energy sources include hydroelectric, nuclear, solar, wind, geothermal, biomass, and other (e.g., tidal).*[18]

- **Clean energy economy jobs** *are jobs that will be involved in (1) the production, transmission and distribution of clean energy; (2) increasing energy efficiency through the manufacturing of energy-saving products, the construction of energy-efficient buildings, and the provision of services that reduce end-use energy consumption; or (3) environmental management and the conservation and regulation of natural resources.*

These definitions attempt to address some of the thorniest issues in clean energy economy research. While there is continual disagreement about whether energy sources like nuclear power, natural gas, coal with carbon capture and sequestration, and others should be considered "clean," this definition provides a specific list of generating sectors.[19] Second, since few job classifications are solely "clean" based on current industry and occupational definitions by the U.S. Bureau of Labor Standards and the Occupational Employment Statistics program, these definitions allow flexibility to qualify occupations over time. As industries respond to consumers, regulations, and markets, some new green occupations will be created, other existing occupations will transform and become cleaner in their activities, and some traditional energy jobs will be lost.[20]

Finally, it is not enough to simply delineate what a clean energy economy occupation is; it's equally important to determine which workers can access those labor market opportunities. To that end, this analysis is interested in the degree to which the clean energy economy provides labor market opportunities for historically disadvantaged groups, with a particular focus on equity.[21]

KEY TERMS:

Industries: Groups of establishments that provide similar goods or services, as determined by the 2012 North American Industry Classification System (NAICS). Private and government owned establishments are included, while agricultural establishments and private households are excluded.

Clean energy economy industries: Industries that provide services closely linked to at least one of the three major clean energy economy categories.

Occupations: The activities that employees regularly carry out for pay, which are grouped into distinct categories on the basis of similar job duties as outlined in the 2010 Standard Occupation Classification (SOC) system.[22] In total, there are more than 800 detailed occupations found across all industries.

Occupations in the clean energy economy: Occupations with an above-expected share of a clean energy economy industry's employment relative to the given occupation's share of total national employment.

Wages: Based on straight-time, gross pay over a standard work period, as defined in the Occupational Employment Statistics (OES) survey. These include tips, production bonuses, cost-of-living allowances, and over-the-road pay based on mileage. However, overtime pay, back pay, and holiday bonuses are among the types of compensation excluded.[23] Wages include mean hourly and annual pay, but also percentile wages (10th, 25th, 50th, 75th, and 90th). The latter are based on the percentage of workers who earn wages below a certain value. For instance, if $9.00 represents the 10th percentile wage for a given occupation, this means that 10 percent of workers employed in the occupation earn less than this amount.

III. Methodology

Most past studies of jobs in the clean energy economy relied on two primary approaches: (1) a firm-level[24] identification of "green" or "clean" jobs using proprietary datasets; or (2) a survey-based approach wherein the researchers extensively survey firms within industries identified as critical to the clean energy economy in order to determine the extent to which those industries are involved in "clean" or "green" activities. From the perspective of clean energy industries centered on specific technologies, such as solar energy or wind energy, past studies also relied on surveys, input-output models, or value chain-based approaches.[25]

Due to the expansive number of potential clean energy economy occupations, we rely on 2016 employment data publicly available from the U.S. Bureau of Labor Statistics (BLS) Occupational Employment Statistics (OES) program and Employment Projections (EP) program.[26] Based on our definition, we classify the clean energy economy in terms of occupations and industries, regardless of the ownership or output associated with individual establishments.

First, we establish a list of industries that are critical to the transition to a clean energy economy by drawing primarily on industries identified in the Department of Energy's 2017 "U.S. Energy and Employment Report," the UCLA Luskin Center's report on "Understanding the Green Economy in California," the BLS green jobs survey, and Brookings's "Sizing the Clean Economy" report. This core list of identified industries is diverse and encompasses a wide range of activities relevant to the clean energy economy.[27] In order to meaningfully identify and categorize critical occupations in these industries, we put closely related groups of industries into three broad clean energy economy sectors, similar to many of the aforementioned reports:

- *Clean energy production:* includes clean energy generation, transmission, and distribution
- *Energy efficiency*: includes manufacturing of energy-efficient products, construction of energy-efficient buildings, and provision of energy efficiency services
- *Environmental management*: includes environmental management, conservation, and regulation

We then examine the specific types of positions within these three sectors. In particular, we identify all the occupations within each clean energy economy sector based on a **concentration quotient (CQ)**, which studies how much a given occupation concentrates within each of the three clean energy economy sectors. The concentration quotient formula is:

$$CQ = \frac{\text{Occupation's share of sectoral employment}}{\text{Occupation's share of national employment}}$$

We qualify occupations in each clean energy economy sector with a CQ value of at least 1 in the given sector, or those occupations with a higher than expected concentration. This threshold yields lists of 113, 172, and 186 occupations for *clean energy production*, *energy efficiency*, and *environmental management sectors*, respectively. Some occupations are found within multiple sectors. To be clear: the CQ is not a job count, nor does a higher CQ suggest a given occupation is any more important to the clean energy transition.

Further, for governmental occupations (which are mostly concentrated in the third clean energy economy sector of *environmental management*), OES's occupational data is highly aggregated and therefore limits our ability to differentiate governmental occupations heavily involved in the clean energy economy. This is a typical issue in such industrial-occupational analyses, and our response is to conduct a thorough manual review of governmental occupations that qualify via our above methodology to confirm that they are relevant to the clean energy economy.[28] We also verify this smaller list with occupation lists identified from prior reports.

Finally, in order to explore the inclusivity of qualifying occupations and their sectors in total, we look at data on six key indicators drawn from a variety of publicly available data sources from the U.S. Bureau of Labor Statistics and the U.S. Census Bureau (Table 1). It is important to note that these indicators do not always provide industry-specific data for a given occupation; for instance, we cannot see how knowledge and skills vary for electricians in these industries vs. electricians in all industries nationally. In turn, each of the relevant metrics is calculated by taking a weighted average based on total sectoral employment of qualifying occupations.

For more detail on the report's methodology, including a list of qualifying industries, see Appendix A.

TABLE 1

Key metrics and data sources

Metric	Data source
Wages	Occupational Employment Statistics (OES)
Knowledge and skills	Occupational Information Network (O*NET)
Demographic characteristics of the employed population: gender, race, and age	Current Population Survey (CPS)
Educational qualifications by occupation; Projected growth of jobs in this sector	Employment Projections (EP) program
Variation in inclusivity between "clean" and "dirty" energy generation activities	All of the above

IV. Findings

FINDING 1

The transition to the clean energy economy will primarily involve 320 unique occupations spread across three major industrial sectors: *clean energy production*, *energy efficiency*, and *environmental management*.

The transition to a clean energy economy implicates a wide range of industries. Most visible are the generation utilities themselves.[29] Often overlooked, however, are the electrical grid component manufacturing and construction that bring energy to people's homes, businesses, and other activity centers. Equally vital are the various manufacturing, construction, and service industries that help create more energy-efficient products. Finally, the wide range of conservation firms, waste management entities, and other government agencies that help monitor and clean the natural environment.

Workers are central to the effectiveness of each of these diverse industries, ranging from activities that are wholly unique to the clean energy economy to support services that are found throughout the economy. Based on our measure of concentration, some 320 unique occupations are essential to these qualifying industries, many of which concentrate across multiple industries involved in the country's clean energy transition.[30] These occupations are not just involved in activities that are already clean, but carry out tasks that could contribute to a cleaner economy over time.

This report places these occupations into three buckets—or sub-sectors—of the clean energy economy, and Table 2 below highlights the most concentrated occupations under each.

Clean energy production. This sector not only concentrates workers involved in actual energy production—such as power plant operators and wind turbine technicians—but also workers involved in the construction, operation, and maintenance of the electric grid, such as power line installers and repairers, electricians, solar photovoltaic installers, and utility meter readers. Workers who manufacture components critical to the production of clean energy, such as wind turbines, transformers, storage batteries, also concentrate in this sector. In addition, the sector employs large numbers of office clerks, general and operations managers, and other business operations specialists.

Energy efficiency. The transition to the clean energy economy necessitates the manufacturing of more energy-efficient products, from home appliances to motor vehicles. At the same time, the country's building stock, which is responsible for nearly 30 percent of all energy consumption, will need to use energy more efficiently.[31] Overall, this diverse set of manufacturing, construction, and service provisions employs a wide range of skilled trades (like electricians and HVAC mechanics), STEM-trained specialists (like architects and civil engineers), and business experts (like cost estimators and accountants).

Environmental management. Efforts to better manage and regulate the environment, reduce greenhouse gas emissions, mandate efficient energy use, and conserve natural resources are critical to this transition. Waste management and treatment is a large part of such efforts, including workers like refuse and recyclable material collectors and wastewater treatment plant operators. Conservation scientists, environmental engineers and technicians, and urban planners also play a big role. Finally, lawmakers, regulators, and other jobs related to judicial activities are responsible for the legal dimensions related to the built and natural environments.

Collectively, 113 different occupations are found under *clean energy production* and account for about 1.3 million workers; 172 occupations are found under *energy efficiency* and account for about 4.4 million workers; and 186 occupations are found under *environmental management* and account for about 877,000 workers. As noted previously, some occupations are found across multiple sectors, making it difficult to determine a specific total for the clean energy economy as a whole. In turn, the individual sector totals – of 113, 172, and 186 occupations – amount to a smaller set of unique occupations.

Rather than sizing the entire clean energy economy, this analysis is primarily concerned with examining how inclusive these occupations can be within each of the three individual sectors, which the following findings describe in greater depth.

TABLE 2

Most concentrated occupations, by clean energy economy sector, 2016

Sector	Occupation	Concentration Quotient (CQ)
Clean energy production	Helpers--electricians	81.9
	Electricians	65.9
	Electrical power-line installers and repairers	62.7
	Nuclear power reactor operators	56.0
	Power plant operators	48.2
	Electrical and electronics pepairers, powerhouse, substation, and relay	47.9
	Nuclear technicians	44.4
	Wind turbine service technicians	43.0
	Power distributors and dispatchers	42.0
	Telecommunications line installers and repairers	35.2
Energy efficiency	Helpers--roofers	27.0
	Roofers	26.4
	Helpers--pipelayers, plumbers, pipefitters, and steamfitters	23.1
	Plumbers, Pipefitters, and Steamfitters	21.5
	Heating, air conditioning, and refrigeration mechanics and installers	20.0
	Sheet metal workers	18.7
	Helpers--carpenters	15.8
	Carpenters	14.9
	Solar photovoltaic installers	14.9
	Construction managers	14.5
Environmental management	Hazardous materials removal workers	68.4
	Refuse and recyclable material collectors	62.1
	Septic tank servicers and sewer pipe cleaners	46.2
	Plant and system operators, all other	11.9
	Conservation scientists	11.0
	Environmental engineering technicians	10.7
	Water and wastewater treatment plant and system operators	9.8
	Forest and conservation workers	9.7
	Legislators	9.3
	Fish and game wardens	9.3

Note: Concentration quotient (CQ) reports how much more likely a given occupation is to be found in the given sector's industries than across all national industries.
Source: Brookings analysis of Occupational Employment Statistics data

FINDING 2

Workers in clean energy occupations earn higher and more equitable wages when compared to all workers nationally.

Decades of wage stagnation, especially among low- and middle-skill jobs, have created deep fissures within the U.S. economy. Fortunately, jobs within the clean energy economy offer a potent antidote to the country's inclusion challenges.

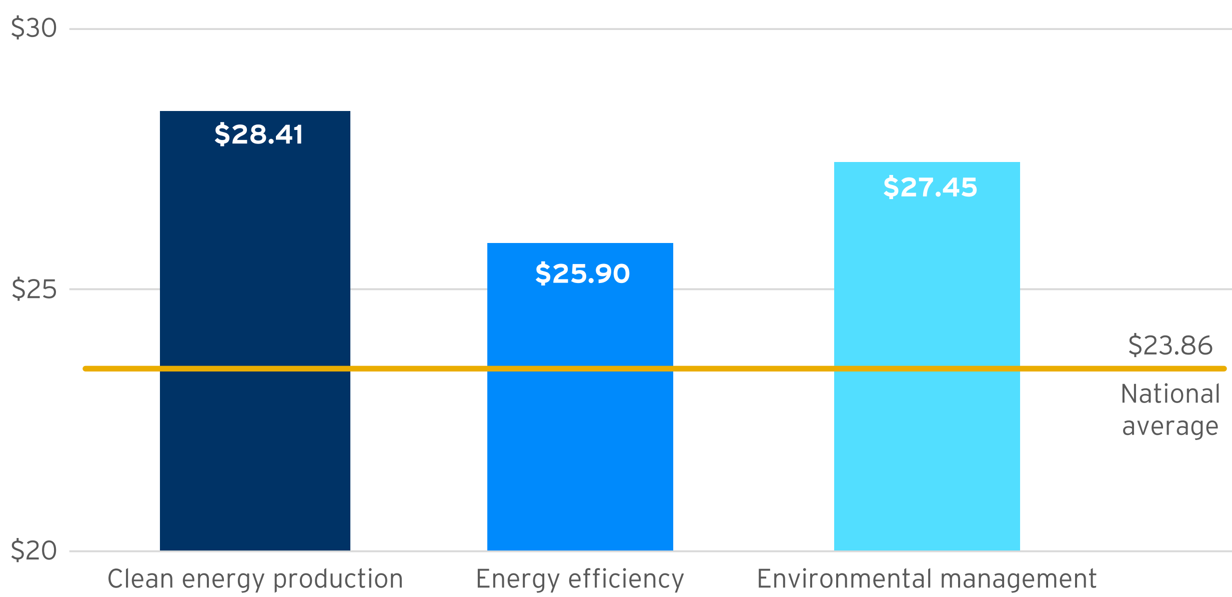
Positions across all three sectors in the clean energy economy offer substantial wage premiums. For example, the average wage under each of the three sectors exceeds the national average ($23.86) by at least $2 per hour, including wage premiums of nearly $5 per hour within the *clean energy production* sector (Figure 1). The hourly differences between a clean energy economy occupation and one elsewhere in the economy can equate to a raise between 8 and 19 percent, if not more.

Even more importantly, the clean energy economy offers higher pay to workers at lower ends of the income spectrum. As it stands, workers at the 10th percentile across the entire economy—or the lowest decile of all earners—typically earn just $9.27 per hour. In contrast, workers at the 10th percentile in the three clean energy economy sectors earn $5 to $7 more per hour (Figure 2). Even larger wage premiums exist for workers at the 25th percentile: The national hourly wage is just $11.60 at this percentile, but clean energy economy occupations pay $7 to $10 more per hour. At these compensation levels, even the lowest-paying clean energy economy jobs can offer a living wage in many corners of the country.

While the earnings floor is significantly higher for clean energy economy jobs, their competitive pay also extends to those workers earning higher wages. Clean energy economy workers earn more at the median compared to all workers nationally, and the 75th percentile of clean energy economy workers earn more as well. It's not until the 90th percentile—where hourly wages equate to over $95,000 in annual earnings—that these wage premiums end. Put simply, clean energy economy employment offers a competitive pay floor to many workers.

FIGURE 1

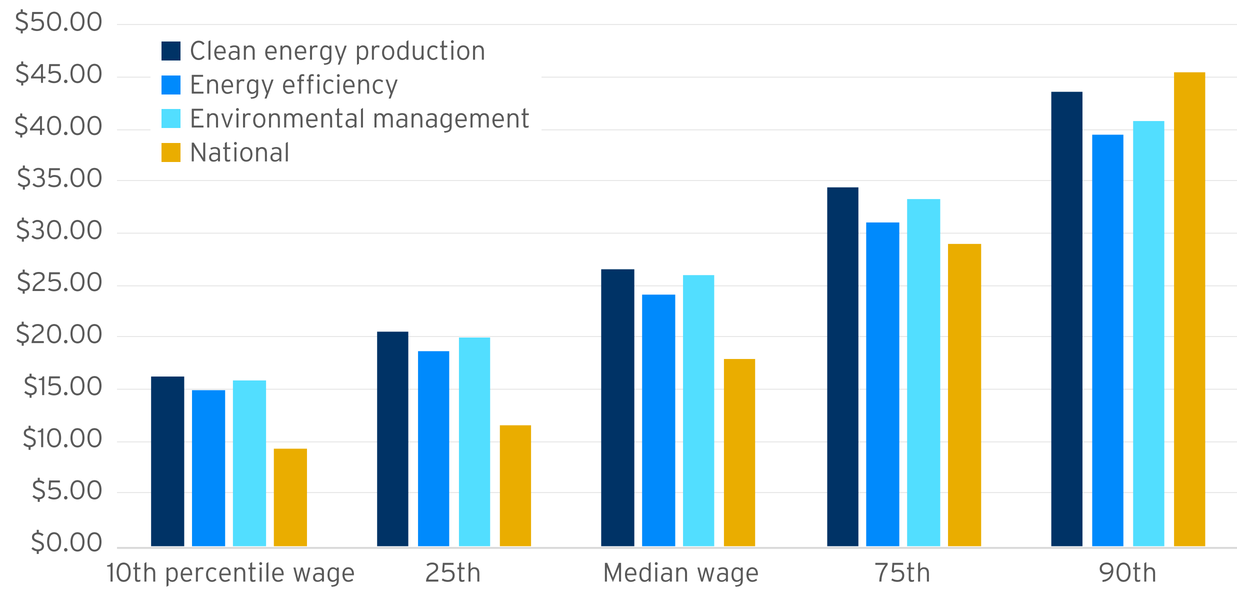
Mean hourly wages by clean energy economy sector, 2016



Source: Brookings analysis of Occupational Employment Statistics data

FIGURE 2

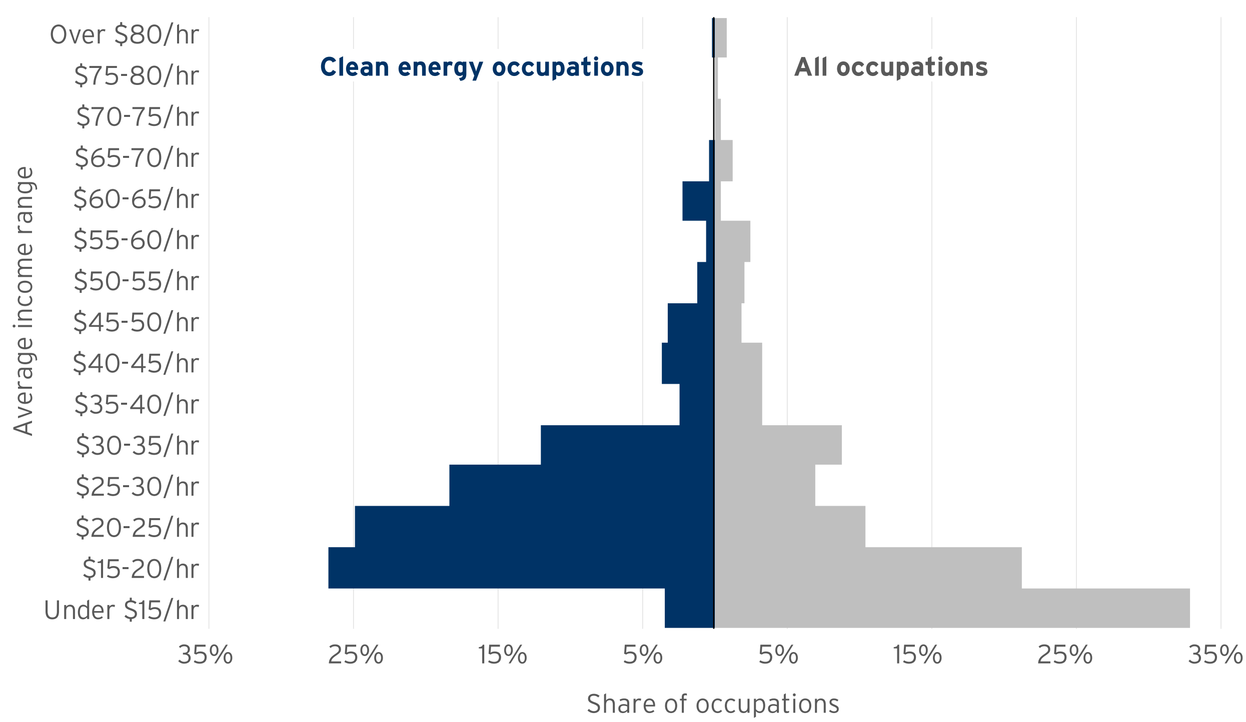
Percent hourly wages, by clean energy economy sector, 2016



Source: Brookings analysis of Occupational Employment Statistics data

FIGURE 3

Share of all occupations by mean hourly wage, clean energy economy occupations and all national occupations, 2016



Source: Brookings analysis of Occupational Employment Statistics data

A major driver of higher pay within the clean energy economy, meanwhile, is the relative absence of low-paying jobs (Figure 3). Looking strictly at average wages, less than 4 percent of all clean energy economy occupations pay under $15 per hour, while nearly one-third of all occupations nationally pay an average wage of less than $15 per hour. Instead, the clean energy economy offers a considerably wider band of middle-income jobs that pay between $20 and $35 per hour. Again, this kind of higher-earning floor helps set up workers for stronger immediate and lifetime earnings when they participate in the clean energy economy.

Some of the clean energy economy's largest occupations demonstrate this "high floor, competitive ceiling" effect. Electricians represent easily the most common occupation within the *clean energy production* sector, as they are essential to both power plant operations and grid functionality. As such, workers in this skilled trade earn more than $14 and $18 per hour at the 10th and 25th percentiles within the sector, and their pay at the median and 75th percentile also exceeds national averages. Plumbers, pipefitters, and steamfitters—the skilled trades that employ the most workers under the *energy efficiency* sector—earn almost the exact same wages as electricians. Meanwhile, refuse and recyclable material collectors are among the most common workers under the *environmental management* sector. These jobs present little barriers to entry but still pay higher amounts at the 10th and 25th percentile compared to all jobs nationally.

FINDING 3

Even when they have higher pay, many occupations within the clean energy economy tend to have lower educational requirements.

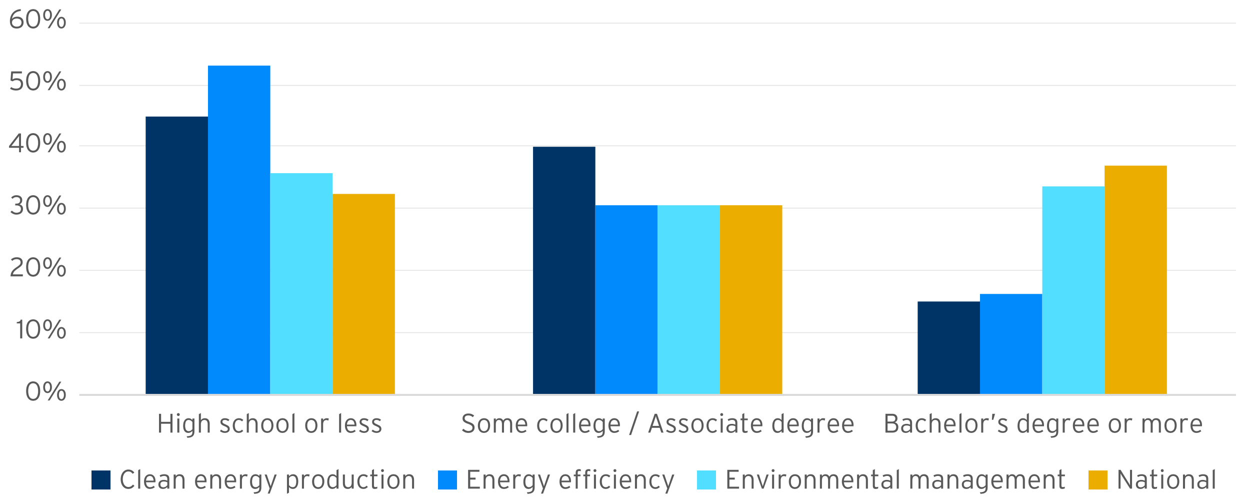
The disappearance of good-paying jobs for workers without college or advanced degrees—and especially the loss of middle skill jobs—is a major concern related to growing income inequality across the country.[32] However, as the prior finding demonstrated, the clean energy economy offers competitive wages even to those workers earning the lowest relative pay within their given occupation. Workers in the clean energy economy tend to have less formal education than all workers nationally, filling jobs that boast an alluring mix of higher-pay and lower barriers to entry.

Levels of educational attainment for these workers are especially low within the *clean energy production* and *energy efficiency* sectors (Figure 4). Workers with no more than a high school diploma fill over half of all *energy efficiency* occupations, while 45 percent of workers in *clean energy production* occupations share this distinction. Yet even more striking are the advanced education statistics: fewer than 17 percent of *clean energy production* and *energy efficiency* workers hold a bachelor's degree or more, suggesting a 4-year degree is rarely required to secure the higher pay available in those sectors. By contrast, far more *clean energy production* and *energy efficiency* workers either hold associate degrees or have completed only some college, suggesting applied skills training is often more important in those positions.

Even with lower levels of educational attainment, though, clean energy economy workers still earn competitive wages. For example, Figure 5 shows the median annual wages for clean energy economy occupations versus those across the entire economy. While both groups demonstrate a relatively strong relationship between pay and education, clean energy economy workers with a high school diploma or less stand out; they consistently earn higher median pay, especially when compared to workers with similar education backgrounds employed across the entire economy. This is clear visual evidence of the higher income floor for clean energy economy workers.

FIGURE 4

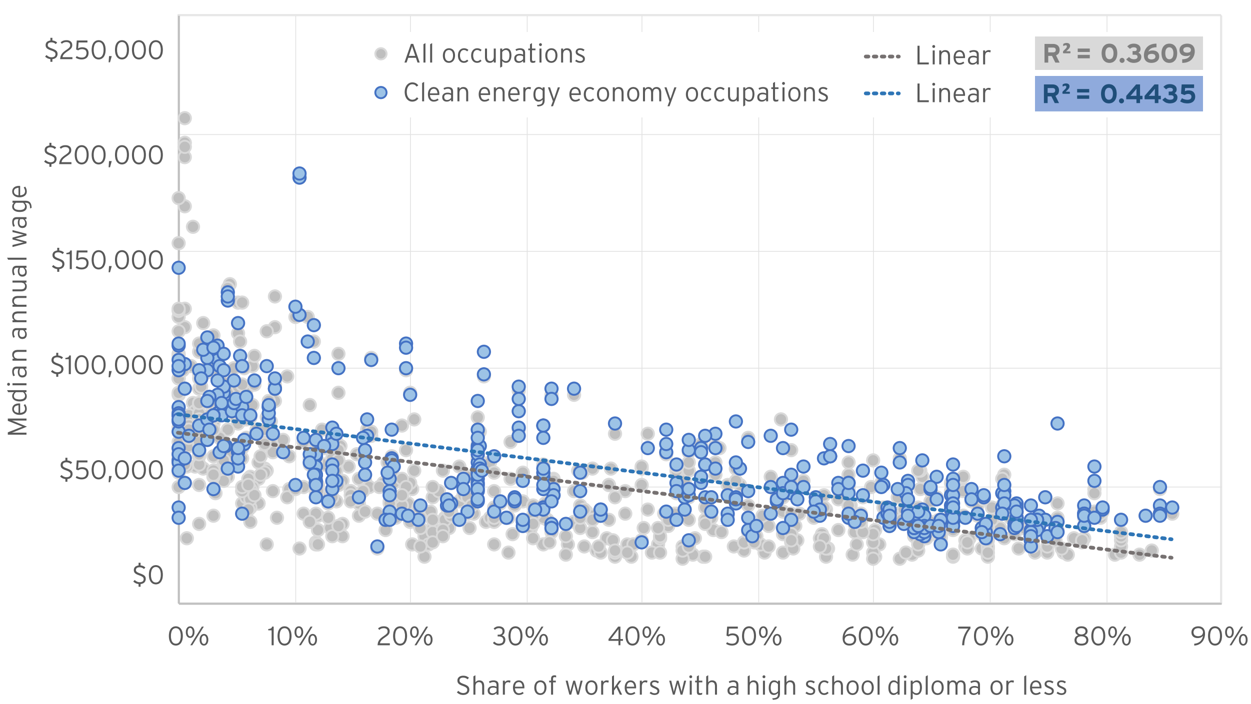
Educational attainment by workers in clean energy economy sectors, 2016



Source: Brookings analysis of Occupational Employment Statistics and Employment Projections data

FIGURE 5

Median annual wages by share of workers with a high school diploma or less, clean energy economy occupations and all national occupations, 2016



Note: The R^2 value here helps determine the level of variation in pay explained by educational attainment. A higher R^2 shows the wages that clean energy economy workers earn are explained more by their levels of educational attainment.
Source: Brookings analysis of Occupational Employment Statistics and Employment Projections data

With that said, the aggregate statistics mask considerable variation within each of the three clean energy economy sectors. Figure 6, for instance, highlights some of the major occupations where workers can differ in their educational backgrounds. Although workers in engineering occupations tend to have advanced degrees—regardless of their sector—workers employed as office clerks, sales representatives, and in other common support occupations tend to have a high school diploma or applied post-secondary training. This variation speaks to the wide range of tasks and educational backgrounds found across the clean energy economy, with many potential career pathways available to prospective workers.

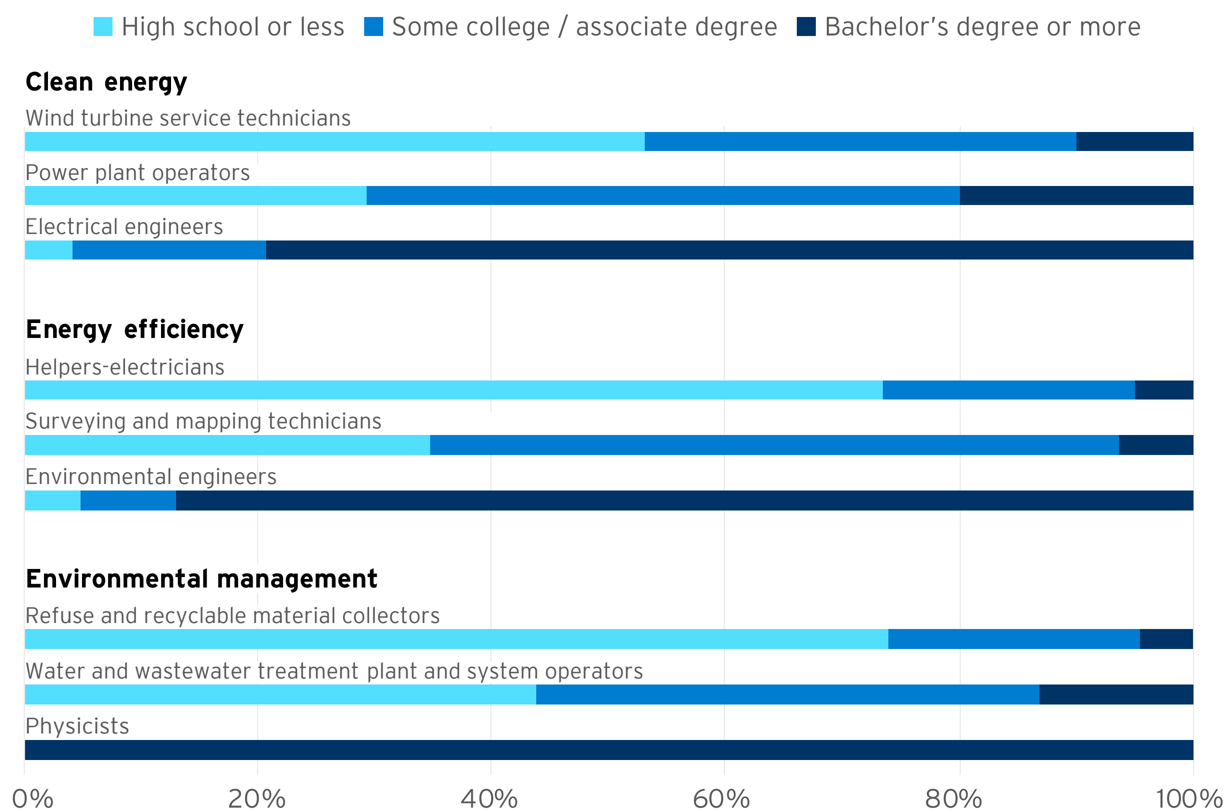
Going to school, of course, is only one way to prepare for a job. Another is by learning on the job, and many clean energy economy positions depend on workers who develop experience and competencies through on-the-job training.[33]

Nearly half of all workers in the *clean energy production* and *energy efficiency* sectors, for instance, have at least one month of on-the-job training. This also includes a sizable percentage of workers who have at least one year of on-the-job training or engage in apprenticeship programs, including electricians, plumbers, and others involved in the construction trades. Effectively, these training statistics confirm that these two clean energy economy sectors tend to emphasize applied learning opportunities to achieve occupational preparedness.

Similar to all occupations nationally, those in the *environmental management* sector tend to require less on-the-job training; more than three-quarters of workers in this sector have no more than one month of on-the-job training. The need for formal education in these positions, especially post-secondary education, shows that many workers must still engage in more formal classroom instruction and training.

FIGURE 6

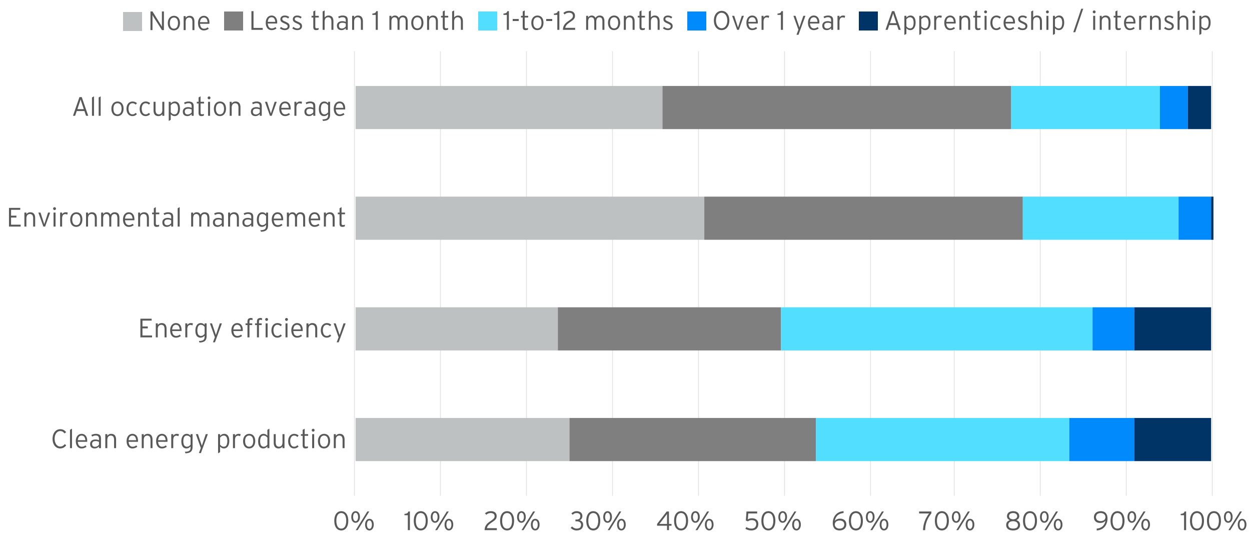
Educational attainment, by share of employment in selected occupations, 2016



Source: Brookings analysis of Occupational Employment Statistics and Employment Projections data

FIGURE 7

On the job training, by share of employment in qualifying occupations, 2016



Source: Brookings analysis of Occupational Employment Statistics and Employment Projections data

FINDING 4

Occupations within the *clean energy production* and *energy efficiency* sectors tend to require greater scientific knowledge and technical skills than the average American job.

While many workers in the clean energy economy tend to have less formal education and more on-the-job training, that is only one signal of the requirements for related occupations. Another important indicator are the specific *knowledge* and *skills* that workers must bring to their respective jobs to successfully carry out their tasks.

This analysis uses O*NET to gauge the "level" of knowledge and skills that workers in each of the three clean energy economy sectors need to perform their expected job duties. Knowledge levels are determined across 33 different content areas—from physics and biology to mathematics and design.[34] Skill levels are determined across 35 different categories—from reading comprehension to writing. These levels are rated from 0 (minimum) to 7 (maximum) based on worker questionnaires, meaning small quantitative jumps in knowledge and skill levels can represent significantly more understanding of a given topic.

Clean energy economy workers often need more knowledge in content areas with a clear scientific component. And given the lower levels of education attainment for workers in most clean energy economy occupations, workers usually develop general scientific and STEM-specific knowledge through applied training.

Scientific knowledge demands are especially high for occupations within the *clean energy production* and *energy efficiency* sectors. Jobs in these sectors are likely to require higher knowledge in three distinct areas—building and construction, mechanical, and design—where scores are at least 1 point higher than the national average. Knowledge of STEM-specific content like physics, mathematics, engineering, and technology is also highly recommended in these two clean energy economy sectors. Even with some differences, Table 3 confirms that these two sectors have a lot in common.

This is also true in reverse: workers in *clean energy production* and *energy efficiency* tend to have lower knowledge scores in many of the same content areas. The content areas with the lowest relative scores tend to relate to liberal arts, including psychology, medicine and dentistry, and fine arts. These lower knowledge requirements are just one more demonstration of how more advanced education, especially the broader programming used in a university setting, is not essential for many occupations within the clean energy economy.

By contrast, *environmental management* occupations tend to demand similar types of knowledge as all occupations do nationally, with a few notable differences. Knowledge of law and government and Clerical are especially high, reflecting the regulatory responsibilities and paperwork duties flowing through that portion of the clean energy economy. Likewise, *environmental management* jobs tend to have lower requirements. Figure 8 charts the knowledge deviations for all three clean energy economy sectors versus all national occupations, ranking each category from the smallest to largest differences. The e*nvironmental management* line clearly sticks closer to the zero-axis representing all jobs.

Switching to skills, occupations in the *clean energy production* and *energy efficiency* sectors require more technical skills than the average job. O*NET codes 8 of the 35 skill categories as "technical," including installation, repairing, troubleshooting, and quality control analysis. These technical skills confirm that *clean energy production* and *energy efficiency* occupations tend to make extensive use of machines and technological systems. Similarly, these occupations also tend to have higher scores in management of both material and financial resources, indicating the need for thoughtfully managing both equipment and financial business. Once again, the *environmental management* sector looked more like national occupational averages. Figure 9 shows how most skills in *environmental management* occupations stay close to the national occupation average.

TABLE 3

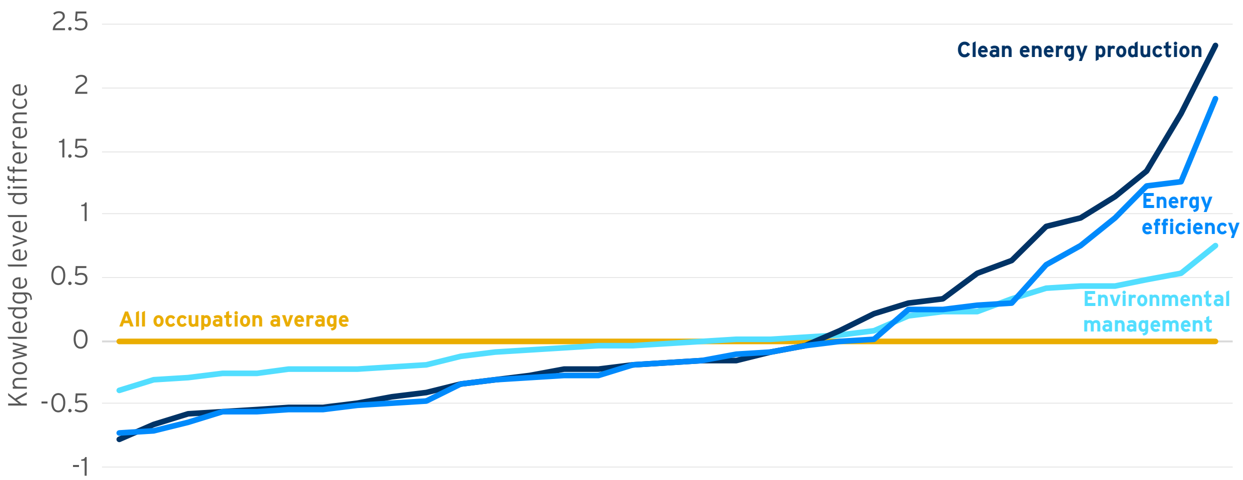
Occupations' knowledge score, by national average and clean energy economy sector, 2016

O*NET knowledge area	Average score across all occupations	Average across occupations by sector		
		Clean energy production	Energy efficiency	Environmental management
Mechanical	2.4	4.0	3.7	2.2
Building and construction	1.4	2.7	2.8	1.6
Engineering and technology	2.1	3.5	3.3	2.3
Design	1.9	3.1	3.2	2.0
Physics	1.6	2.7	2.4	1.8
Production and processing	2.2	2.9	3.0	2.0
Mathematics	3.3	3.7	3.7	3.6
Public safety and security	2.5	2.9	2.7	2.9
Chemistry	1.9	2.3	2.3	1.9
Transportation	1.8	2.1	2.0	2.1
Telecommunications	1.4	1.7	1.3	1.6
Computers and electronics	3.2	3.2	2.9	3.6
Administration and management	3.0	3.0	3.0	3.4
Geography	1.6	1.5	1.4	2.2
Economics and accounting	1.6	1.5	1.5	1.9
Food production	0.6	0.4	0.4	0.6
Education and training	3.5	3.3	3.2	3.7
Law and government	2.2	2.0	1.9	2.9
Personnel and human resources	2.2	2.0	2.0	2.6
Foreign language	1.0	0.7	0.8	1.1
Biology	1.3	1.0	0.9	1.5
Clerical	2.9	2.5	2.4	3.4
History and archeology	0.9	0.5	0.6	1.1
Sales and marketing	2.0	1.6	1.8	1.9
English language	3.7	3.3	3.3	4.0
Fine arts	0.6	0.2	0.4	0.4
Medicine and dentistry	1.2	0.8	0.7	1.1
Communications and media	2.1	1.7	1.6	2.4
Customer and personal service	3.8	3.3	3.2	4.1
Therapy and counseling	1.4	0.8	0.7	1.5
Philosophy and theology	1.3	0.7	0.7	1.4
Psychology	2.4	1.8	1.7	2.7
Sociology and anthropology	1.6	0.9	0.9	1.9

NOTE: Knowledge Areas listed in order of the largest differences between clean energy production and all occupations
Source: Brookings analysis of Occupational Employment Statistics and O*NET data

FIGURE 8

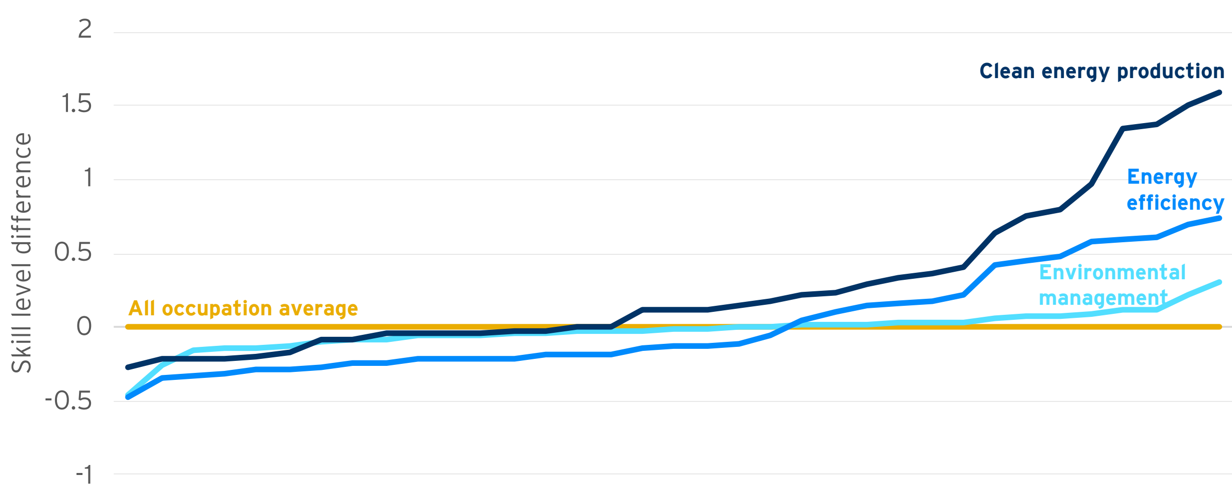
Differences in knowledge score across 33 knowledge areas, clean energy economy sectors, 2016



Note: For each clean energy economy sector, knowledge areas ordered independently based on largest negative to largest positive scores; the chart effectively measures deviation from the all occupation average in each of the 33 knowledge content areas. Due to space limitations, the 33 knowledge categories are not individually shown on the chart's X axis
Source: Brookings analysis of Occupational Employment Statistics and O*NET data

FIGURE 9

Differences in skills score across 35 skill categories, clean energy economy sectors, 2016



Note: For each clean energy economy sector, skills ordered independently based on largest negative to largest positive scores; the chart effectively measures deviation from the all occupation average in each of the 35 skill categories. Due to space limitations, the 35 skill categories are not individually shown on the chart's X axis
Source: Brookings analysis of Occupational Employment Statistics and O*NET data

FINDING 5

The clean energy economy workforce is older, dominated by male workers, and lacks racial diversity when compared to all occupations nationally.

While it's impressive that the clean energy economy includes so many jobs with high pay and low educational barriers to entry, judging the entire sector's inclusivity also requires consideration of who fills those jobs. Unfortunately, across a series of demographic indicators, workers in the clean energy economy continually fall short of national benchmarks of labor market inclusion. The current lack of diversity indicates opportunities to broaden the labor pool in the long run but is a limitation in the short-term.

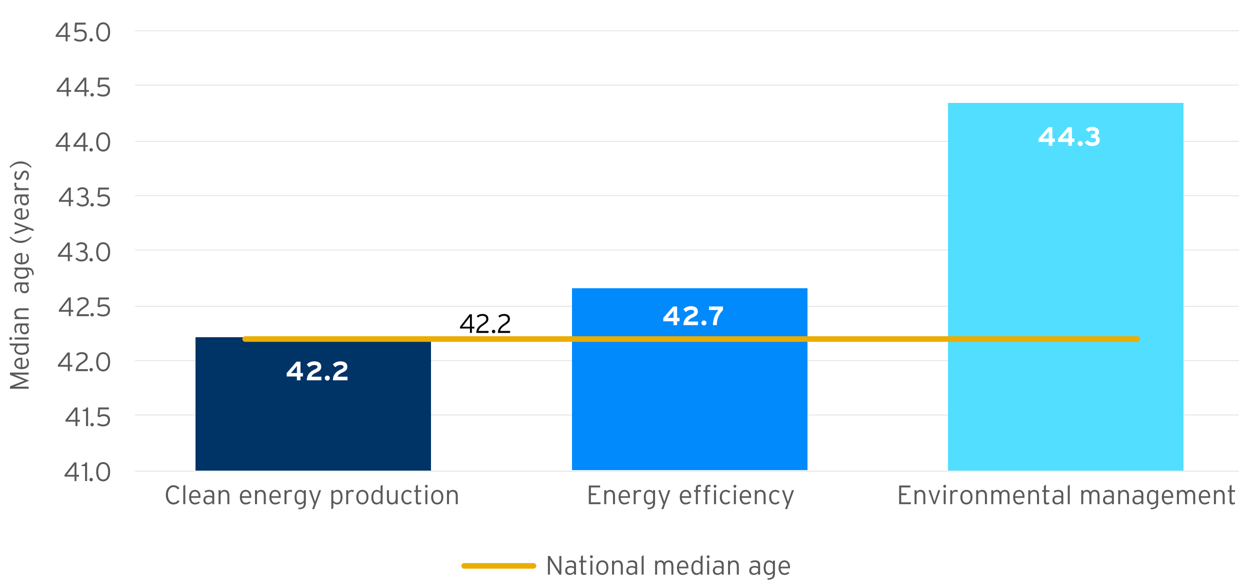
To start, the clean energy economy workforce is relatively old (Figure 10). The median age of workers in each of the three clean energy economy sectors is at least as high as the national median (42.2 years). In the case of *environmental management* workers, the gap increases by two years. This sector's combination of stable public-sector employment and more advanced education requirements may contribute to workers entering their careers later, staying entrenched in jobs longer, or waiting longer to retire depending on the occupation and individual worker. When looking across all three clean energy economy sectors in total, these results suggest it's worth investigating whether younger workers face hidden barriers to entry that outweigh the reduced education requirements discussed in Finding 3.

Far more pronounced than the age tilt is the predominance of men in the sector. For example, while women composed 46.8 percent of all employed workers in 2016, fewer than 20 percent of workers in the *clean energy production* and *energy efficiency* sectors were women.

Nationally, there are established conversations about the barriers women face in acquiring a job in the skilled trades—and the skilled trades are a sizable portion of the clean energy economy, as evidenced by the knowledge and skills discussion in this finding.[35] But that makes it even more essential to assess why specific skilled trades in the clean energy economy see such low female employment, ranging from electricians (3 percent female) to heavy and tractor-trailer truck drivers (6 percent) to cement masons and concrete finishers (2 percent). At the same time, many nonskilled trades confront the same barriers,

FIGURE 10

Median age by clean energy economy sector, 2016



Source: Brookings analysis of Occupational Employment Statistics and Current Population Survey including general and operations managers (30 percent female) and cost estimators (12 percent). Many STEM-specific positions like engineers also employ below-average shares of females.

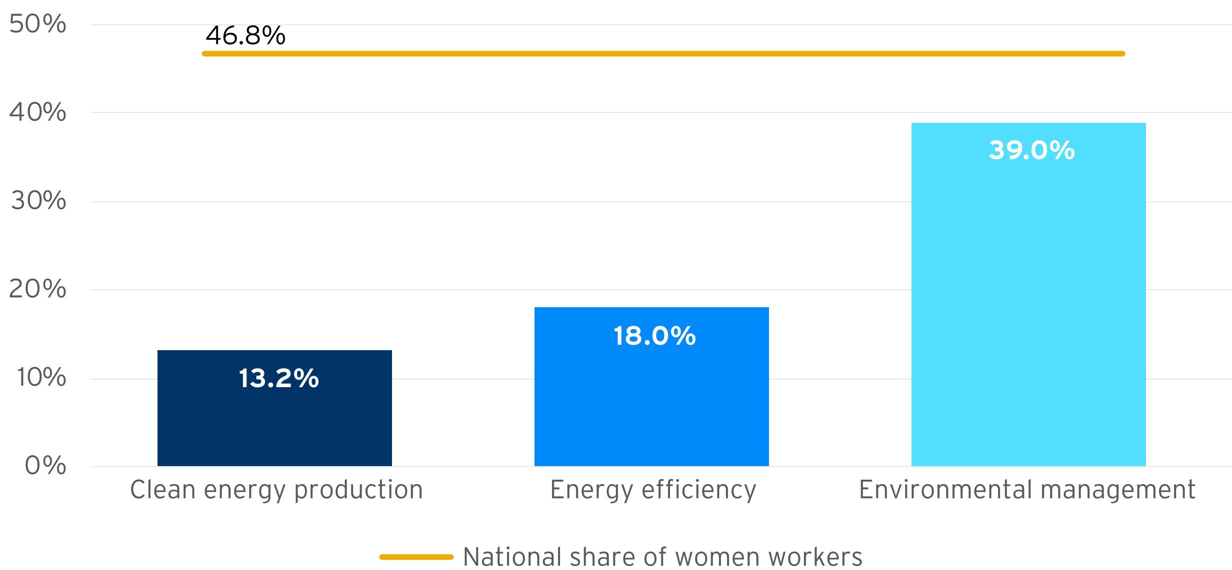
Finally, racial diversity is lacking in many positions critical to the clean energy economy. The share of black workers across the three clean energy economy sectors typify this imbalance. On the one hand, black workers represent a much smaller share of total *clean energy production* and *energy efficiency* employment than that of national employment. Conversely, *environment management* occupations employ an above-average share of black workers. The situation is reversed for Hispanic workers: above-average shares in the *clean energy production* and *energy efficiency* sectors, but below-average employment in the *environmental management* sector. Across all three clean energy economy sectors, Asian employment is relatively low.

Certainly, some of these diversity trends reflect industry-wide employment practices. Public-sector occupations that dominate the *environmental management* sector are known for using equal opportunity hiring and recruitment practices, which tend to benefit minority and female workers. Likewise, the relatively high share of construction work under both the *clean energy production* and *energy efficiency* sectors naturally leads to greater likelihood of Hispanic employment.

For the most part, the diversity shortfalls across the clean energy economy result in real economic consequences for the country's households. When occupations with sizable employment counts, high pay, and low barriers to entry are not being filled by all demographic groups, something is amiss with either widely-used recruitment practices, specific occupation practices, or both.

FIGURE 11

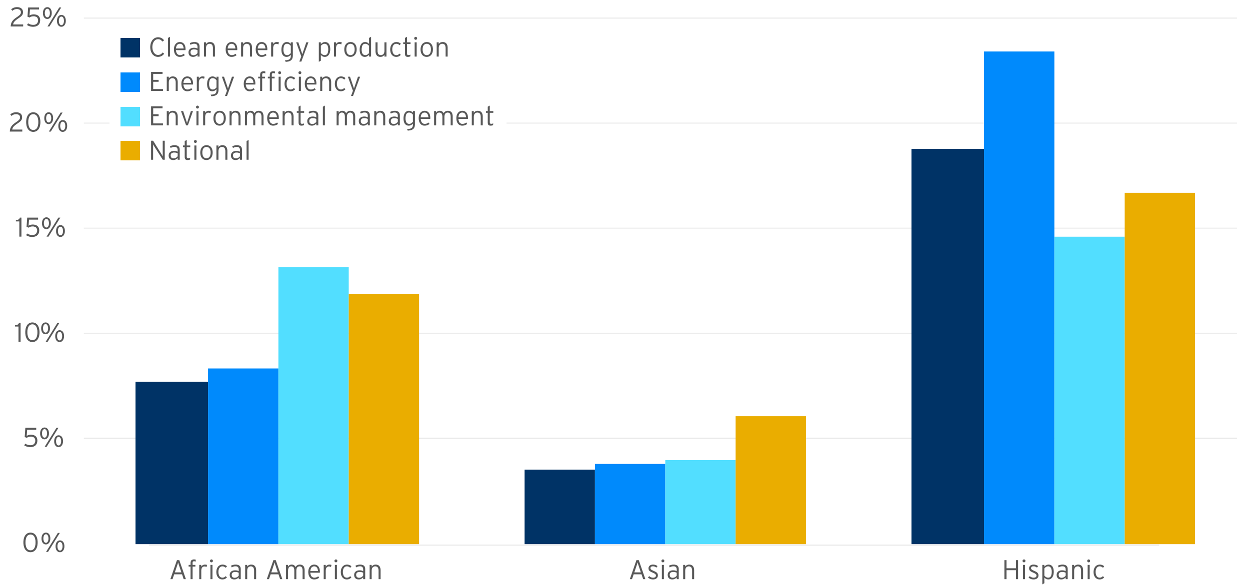
Share of female workers by clean energy economy sector, 2016



Source: Brookings analysis of Occupational Employment Statistics and Current Population Survey

FIGURE 12

Racial diversity in the clean energy economy versus all occupations nationally, 2016



Source: Brookings analysis of Occupational Employment Statistics and Current Population Survey

HOW INCLUSIVE ARE R&D OCCUPATIONS IN THE CLEAN ENERGY ECONOMY?

Transitioning to an economy powered by cleaner and reduced energy use demands a purposeful, aggressive pursuit of technological innovation. Without new products, services, and regulatory approaches to energy generation and consumption, the economy's energy profile would be static. Delivering on this need to innovate requires purposeful, well-funded, and patient research across the university community, public agencies, and research-driven companies. It's why Department of Energy laboratories like Oak Ridge National Lab and Sandia National Labs are invaluable public assets, and why encouragement of startup programs and innovation hubs around clean energy technology have bridged the gap between laboratory-based research and market-ready products and services.[36]

Altogether, research and development (R&D) is central to pursuit of a cleaner economy. And that means that evaluating occupations within R&D-focused industries and specific establishments—including on the same pay, education, and demographic components found in this paper—is an important priority for efforts to assess the overall inclusivity of the clean energy economy.

Unfortunately, our NAICS-based approach makes it impossible to narrow R&D occupations to only those related to energy activities. The categorization schema is simply too aggregated to disentangle which researchers, businesspeople, and other support services are working on energy issues and which are working on other topics. However, there is still value in reporting on pay and education trend for research-specific industries in general. Relying on past research, therefore, we identify several key industries here for research and technical services:

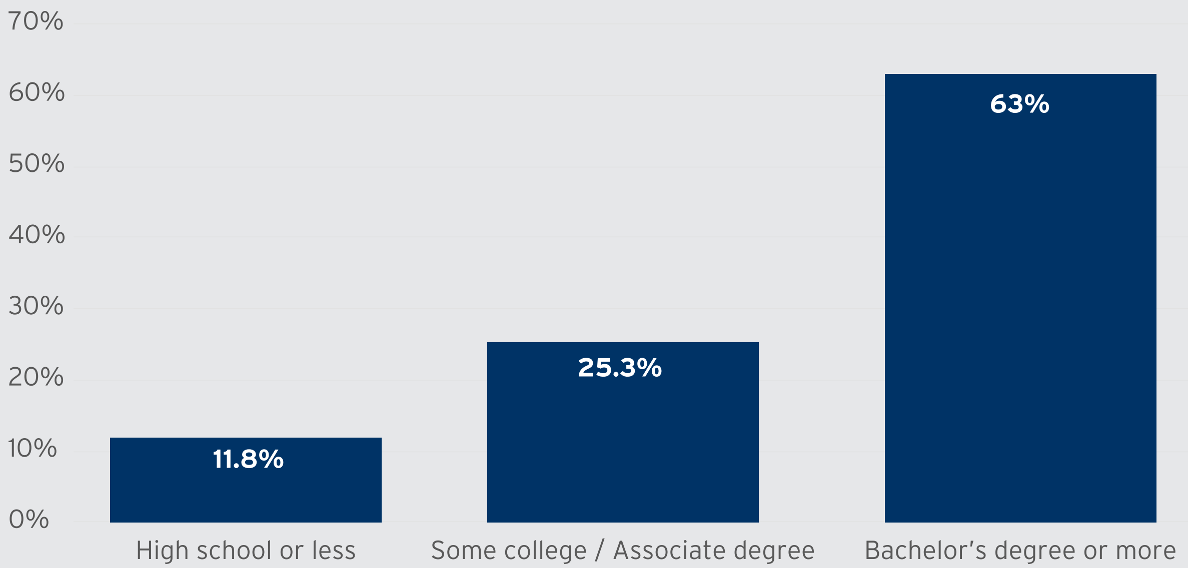
541330	Engineering Services
541360	Geophysical Surveying and Mapping Services
541380	Testing Laboratories
541690	Other Scientific and Technical Consulting Services
541711	Research and Development in Biotechnology
541712	Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)

Occupations in these industries are highly paid, highly skilled, and heavily technical in nature. Workers in these occupations have a mean hourly wage of $42.40, significantly higher than those in any of the three other clean energy economy sectors. Workers in these occupations also have very high levels of education: more than 60 percent of workers in these occupations have a bachelor's degree or more. It should come as no surprise that many of these occupations are STEM-heavy in their knowledge and skills requirements as well. Engineering and technology, physics, design, chemistry, and mathematics are the top five knowledge areas for these occupations, while the top five skills are science, mathematics, operations analysis, programming, and technology design.

These data points confirm that R&D jobs—not just those limited to the clean energy economy—offer the kind of career earnings that merit the significant upfront investment in education and skills development. These are also relatively elite jobs, with very few top-level research positions available. That combination makes R&D work inherently more exclusive than other aspects of the clean energy economy. If that is the case, then addressing inclusion gaps will require starting earlier in workers' careers. That means focusing on primary-school curriculum, university recruitment and retention, and which demographic groups benefit from such STEM-focused programming improvements.

FIGURE 13

Levels of educational attainment in research and technical services, 2016



Source: Brookings analysis of BLS Employment Projections data

V. Implications

As the U.S. transitions to a clean energy economy, it is going to require a sizable workforce to carry out and manage the transition. It's not surprising that recent calls for a Green New Deal have further elevated the importance of these jobs, including the need to hire and train a new generation of workers.[37]

Happily, this analysis shows that the types of jobs implicated in this shift possess special benefits for society. Specifically, they offer an attractive combination of variety, good pay, and accessibility, suggesting the ongoing energy transition is helping to address economic inclusion challenges from the national to the local level.

Clean energy jobs span numerous occupational groups and encompass numerous career tracks. Many workers are involved in the skilled trades, while others perform essential administrative, technical, and financial functions. Thus, the sector creates an unusually diverse set of career tracks to prospective workers.

Likewise, jobs related to the clean energy economy pay notably higher wages. Workers not only receive more competitive wages on average compared to all occupations nationally, but workers at the bottom end of the income spectrum (at the 10th and 25th percentiles) benefit from wage premiums that far exceed entry-level jobs found in other sectors. The equitable distribution of pay in this sector holds considerable economic promise for all types of workers across all skill levels at a time of stagnate and uneven incomes in many regions.

What's more, despite the availability of relatively high wages in the sector, there are notably fewer formal educational barriers to entry in most clean energy occupations. Except for certain specialized positions—many concentrated in *environmental management*; others related to advanced skills taught at universities—workers in the clean energy economy tend to only need a high school diploma or less. And in other cases, workers only need an associate degree or other types of vocational and technical education.

As a result, the relative accessibility of these good-paying positions has the potential to attract and employ workers from all backgrounds and help the nation construct a sustainable, advanced economy that works for all.

With that said, a number of obstacles are preventing underrepresented populations from accessing these low-barrier-to-entry jobs.

The first obstacle is a lack of young talent entering the clean jobs economy, where the median age of workers continues to edge higher and a shortfall of skilled replacements is becoming increasingly likely. A pending wave of retirements and other occupational shifts is an issue facing many clean energy employers (and an opportunity for improved inclusion), but such staffing challenges will only be well managed if efforts are made to cultivate an appropriately ready, and trained, pool of younger workers.[38] In recent surveys, employers have also frequently noted hiring difficulties for new workers, who lack related experience, training, and technical skills.[39]

Perhaps more concerning though, is the lack of gender diversity across the three clean energy economy sectors and inconsistent racial diversity in certain occupations. Combined, each of these indicators signals a continued lack of visibility and outreach among certain underserved jobseekers (and students) to these skilled trades. In turn, there is a need for clearer career pipelines and opportunities to effectively introduce and market the clean energy economy to *all* prospective workers.

In that light, stressing additional education and workforce development strategies is crucial for national, state, and local leaders alike. Conveniently, this need comes at the same time there is a national renaissance around developing new training models. There are three primary areas where clean energy economy industries and their public and civic partners can learn from current models in use across the country.

Given the importance of science-related knowledge, **modernizing and emphasizing energy science curricula** should be a priority at all levels of education:

- *Extracurricular, supplemental, and short-term programs:* At the college level, the development of both STEM and energy degree supplemental programs and "minors" for even liberal arts and underrepresented students are an essential way to allow more students to become engaged in clean energy careers. Many of the Department of Energy's national laboratories, most notably Brookhaven National Laboratory, are showing the way by significantly widening the availability of energy science summer programs, workshops, and internships to women and underrepresented in their regions, often with the goal of preparing students for full degrees, graduate programs, or employment in clean energy fields. In addition, the applied nature of the energy field—and its ties to a large industry and many other domains of knowledge—facilitates a fast-track for "certificate" programs to allow students in a variety of majors to quickly learn the basics of energy science, technology, and adoption.

- *Associate degree programs:* Relatedly, many community colleges have developed multi-dimensional, employment oriented clean-energy oriented associate programs with strong relevance to the realities of clean energy labor markets. For example, Lane Community College in Oregon has developed a two-year online degree in energy management focused on large-building energy efficiency solutions. Other community colleges that have implemented renewable energy and "green collar" study programs are Cape Fear Community College in North Carolina, Cod Community College, and Columbia Gorge Community College, also in Oregon. The easy (and online) availability of such degrees and certifications—preferably with a "hands-on" component and orientation to local clean energy activity—remains a critical education and training tool in regions.

Regional initiatives, meanwhile, with a focus on local industries, are also required to cultivate a strong, relevant workforce and widen inclusion to **improve the alignment of education and training offerings**—including "experiential" or on-the-job learning. While this is always important, the breadth of industries and actors implicated in the clean energy economy transition makes collaboration particularly tricky given that many workers and employers in this space may not see themselves as part of an integrated sector.[40] Fortunately, a number of initiatives are setting an example and may be applicable in the clean energy space:

- *Public/private partnerships:* One such approach is Skillful, a new skills-matching platform led by an array of national partners that is underway in Colorado. Skillful uses deep collaboration among public and private partners, plus evidence-based analysis and persistent transparency, to help workers and students identify needed skills, obtain them, and connect to promising employers. Skillful demonstrates a model of data-driven matching, and it points the way toward solutions for the clean energy labor market, whether as a sub-set of larger solutions or in its own right. Such programs show promise of helping connect workers to employers in a diffuse field where multiple industries, trades, and occupations are all involved.

- *On-the-job learning:* Apprenticeships and experiential learning are especially welcome in the clean energy sector, given the large role of tacit knowledge and that many positions do not require an associate or bachelor's degree. Such learning represents an excellent mechanism for both filling job openings and linking *all* aspiring workers to employers in an important sector. Indeed, the utility industry, the construction industry, and the advanced manufacturing sector—key elements of the clean energy economy—have long track records of providing on-job experiential learning or apprenticeships. Frequently, however, there are too few opportunities to expand experiential learning, with too little knowledge about the opportunities available, and they must be more widely publicized. That is why the Center for Apprenticeship Innovation in Michigan has been working to build awareness and commitments on the part of both employers and students with its Experience Sooner public education campaign. Infusing such campaigns with a focus on local clean energy opportunities is clearly part of the way forward. In addition, aligning existing job-training programs with emerging experiential learning and apprenticeship opportunities could increase the effectiveness of both.

Lastly, efforts to **reach underrepresented workers and students** will be essential to capture a broader pool of talent for this sector, and ultimately forge a stronger economic connection with the communities that utilities and other employers serve.

Research by Joan Williams, Kathrine Phillips, and Erika Hall offers an essential starting point to understand bias in STEM-related occupations and to design objective methods to measure employer policies for the most common violations.[41] For example, female representation is alarmingly low in many clean energy economy occupations, which should push employers and civic organizations to first review what systemic biases may be at play. Early involvement in STEM, apprenticeships focused on inclusivity, and concentrating on local entities are first steps to ensuring that these workers have a seat at the table:

- *Early involvement:* Three actions to ensure that inclusivity starts early include: develop stronger recruitment and referral systems for engagement programs; create "pre-apprenticeship" feeder programs to bridge divides; and enhance the availability of support, such as mentors, to improve completion rates of apprenticeships and other programs.[42] Pre-apprenticeship programs can play a vital role in ensuring success just the way job-readiness programs prepare individuals for full employment. The tech sector is already gauging the existence of usable practical models for supporting inclusion in technical industries. Many of these programs pair gender- or race-focused cohort strategies with focused, flexible training, and supportive culture. A case in point are the superior results of coding "boot camps" like Black Girls Code, especially when they employ group-specific cohorts. Clean-energy industries should explore ways to reach new communities through trainings and recruitments that prize job-readiness, supportive spaces, and group consciousness.

- *Inclusive apprenticeships:* While the scale-up of experiential learning and apprenticeships appears especially important to staffing the field, steps must be taken to ensure that such strategies deliver on the sector's promise for inclusion. Apprenticeships do have a track record of success in connecting would-be workers to careers in fields like clean energy. However, apprenticeships have historically also been less accessible to women, people of color, and youth. Federal statistics confirm that women, especially, and people of color, are underrepresented in apprenticeships and overrepresented in the lowest-wage positions. Such realities underscore the need for focused attention on making sure apprenticeships and experiential learning in the clean energy sector deliver on inclusion as the nation grows more diverse. One advantage clean energy segments, such as solar installation, have is that they are "new" and include firms and occupations that may be less hidebound and more inclusive.

- *Local connections:* Finally, locally based community groups, neighborhood centers, churches, and affordable housing groups are good partners in recruiting diverse candidates for a work-based learning experience. Local organizations like the Greater Cincinnati Workforce Network have curated best practices research on retention in the building trades that may be applicable to clean energy on-job learning.[43] With these approaches, more clean energy employers and industry clusters can work to ensure their sector delivers on its great promise for economic inclusion.

VI. Conclusion

The momentum of the country's clean energy transition is impossible to ignore. Zero-emission energy sources continue to drop in price. Consumer products increasingly rely on rechargeable power sources. New regulations to minimize environmental impacts are growing in popularity. More must be done, but market forces are pointing in a more sustainable, resilient direction.

As the clean energy transition continues to unfold, this report confirms that the benefits from this transition will extend beyond the planet's natural health.

Occupations related to the clean energy transition offer a potent antidote to the inclusion challenges of the modern American economy. A diverse array of jobs pay above-average wages in careers that often do not require formal education beyond high school. Just as importantly, most careers provide on-the-job training to teach workers in an applied setting. These are the types of professional opportunities the macroeconomy needs in a time of significant industrial transformation.

As this energy-related transition advances, there are clear areas where improving workforce development practices can expand the number of workers who have a chance to benefit from the inclusive pathways the clean energy economy will offer. This especially applies to women and communities of color, both of whom are consistently underrepresented in many occupations. Fortunately, the timing is ideal. Workforce development is firmly entrenched as a top economic priority from the local to federal level, among employers of all sizes, and within a growing number of organizations committed to career training. The key will be seeing clean energy as more than just a way to combat a scientific phenomenon, but also an economic opportunity, and one that can benefit the labor market by promoting economic inclusion.

Appendix A: Detailed methodology

IDENTIFYING INDUSTRIES AND OCCUPATIONS IN THE CLEAN ENERGY ECONOMY

For the purposes of this report, we defined jobs in the clean energy economy as follows:

> ***Jobs in the clean energy economy*** *are jobs directly involved in (1) the production, transmission and distribution of clean energy; (2) increasing energy efficiency through the manufacturing of energy-saving products, the construction of energy-efficient buildings, and the provision of services that reduce end-use energy consumption; (3) environmental management and the conservation and regulation of natural resources.*

Based on our definition, we classify the clean energy economy in terms of occupations and industries, regardless of the ownership or output associated with individual establishments. As a first step, we establish a list of industries that are critical to the transition to a clean energy economy by drawing on the Department of Energy's 2017 U.S. Energy and Employment Report, the UCLA Luskin Center's report on 'Understanding the Green Economy in California,' and the BLS Green Jobs survey. This core list of identified industries is diverse and encompasses a wide range of activities relevant to the clean energy economy. In order to meaningfully identify critical occupations in these industries, we assemble closely-related groups of industries in three broad clean energy economy sectors:

- Clean energy production, transmission, and distribution
- Energy efficiency, which includes the:
  - Manufacturing of energy-efficient products
  - Construction of energy-efficient buildings and provision of energy efficiency services
- Environmental management, conservation, and regulation

TABLE A1

Industries in the clean energy economy by sector

NAICS	NAICS Title
Clean energy generation, manufacturing and construction	
Generation utilities	
221111	Hydroelectric power generation
221113	Nuclear electric power generation
221114	Solar electric power generation
221115	Wind electric power generation
221116	Geothermal electric power generation
221117	Biomass electric power generation
221118	Other electric power generation
221121	Electric bulk power transmission and control
221122	Electric power distribution
221330	Steam and air-conditioning supply
Grid component manufacturing and construction	
332410	Power boiler and heat exchanger manufacturing

333611	Turbine and turbine generator set units manufacturing
335311	Power, distribution, and specialty transformer manufacturing
335911	Storage battery manufacturing
335931	Current-carrying wiring device manufacturing
237130	Power and communication line and related structures construction
237990	Other heavy and civil engineering construction
238210	Electrical contractors and other wiring installation contractors
Energy efficiency	
Manufacturing of energy-efficient products	
327993	Mineral wool manufacturing
332321	Metal window and door manufacturing
332322	Sheet metal work manufacturing
333415	Air-conditioning and warm air heating equipment and commercial and industrial refrigeration equipment manufacturing
336111	Automobile manufacturing
336112	Light truck and utility vehicle manufacturing
336120	Heavy duty truck manufacturing
336211	Motor vehicle body manufacturing
336310	Motor vehicle gasoline engine and engine parts manufacturing
336320	Motor vehicle electrical and electronic equipment manufacturing
336330	Motor vehicle steering and suspension components (except spring) manufacturing
336340	Motor vehicle brake system manufacturing
336350	Motor vehicle transmission and power train parts manufacturing
336360	Motor vehicle seating and interior trim manufacturing
336370	Motor vehicle metal stamping
336390	Other motor vehicle parts manufacturing
334512	Automatic environmental control manufacturing for residential, commercial, and appliance use
334513	Instruments and related products manufacturing for measuring, displaying, and controlling industrial process variables
334515	Instrument manufacturing for measuring and testing electricity and electrical signals
336510	Railroad rolling stock manufacturing
335110	Electric lamp bulb and part manufacturing
335121	Residential electric lighting fixture manufacturing
335122	Commercial, industrial, and institutional electric lighting fixture manufacturing
335210	Small electrical appliance manufacturing
335221	Household cooking appliance manufacturing
335222	Household refrigerator and home freezer manufacturing
333413	Industrial and commercial fan and blower and air purification equipment manufacturing
333414	Heating equipment (except warm air furnaces) manufacturing

334413	Semiconductor and related device manufacturing
335312	Motor and generator manufacturing
335999	All other miscellaneous electrical equipment and component manufacturing
Construction of energy efficient buildings & provision of energy efficiency services	
236115	New single-family housing construction (except for-sale builders)
236116	New multifamily housing construction (except for-sale builders)
236117	New housing for-sale builders
236118	Residential remodelers
236210	Industrial building construction
236220	Commercial and institutional building construction
237210	Land subdivision
238350	Finish carpentry contractors
238220	Plumbing, heating, and air-conditioning contractors
238160	Roofing contractors
238990	All other specialty trade contractors
541310	Architectural services
541340	Drafting services
541320	Landscape architectural services
541350	Building inspection services
Environmental management, conservation and regulation	
541620	Environmental consulting services
562111	Solid waste collection
562112	Hazardous waste collection
562119	Other waste collection
562211	Hazardous waste treatment and disposal
562212	Solid waste landfill
562213	Solid waste combustors and incinerators
562219	Other nonhazardous waste treatment and disposal
562910	Remediation services
562920	Materials recovery facilities
562998	All other miscellaneous waste management services
813312	Environment, conservation and wildlife organizations
924110	Administration of air and water resource and solid waste management programs
924120	Administration of conservation programs
925120	Administration of urban planning and community and rural development
926120	Regulation and administration of transportation programs
926130	Regulation and administration of communications, electric, gas, and other utilities

Next, we identify all the occupations in each clean energy economy sector and develop a measure of *occupational concentration*—the share of cross-industry national employment for a specific occupation concentrated in a given clean energy economy sector. In order to study inclusion, we consider the occupations in each clean energy economy sector that have at least 1 percent of their cross-industry national employment concentrated in that sector. This threshold yields lists of 113, 172, and 186 occupations each for clean energy production, energy efficiency, and environmental management sectors, respectively. Since many of the same occupations qualify as concentrated in either two or three of the sectors, the total number of unique clean energy economy occupations is 320.

Clean energy economy sector	Total number of occupations in the sector	Occupations with a greater than 1% concentration in the sector
Clean energy production	296	113
Energy efficiency	436	172
Environmental management	647	186

LIMITATIONS AND CHECKS

The use of publicly available data sources offers advantages in the transparency and replicability of work in this report, as well as greater ease in updating key findings over time. However, there are certain limitations imposed on the analysis due to limitations within the data, as well as constraints in combining data from a variety of public sources to create a reliable central database.

Exclusion of clean energy inputs. Although some research qualifies certain agricultural inputs like biofuels as components of the clean energy economy, agriculture as an industry sector has limited detailed OES employment data. The only way of deriving any occupational data for the 6-digit NAICS codes for biofuel-related agricultural industries would require aggregation to the 2-digit NAICS level (NAICS 11). This makes the occupational estimates unreliable, and so we refrain from including agricultural inputs in the list of NAICS industries pertinent to the clean energy economy. In order to maintain consistency, we therefore also exclude industries and occupations relevant to the mining and processing of nuclear fuel.

Exclusion of manufacturing processes that are more energy efficient. It is incredibly difficult to characterize which establishments are more efficient in their use of energy as compares to other establishments providing the same product or service, even when we rely on detailed establishment-level proprietary information. For instance, one car manufacturing facility might use energy more efficiently than the other. Due to our reliance on public information, it is impossible to distinguish between different types of establishments within industries. Further, the goal of the report is to understand inclusion of employment opportunities, which can be understood at a more aggregated industry level.

Separate analysis of research and technical services. Research and development are central to expanding the clean energy economy. However, NAICS data does not differentiate energy-focused R&D activities from broader industrial research activities, like within Research and Development in the Physical, Engineering, and Life Sciences (NAICS 541712). As a result, this analysis compartmentalizes occupations within R&D-focused industries under a box.

EMPLOYMENT DATA

This report uses 2016 employment data publicly available from the U.S. Bureau of Labor Statistics (BLS) Occupational Employment Statistics (OES) program and the Employment Projections (EP) program. We draw employment and wage totals primarily from the OES program, which releases estimates annually. The OES program bases these estimates on a semi-annual mail survey in May and November in partnership with State Workforce Agencies. The survey measures employment for workers in non-farm establishments. Estimates for 2016 were drawn from 1.2 million establishments across six panels of data collected over three years.[44] The sample is developed from state unemployment insurance files. OES employment and wage data are defined in terms of specific occupations and industries, as established under the 2010 Standard Occupational Classification (SOC) system and 2012 North American Industry Classification System (NAICS). This report focuses on detailed SOC occupations and 4- to 6-digit NAICS industries.

Employment totals used to analyze skills and projections in this report are drawn from the EP program, which relies on a National Employment Matrix that combines employment data from several different sources, including the OES program, the Current Employment Statistics (CES) program, and the Current Population Survey (CPS). Detailed information on EP skill and projection estimates is described later in this appendix. Data on knowledge and skills for workers in all occupations is derived from the Occupational Information Network (O*NET), an online resource center and database sponsored by the Department of Labor's Employment and Training Administration. Education data is from the U.S. Bureau of Labor Statistics Employment Projections program (Educational attainment for workers 25 years and older by detailed occupation), which uses the 2015 and 2016 American Community Survey Public Use Microdata as its source.

Analysis of OES wage data

Throughout the report, OES wages are based on straight-time and gross pay (includes forms of compensation such as cost-of-living allowances and over-the-road pay, but excludes overtime pay and holiday bonuses). Mean hourly and annual wages are highlighted in this report, in addition to percentile wages (10th, 25th, 50th, 75th, and 90th). By definition, workers at the 10th and 25th percentiles earn wages at the lower end of each occupation and industry, while workers at the 75th and 90th percentiles earn wages at the higher end.

Each clean energy economy sector as identified in this report has multiple industries, which means that certain occupations might be linked to many industries within the sector. For instance, Power Line Installers and Repairers might be employed by utilities as well as construction-oriented industries. Therefore, the average hourly wage for each clean energy economy sector is calculated using a 2-step process:

1. Within-occupation weighted mean: We first generate employment-weighted wages for each detailed occupation in the clean energy economy sector.

2. Across-occupation weighted mean: Using within-occupation weighted means, we calculate the employment-weighted mean across all occupations in a given sector to generate a single mean wage for the sector as a whole.

Measuring skills in terms of education and training

This report examines skills in terms of education and training typically needed for clean energy economy occupations. BLS tracks levels of education, related work experience, and on-the-job training required for different occupations. While some occupations can potentially have multiple paths of entry, BLS only tracks one typical path in its classification system. Gathering information from O*NET, the National Center for Education Statistics, and the U.S. Census Bureau's American Community Survey (ACS), BLS uses a combination of quantitative and qualitative measures to evaluate skills across detailed occupations.

Typical levels of education attained—and needed for entry—are based on the following education levels for workers ages 25 years and older: doctoral or professional degree; master's degree; bachelor's degree; associate degree; postsecondary non-degree award; some college, no degree; high school diploma or equivalent; and less than high school. EP educational attainment by detailed occupation, in particular, is based on 2015 to 2016 totals. Related work experience is often considered necessary for many other jobs nationally and defined in three categories:

5 years or more, less than 5 years, and none. Based on competency requirements, typical on-the-job training needed falls into six categories: internship/residency; apprenticeship; long-term on-the-job training (more than 12 months); moderate term on the job training (more than 1 month and up to 12 months); short-term on-the-job training (1 month or less); and no training.

Analysis of O-NET knowledge and skills data

In order to determine the types of knowledge and skills that workers in each of the three categories would need, we rely on O*NET data. O*NET gauges the "level" of knowledge needed in 33 different content areas to perform job duties. These levels are rated from 0 (minimum) to 7 (maximum) based on worker questionnaires. By calculating the average score for each content across the 50 most concentrated occupations in each category[45] and then comparing these averages to what is found across all occupations nationally. One specific caveat in O*NET data is that the residual "All other" occupations do not have knowledge and skills information. In the absence of technical guidance on imputing this data from existing O*NET data, we exclude occupations with missing information from the knowledge and skills analysis.

Analysis of Current Population Survey (CPS) demographics data by occupation

The Current Population Survey utilizes a different coding structure for occupations. Since we rely on SOC 2010 occupation codes throughout this report, it necessitates the successfully linking of worker demographics data from the Current Population Survey to the SOC 2010 occupations. The occupations in the SOC are classified at four levels of aggregation to suit the needs of various data users: major group, minor group, broad occupation, and detailed occupation. In matching CPS data to SOC data, there are some additional constraints on data availability at the right level of aggregation. In this report, we first identify perfectly matched data at the 'detailed' occupation level when linking CPS to SOC data. In the absence of detailed occupation data, we impute demographic characteristics from certain occupations at the 'broad' level.

Endnotes

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21. For instance, several equity frameworks are useful to consider in this respect, including those established by organizations like the Rockefeller Foundation. For more context, see: Chris Brenner and Manuel Pastor, "Inclusive Economy Indicators: Framework and Indicator Recommendations" (New York: Rockefeller Foundation, 2016).

22. Note that employment totals for skills and projections are drawn from the BLS Employment Projections (EP) Program, which relies on different methods than those used in the OES data. As a result, these figures may vary slightly. For more information on EP methods, see: http://www.bls.gov/emp/ep_projections_methods.htm.

23. For more information on OES pay terms, see: http://www.bls.gov/respondents/oes/payterms.htm.

24. A firm is an establishment or combination of establishments involved in a given industrial activity. For example, see the following article for additional context: https://www.bls.gov/opub/mlr/2016/article/establishment-firm-or-enterprise.htm.

25. For instance, consider the Solar Foundation's "National Solar Jobs Census," available at: https://www.thesolarfoundation.org/national/.

26. Additional information on the BLS Occupational Employment Statistics program is available at: https://www.bls.gov/oes/oes_emp.htm. For more background on the BLS Employment Projections program, see: https://www.bls.gov/emp/.

27. See Appendix A for the full list of industries.

28. This special approach to governments-specific occupations is necessitated by the deep challenges around public industry data.

29. These are often covered in the media through the growing price efficiencies and new deployments of renewable energy sources. For full list, see Table A1 in Appendix A.

30. Note that 117 occupations are represented multiple times across the three sectors, meaning there are only 320 unique occupations by SOC code. However, when calculated separately by each of the three industrial categories, it leads to a count of 471 occupations.

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45. The concentration for any given occupation is determined by the share of national cross-industry employment that is accounted for in a specific industry/set of industry.

Acknowledgements

The Metropolitan Policy Program at Brookings would like to thank the Nathan Cummings Foundation for its generous support of this analysis, and the Metropolitan Council, a network of business, civic, and philanthropic leaders that provides both financial and intellectual support for the program.

The authors would like to thank the following colleagues for providing valuable insights and critiques of early versions of the analysis and report: Darnita Akers, Alan Berube, Philip Jordan, Susan Iott, Martha Ross, Danielle Deane-Ryan, David Victor, and Carol Zabin. The authors would also like to thank the following colleagues for valuable support in producing the report and contributing to outreach efforts: Rachel Barker, Liza Cole, David Lanham, Anthony Fiano, Carly P. Anderson. Thanks to Luisa Zottis for layout and design.

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