Workforce Development for U.S. Hydropower:

KEY TRENDS AND FINDINGS

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Figures & Tables

The purpose of this report is to provide a brief assessment of the current U.S. hydropower industry workforce and educational programs, as well as potential future hydropower workforce needs. This report is based on data collected in 2016 for the U.S. Department of Energy (DOE) by Navigant Consulting and the National Renewable Energy Laboratory (NREL),[1] which included a 2014 survey of hydropower employers to assess future workforce needs for potential growth scenarios.

[1] This report can be found at https://www.osti.gov/biblio/1510033.

Long the nation's largest source of renewable energy, hydropower in the United States continues to grow. As of 2018, hydropower represented almost 7% of U.S. energy generation (11% of electricity) and 41% of all renewable energy generation, with approximately 80 gigawatts (GW) of installed capacity. During the preceding decade (2006-2016), installed capacity for hydropower and pumped storage each separately grew by more than 2 GW. (Energy Information Administration [EIA], 2018, 2019; DOE 2018)

Hydropower is also increasingly recognized for the valuable flexibility and reliability of the services it provides to the grid. For example, in a widespread power outage, a hydropower plant has the ability to start its generator unit(s) from a completely unenergized state without requiring grid-fed external power—a practice commonly referred to as a "black start" (Gracia, et al. 2019). Hydropower is also well-positioned to enable the integration of variable renewable resources, such as wind and solar, while supporting grid reliability and resilience. For these reasons and many more, **the future U.S. hydropower workforce will play an important role in the future of the U.S. grid.**

Hydropower is among the oldest sources of electricity generation in the nation, and hydropower plants can be found in each of the 50 states (Paidipati et al. 2017). Over time, the workforce has evolved as the industry, technology, and population have changed, requiring more skilled professionals specializing in a range of trades to fill the growing number and types of jobs. A qualified workforce will be needed as the industry continues to modernize and evolve, and sustained growth in different areas of the hydropower fleet (development of more non-powered dams, new small hydro facilities, and pumped-storage hydropower) could create further staffing demands.

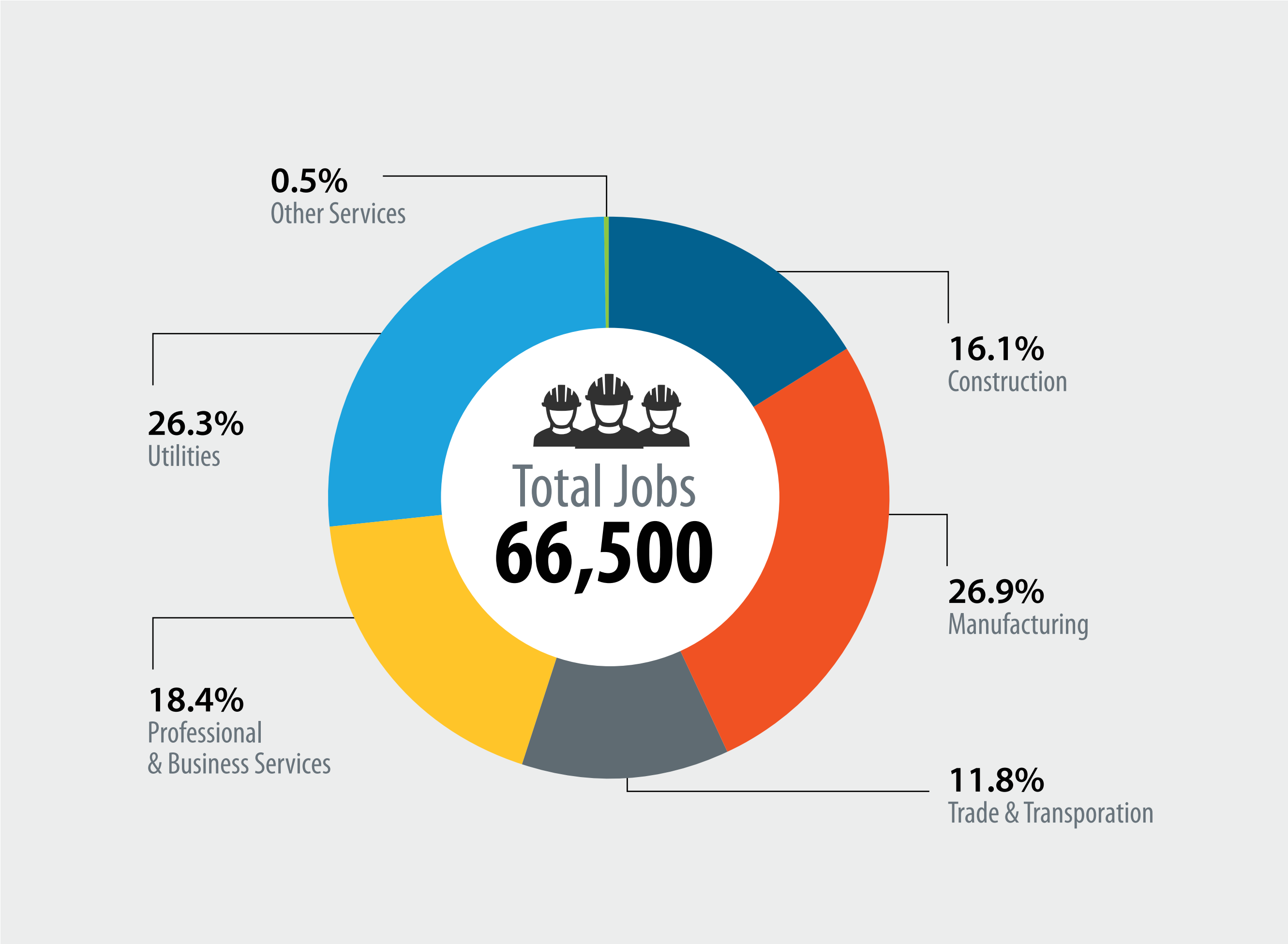


Figure 1. Hydropower Sector Employment by Industry *Source: NASEO (2019)*

Surveys conducted by Paidipati, et al. (2017) and the National Association of State Energy Officials (NASEO 2019) characterize this workforce and the hydropower sector in general, and share key information about workforce demographics, industry needs, and what the future may hold.

Hydropower is an established industry in the United States, employing 66,500 workers (NASEO 2019).

In 2018, the hydropower industry employed 66,500 electricity workers in the United States, more than nuclear but fewer than coal, wind, natural gas, and solar (NASEO 2019). These numbers represent both construction tied to capacity expansion or upgrades and operation and maintenance (O&M). The industries that employ the most workers are also the fastest growing (EIA 2019). NASEO (2019) does not differentiate between construction and O&M, but limited additions in hydropower generation suggest that most are ongoing O&M positions.

Hydropower workers are employed in a number of industries, including businesses that provide goods and services to support hydropower operations. Most hydropower workers are in the manufacturing sector (32%), followed by the utilities sector (27%), which includes hydropower plant operators, maintenance staff, engineers, and other professionals (NASEO 2019; see Figure 1).

The majority of hydropower organizations reported difficulty hiring in all industries within the hydropower sector, except for utilities (NASEO 2019).

When asked about the ease of filling positions, hiring managers from all industries reported difficulties, as shown in Figure 2. The pervasiveness of reported hiring difficulty ranged from 100% of all trade and transportation businesses to 33% of utilities, as surveyed for the 2019 U.S. Energy Employment Report (NASEO 2019). Utilities were the only employers who indicated less than 70% of businesses experienced difficulty hiring (NASEO 2019).

Difficulty hiring, attrition due to retirement, and other reasons such as workers leaving the labor force due to disability or mortality have implications for the growth of the hydropower sector. Utility operators within the hydropower sector reported the lowest total percentages of hiring difficulty compared to other hydropower-related industries, but the types of difficulties they reported fell entirely in the most extreme Very Difficult category in attracting new talent.

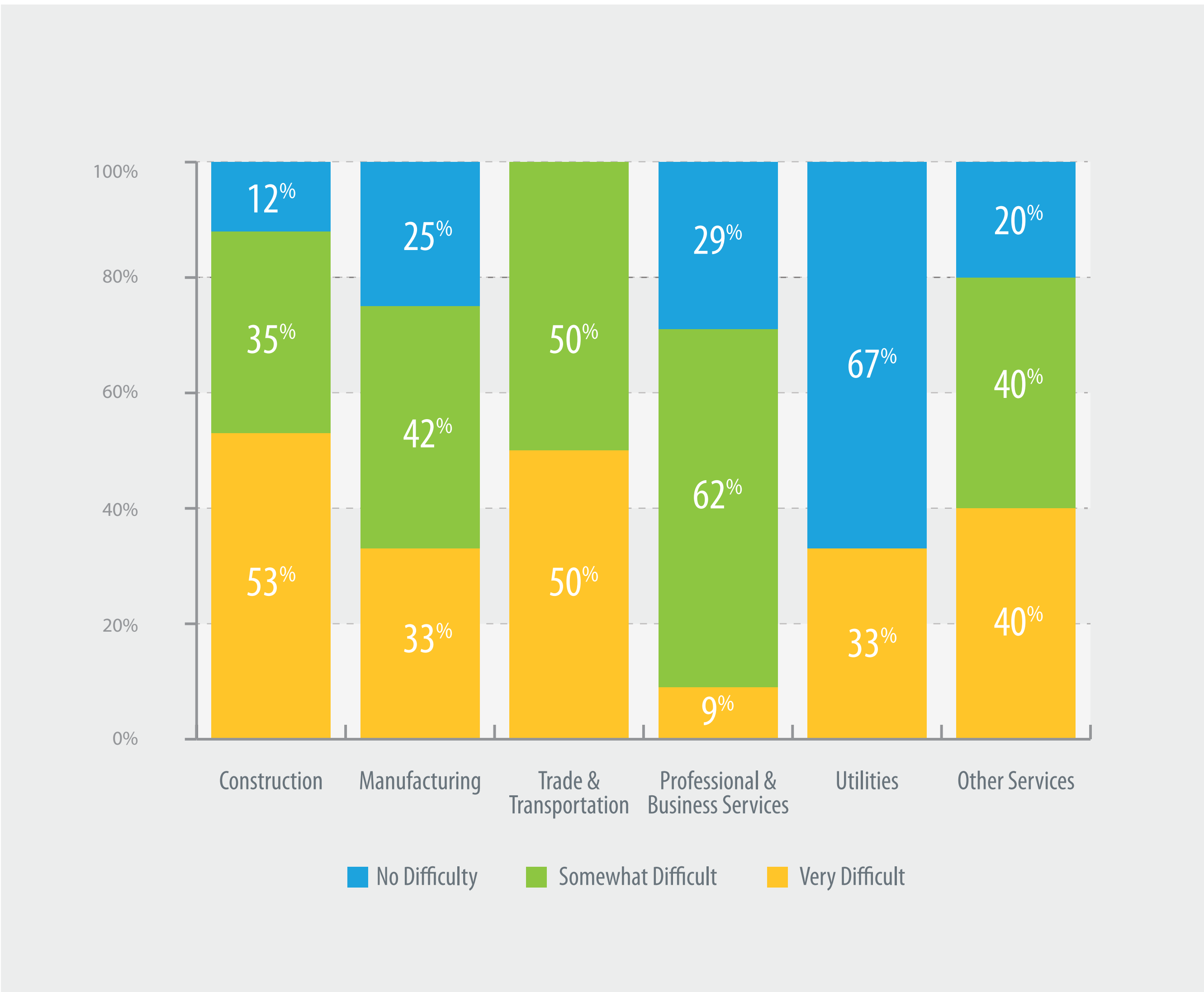


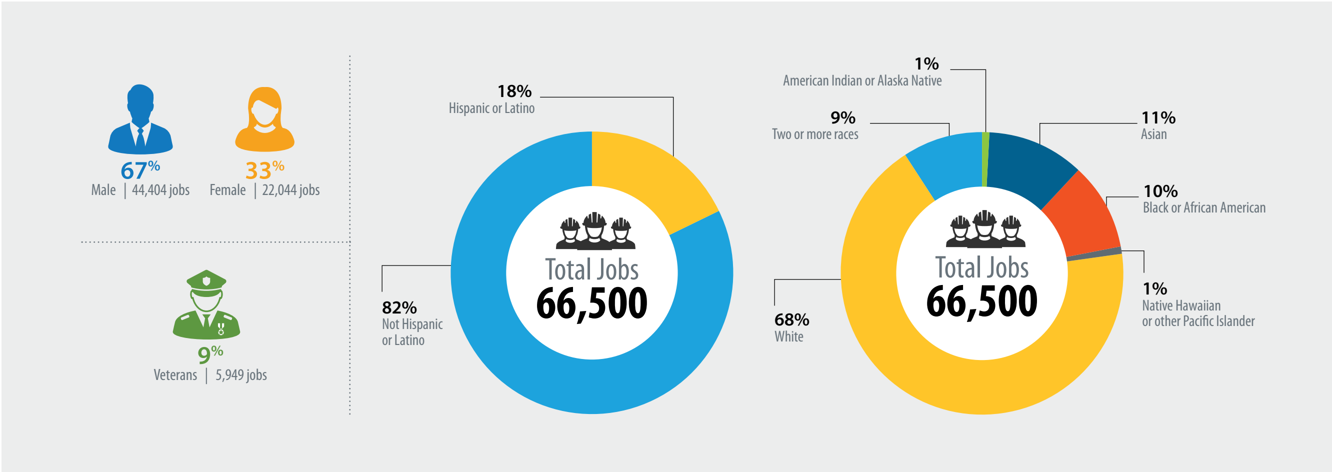
Figure 2. Hiring Difficulty Across the Hydropower Sector, According to Hiring Managers *Source: NASEO (2019)*

The hydropower industry employs a higher percentage of military veterans and minorities than are found in the U.S. working age population.

Table 1 shows the demographics of the hydropower workforce by gender, Hispanic/non-Hispanic ethnicity, race, veteran status, and age. The workforce is primarily male and white, although both veterans and minorities are represented at slightly higher levels than in the U.S. population as a whole. While nonwhites make up 28% of the U.S. population over the age of 15, 32% of the hydropower workforce is nonwhite. Similarly, veterans make up 8% of the U.S. population over the age of 18, whereas at least 9% of the total hydropower workforce[2] has served in the military (NASEO 2019; Census 2019).

The hydropower workforce is less diverse than the general U.S. workforce in terms of gender. Nationally, 49% of the working age population is female, and the other 51% is male (U.S. Census Bureau [Census] 2019). Women make up only 33% of the hydropower workforce (NASEO 2019). There could be many reasons for this, including the mix of occupations (BLS 2019).

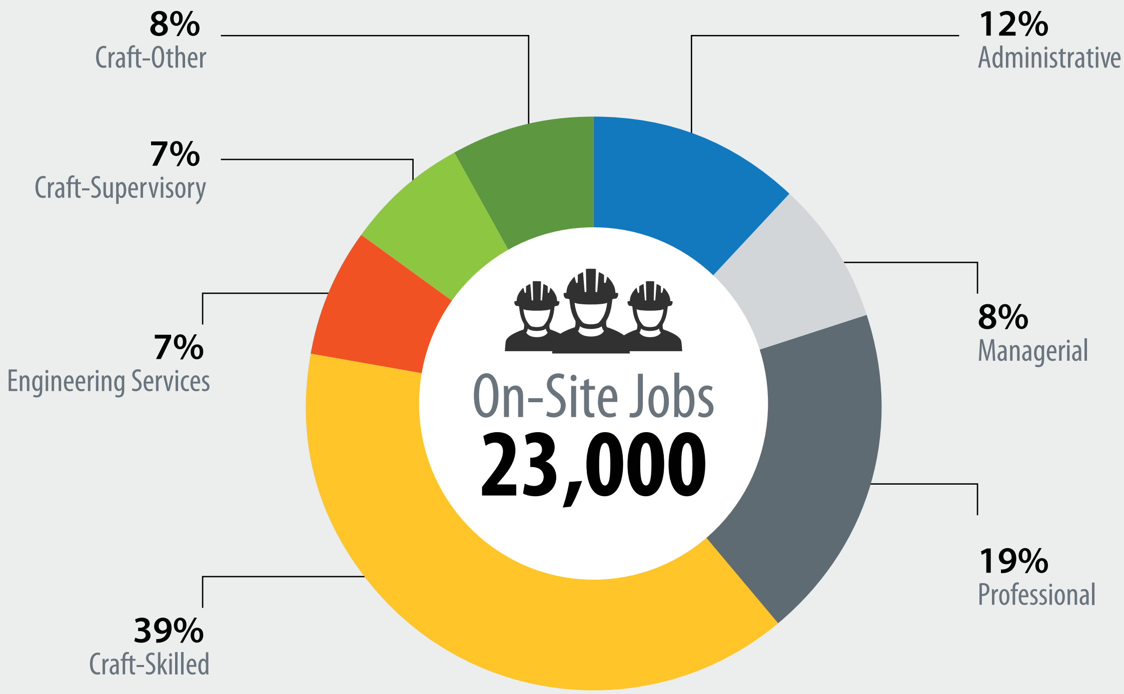
[2] Includes hydropower workers under the age of 18. If comparable statistics were available, then it is assumed the portion of the hydropower workforce over the age of 18 with veteran status would be higher than 9%.



Demographic	Hydropower Jobs	Percent of Hydropower Jobs	Percent of U.S. Working Age Population[3]
Male	44,404	67%	49%
Female	22,044	33%	51%
Hispanic or Latino	11,923	18%	21%
Not Hispanic or Latino	54,525	82%	79%
American Indian or Alaska Native	928	1%	1%
Asian	7,104	11%	6%
Black or African American	6,452	10%	13%
Native Hawaiian or other Pacific Islander	825	1%	0%
White	45,209	68%	72%
Two or more races	5,929	9%	8%[4]
Veterans	5,949	9%	8%[5]

Table 1. Demographics of the U.S. Hydropower Workforce *NASEO (2019); Census (2019)*

[3] The working age population is defined as ages 15 and up.
[4] Includes those who indicated a race not listed in Table 1.
[5] Population over the age of 18.



Staff Classification	Description
Administrative	Clerk, administrative assistant, customer service, etc.
Craft-Skilled	Electrician, mechanic, instrumentation technician, operator, etc.
Craft-Other	General laborer, custodian, etc.
Craft-Supervisory	Direct reports include craft-foremen and craft personnel (maintenance manager/superintendent, shift supervisor, etc.) or skilled craft personnel
Managerial	Direct reports include supervisors and other managers (general management, project and program manager, supply chain manager, etc.)
Professional	Finance, human resources, legal personnel, financial analyst, biologist, etc.
Engineering Services	Engineer (civil, environmental, mechanical, electrical), draftsman, engineering technician, etc.

Figure 3. Occupations of On-Site Hydropower Workers *Source: Paidipati et al. (2017)*

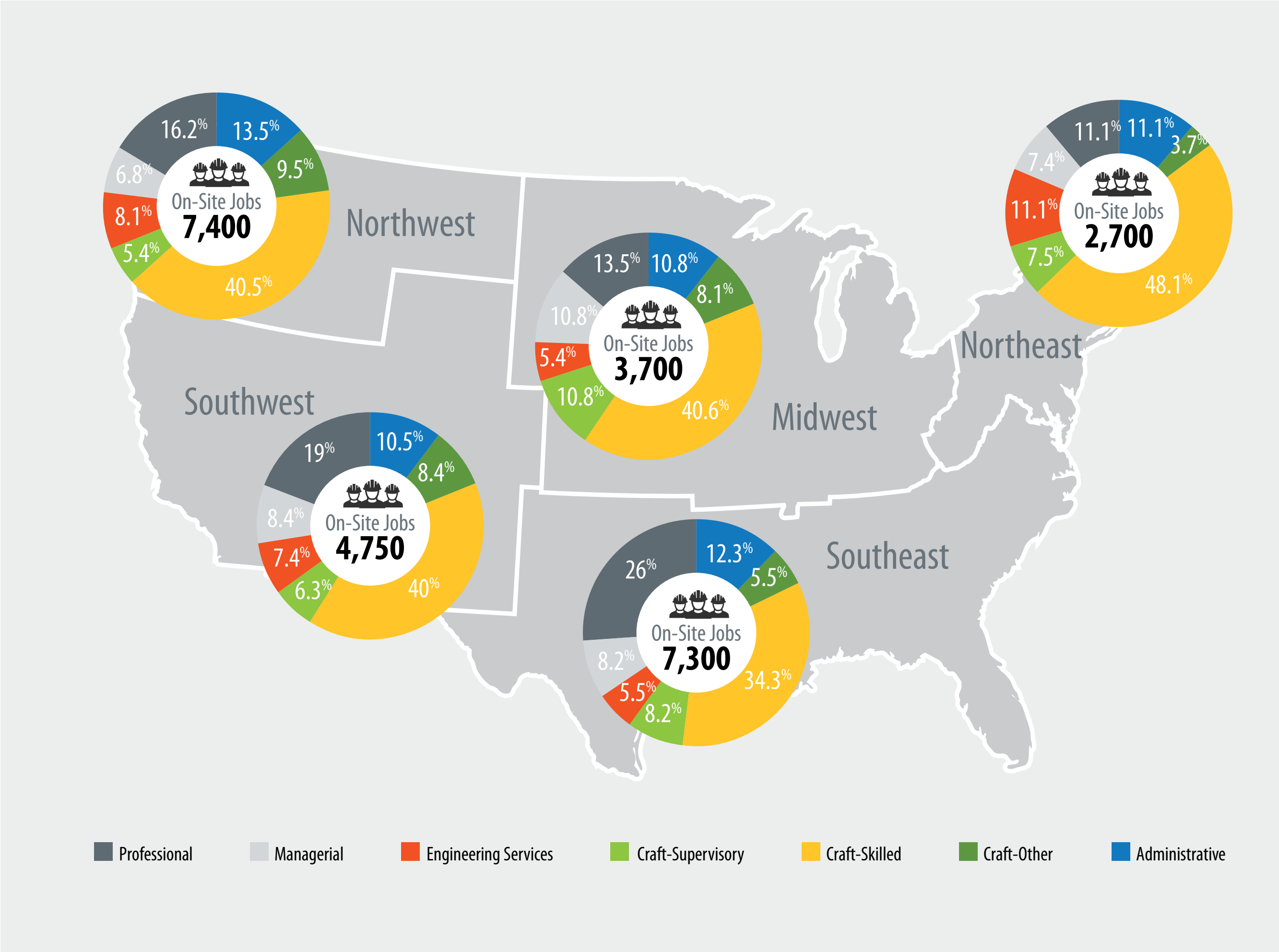


Figure 4. Geographic Distribution of On-Site Hydropower Jobs by Occupation *Source: Paidipati et al. (2017)*

35% of hydropower workers are located on site or are directly involved in the operation and maintenance of hydropower facilities.

Of the 66,500 hydropower sector workers, approximately 23,000 workers had jobs at a hydropower facility in 2014 (Paidipati, et al. 2017). This subset of workers was directly involved with the operation of or upgrades to hydropower facilities, and the count does not factor in supply chain or contractual service workers included in NASEO (2019). The on-site workers come from the eight different occupations listed in Figure 3.[6] The majority of hydropower workers fall within the "Craft-Skilled" category, followed by workers classified as "Professional" and "Administrative" (Figure 3).

Large numbers of hydropower facilities with significant amounts of generation are located in the northwestern and southeastern regions of the United States, and the mix of occupations varies geographically.

[6] Examples of skill standards for these occupations can be found at https://www.cleanenergyexcellence.org/industry/skill-standards/

The types of on-site hydropower jobs vary by region, with skilled craft workers comprising the largest share across the United States. This variation is due to the differences in hydropower resources and technology applications across the country. It is anticipated that future workforce needs will vary geographically, as well. The impact of workforce shortages may be more significant in certain areas.

Hydropower workers in many occupations—especially supervisors/managers, engineers, skilled craft workers, and other professionals—are older than the average overall U.S. workforce.

An aging workforce has a significant impact on the industry as employees begin to retire. The need to quickly hire large numbers of workers presents challenges in recruitment and in the transfer of knowledge from older, experienced workers to new, often less-experienced staff members. Interviewers found that employers in the hydropower industry were already having difficulty filling key positions or were concerned about prospects for filling future positions as the current workforce ages and retires.

As shown in Figure 5, supervisory and managerial workers in hydropower are generally older than the average U.S. worker, with higher concentrations of supervisors and managers among all categories beyond 36 years of age. Managerial positions typically require extensive professional experience, which leads to this distribution.

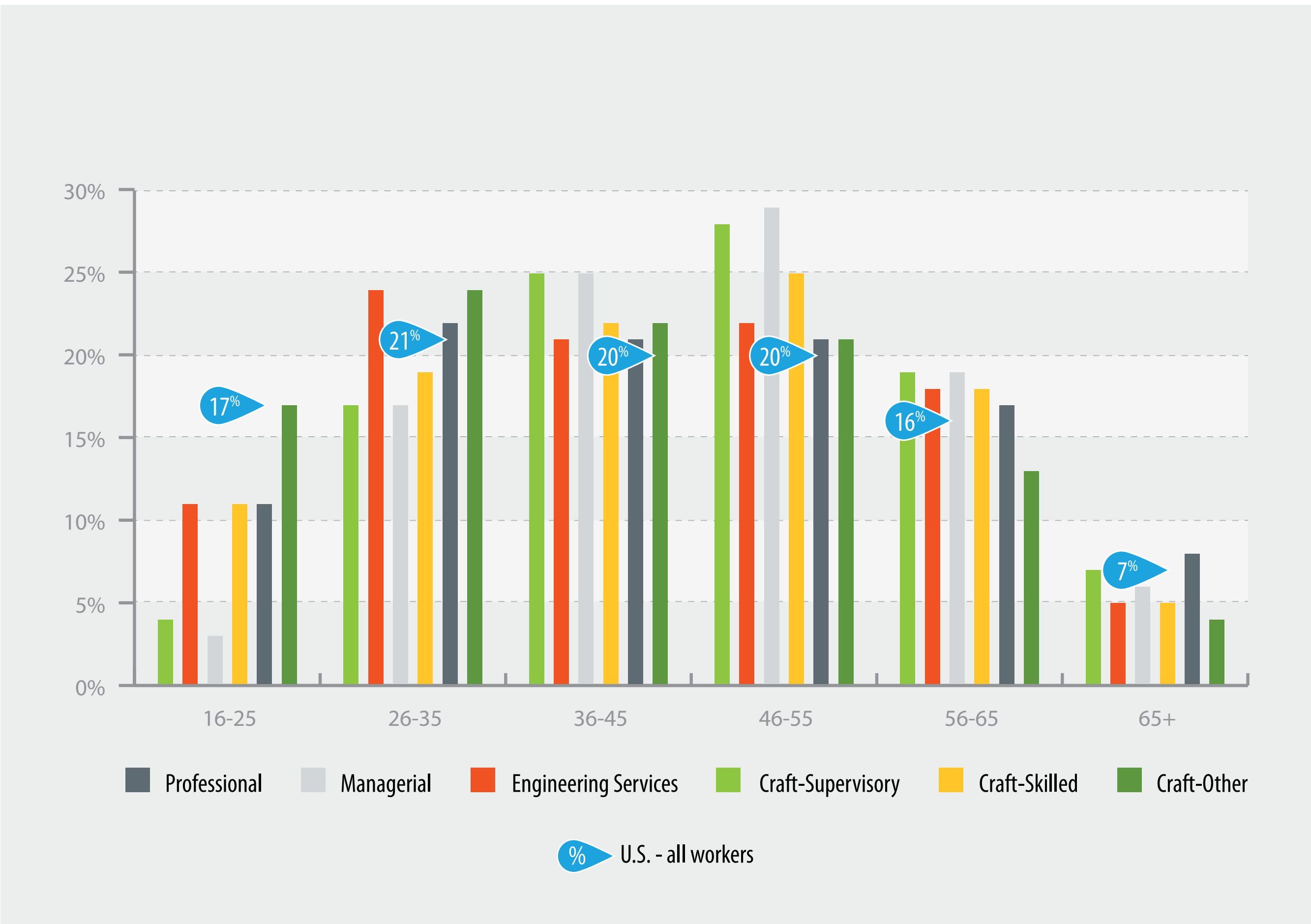


Figure 5. Age Distribution of On-Site Hydropower Workers by Occupation Compared to the Average U.S. Workforce *Source: Paidipati et al. (2017)*

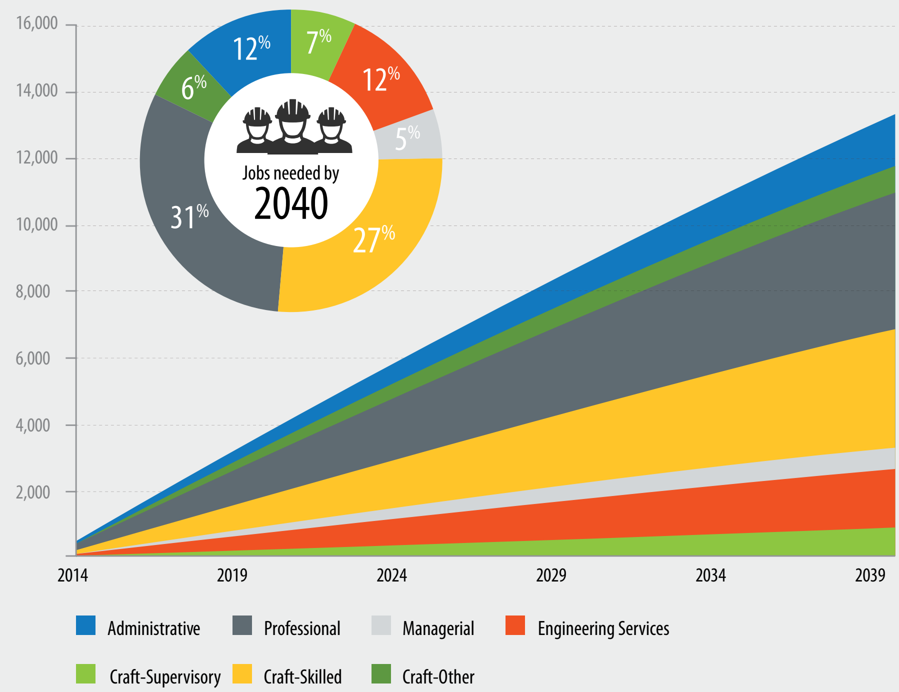


Figure 6. Hydropower Employment Needs Due to Attrition *Source: Paidipati et al. (2017)*

Conversely, general craft workers tend to be younger than the average age of the overall national workforce. The numbers of craft workers are more concentrated in age groups younger than 45 years old, which may be due to the physical demands of these roles or to the workers transferring to either the skilled craft worker or managerial/supervisory categories as they gain skills.

Engineers tend to be older than the average U.S. worker, but this reflects attending college prior to age 26 and retiring around age 65. The median age in this category is between 46 and 55, similar to the U.S. median.

Approximately 26% of the hydropower workforce is age 55 and older and will reach retirement age within the next decade (Paidipati et al. 2017). The rate of hydropower workers aging and leaving the workforce due to retirement, death, or other reasons can be estimated using a demographic methodology outlined in the 2016 Hydropower Vision report by DOE and Paidipati et al. (2017). This methodology was used to estimate hydropower workforce replacement needs by 2030 and 2040. The estimates suggest nearly 9,000 workers will leave the hydropower workforce by 2030, and 13,000 will leave by 2040, as shown in Figure 6.

Expansion of the industry will drive additional hiring. Jobs with the highest level of demand—skilled craft workers and professional workers—typically require the most education and specialized training.

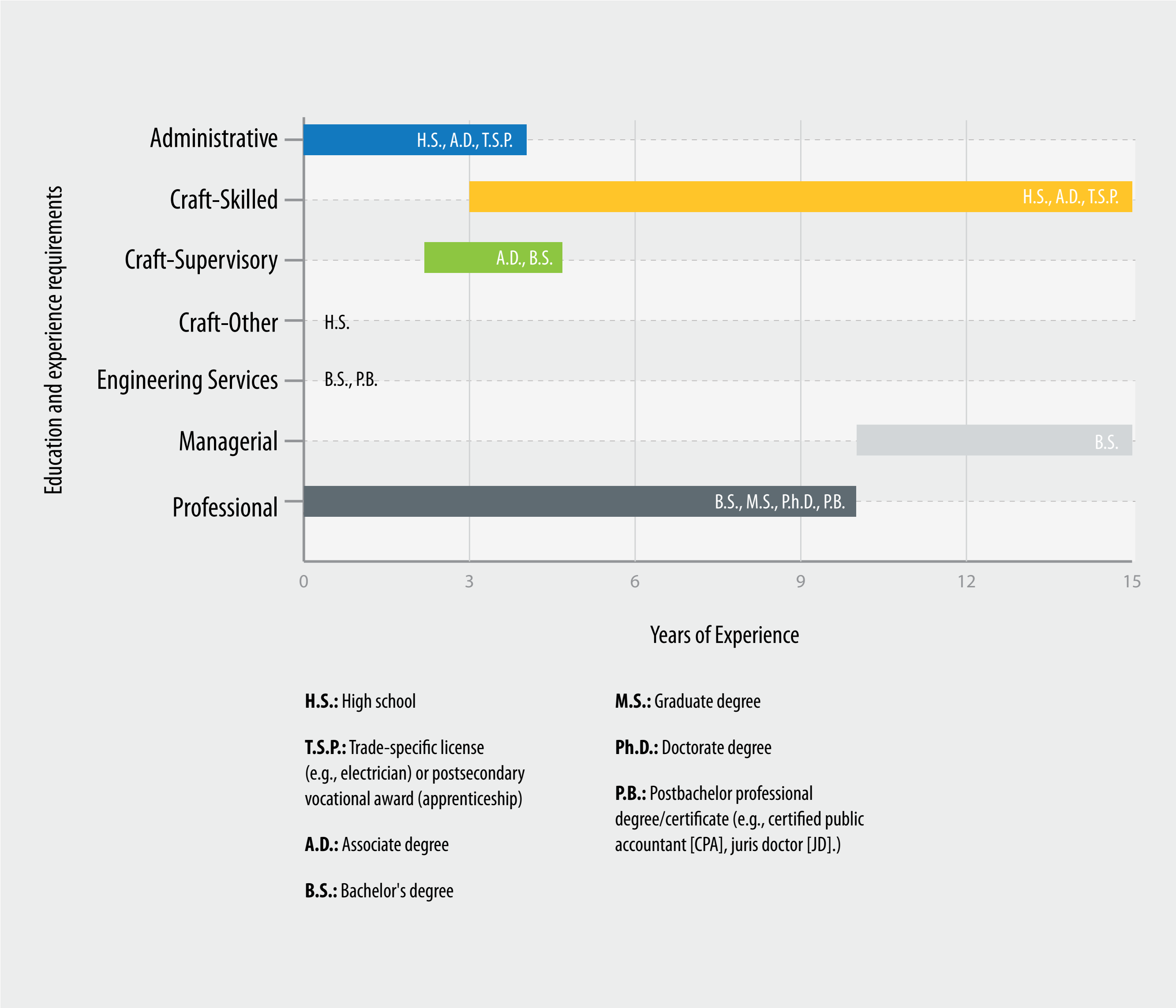


Figure 7. Education and Experience Requirements *Source: Paidipati et al. (2017)*

Even without industry growth, attrition will drive the need for more hydropower workers.

Education and training needs of hydropower workers are important, as they affect new worker availability and ease of recruiting. The current industry relies on replacing workers with a pipeline of existing hydropower workers. Recruitment of workers from outside the hydropower industry presents challenges. Planning for attrition may require anticipating workforce needs years in advance to encourage students to prepare for careers in the field or to train and develop workers from other industries. The ability to succeed in these approaches will be contingent on the availability of relevant training and education programs.

Figure 7 lists training and education requirements for each occupation group, in addition to subsequent experience required. The two categories estimated to need the greatest numbers of employee replacements in the future—skilled craft workers and professionals—have some of the highest educational and training needs.

The occupations in highest demand are professional workers and skilled craft workers, both which tend to have workers older than the U.S. average and require the highest level of education. With attrition, these experience and educational requirements could make it difficult to hire new workers or maintain productivity levels due to challenges in transferring knowledge between senior and junior staff.

Anticipated attrition will require the hydropower industry to hire more workers in order to maintain existing employment levels under potential growth scenarios.

DOE explored various scenarios for the potential future of the U.S. hydropower industry in its Hydropower Vision (2016) and Paidipati et al. (2017), as shown in Table 2.

Each scenario in Table 2 is associated with the expansion of hydropower generation capacity within the United States. The business-as-usual scenario reflects the lowest levels of expansion, whereas the advanced-technology, low-cost-finance, and high-fossil-fuel-cost scenarios reflect the highest levels of expansion (Table 2). DOE (2016) estimates the number of hydropower jobs needed to support these scenarios, and that number is associated with capacity levels.

Hydropower Vision Study Scenarios	Description
Business as usual	Reference model conditions and future cost reduction paths (legally protected lands are excluded)
Advanced technology, low-cost finance, combined environmental exclusions	Reduced hydropower costs from innovation, financing that reflects lower risks and longer asset life, and seven environmental considerations
Advanced technology, low-cost finance, critical habitat exclusions	Reduced hydropower costs from innovation, financing that reflects lower risks and longer asset life, and one environmental consideration
Advanced technology, low-cost finance, high fossil fuel cost	Reduced hydropower costs from innovation, financing that reflects lower risks and longer asset life, and high fossil fuel costs (environmental considerations are excluded)

Table 2. Hydropower Vision Study Scenarios *Source: DOE (2016)*

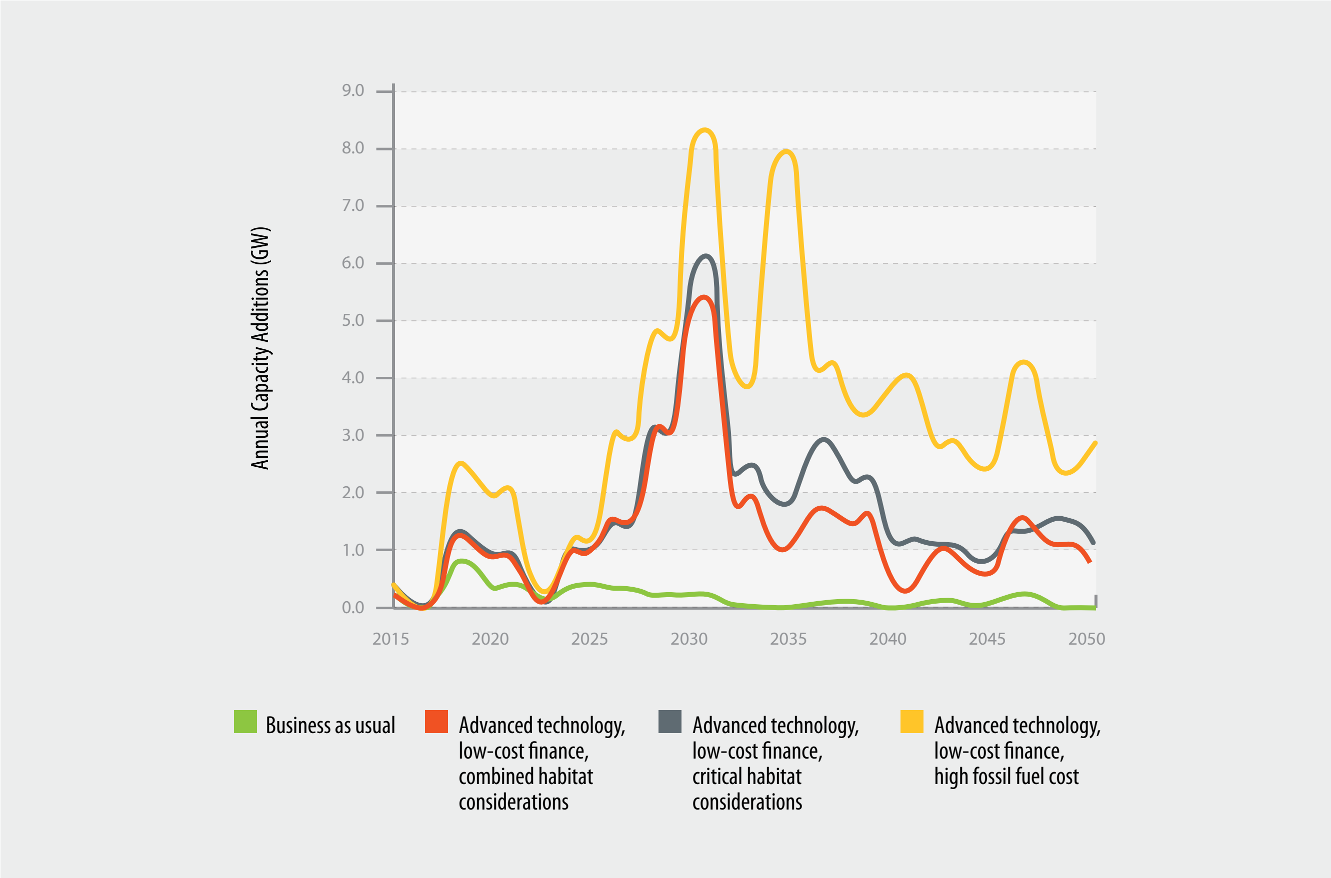
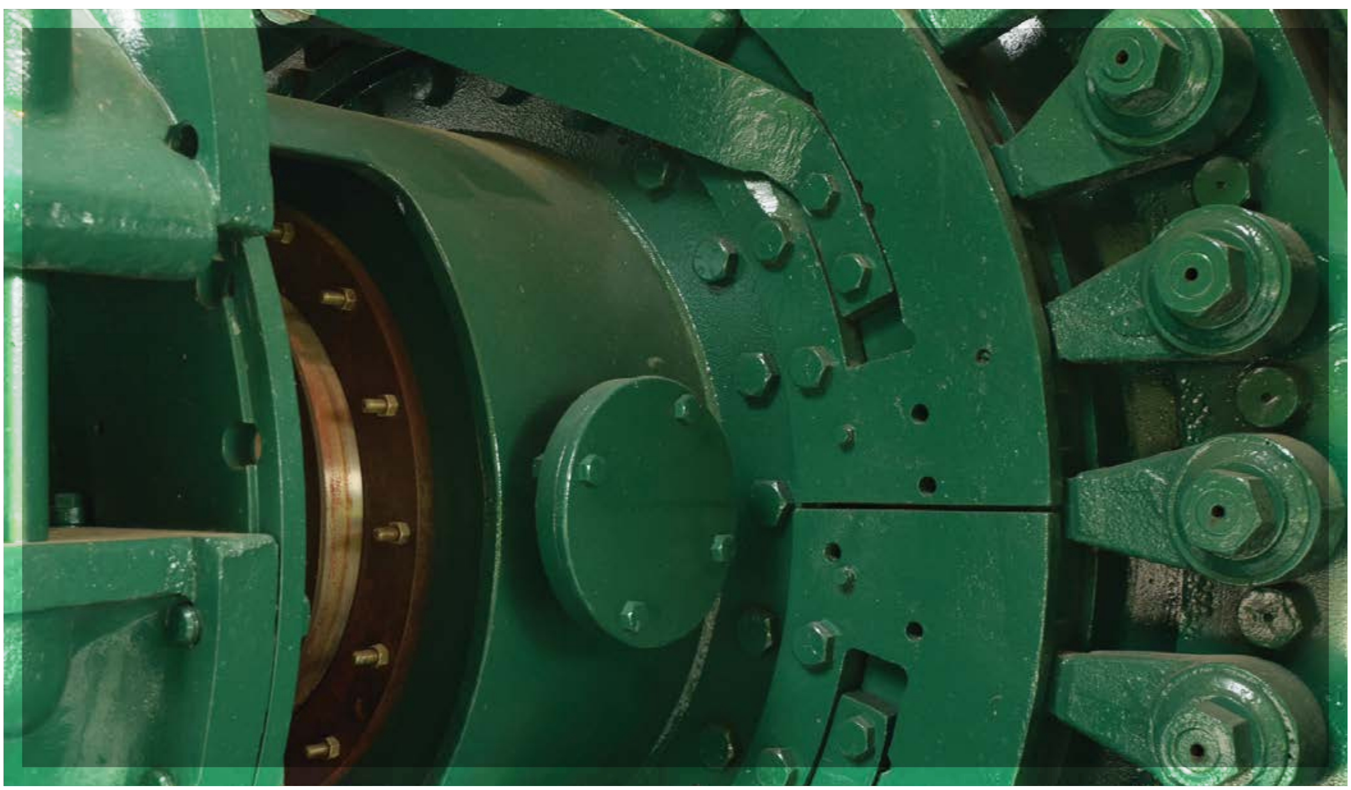


Figure 8. Hydropower Capacity Expansion Scenarios *Source: DOE (2016)*



There is a high and low domestic content version of each scenario for hydropower supply chain job estimates. Domestic content refers to the percentage of expenditures for goods and services such as replacement parts or accounting services that are made in the United States. The percentage of expenditures made in the United States affects the number of jobs and economic activity that occur nationally. Greater domestic content drives higher job numbers[7]. By 2030, the total number of on-site and supply-chain hydropower jobs ranges from 83,000 to 118,000 under the low scenario and 83,000 to 120,000 under the high scenario. By 2050, these ranges are 84,000 to 155,000 and 84,000 to 158,000, respectively (Figure 9).

Under the most aggressive scenario, the U.S. hydropower workforce could grow to 120,000 jobs by 2030 and 158,000 by 2050.

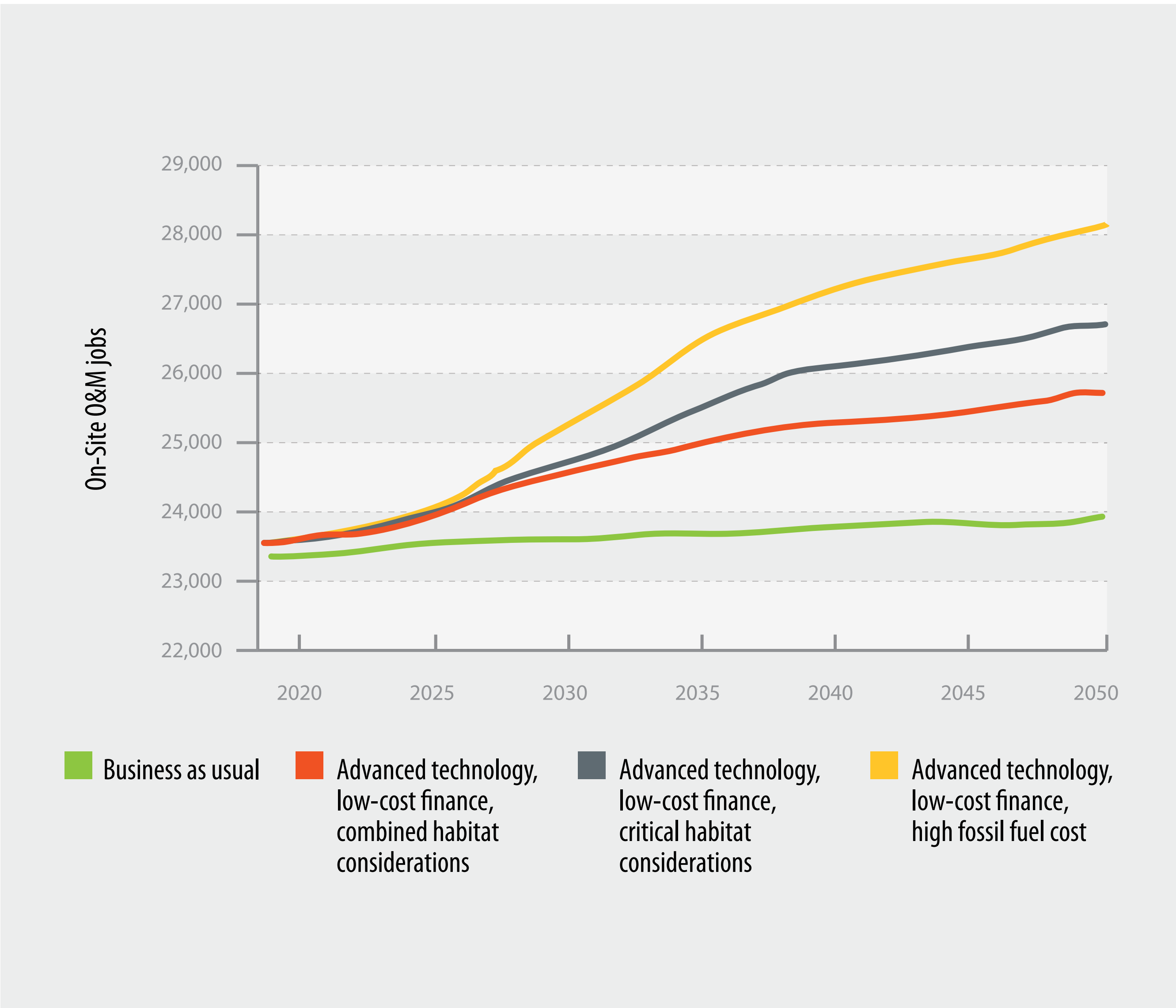


Figure 9. On-Site O&M Jobs[8] *Source: DOE (2016)*

[7] For more detail on domestic content percentages and how they were derived, see DOE (2016).

[8] On-Site O&M Jobs – does not include on-site construction jobs.

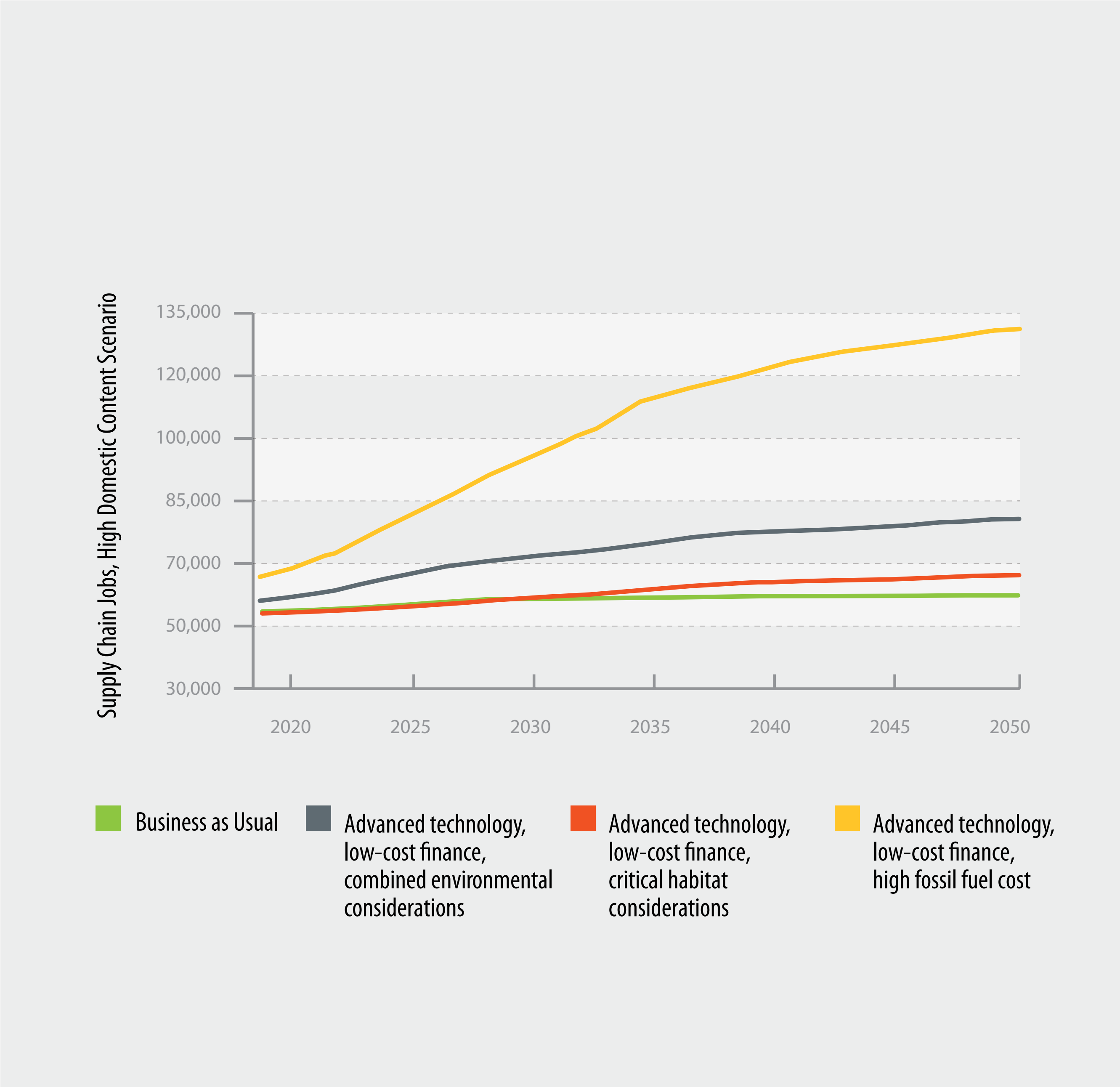


Figure 10. Supply Chain Jobs, High Domestic Content Scenario

Figure 10 shows the estimated number of new jobs by 2050 under the high domestic content scenario. With low domestic content, the maximum number of new hires needed is 66,000 under the high fossil fuel scenario. The number of new workers needed is 5,000 to 22,000 under the other three scenarios. The high fossil fuel scenario produces 69,000 new positions with high domestic content and the range for the other three scenarios increases to 5,000 to 23,000 jobs.

The number of on-site jobs ranges from 24,000 to 25,000 in 2030, 24,000 to 27,000 in 2040, and 24,000 to 28,000 in 2050. The maximum number of new hires due to expansion is 4,000 by 2040 and 5,000 by 2050. Combined with attrition, a maximum of 17,000 on-site jobs would need to be filled by 2040 under these scenarios.

Training and education programs are necessary to meet future hydropower industry workforce needs, but these programs can be difficult to find.

Using the Hydropower Vision growth scenarios provided earlier, additional highly qualified workers will be needed to match the demands of hydropower and related industries in the future. Training and educational programs will be required to meet workforce needs triggered either by attrition or potential growth. Paidipati, et al. (2017) conducted a survey of hydropower operators, postsecondary learning institutions, and government training programs to determine the availability of education and training resources. Of the respondents, 27 offered hydropower-specific programs. Nearly 70% of these, or 18 respondents, were at four-year universities. Four community colleges and government training programs indicated that they had hydropower education and training programs, and interviews identified one in-house program (Figure 11).

Four-year universities can supply the education necessary for professional occupations, which is anticipated to have the greatest demand for workers because of attrition. The second highest-demand occupation—skilled craft workers—would be better served by community colleges. Workers with generalized education can also learn hydropower-specific skills through apprenticeships or on the job.

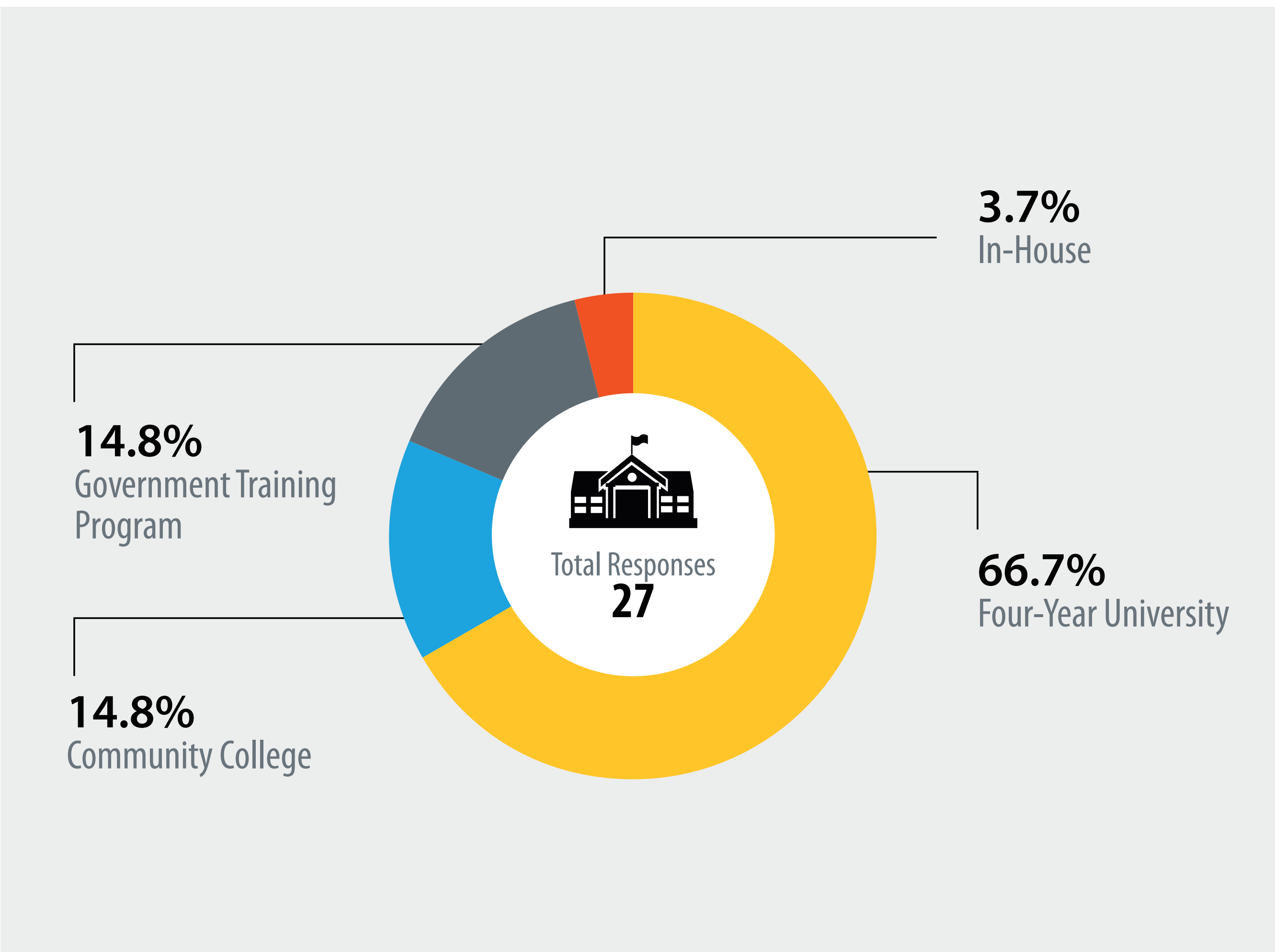


Figure 11. Institutions Offering Hydropower-Specific Programs *Source: Paidipati et al. (2017)*

Paidipati, et al. (2017) asked 32 hydropower operators about knowledge-transfer systems that they have in place for information sharing and succession planning, shown in Figure 12. More than 20% of operators who replied indicated that they did not have a system in place. The largest single mode of knowledge transfer was person-to-person interaction, which requires new employees to interact with existing workers. The remaining nearly 40% of responses had knowledge-transfer processes that do not rely on existing employees.

Nearly 22% of hydropower operators indicated that they have either a weak knowledge-transfer system or no transfer system at all.

When asked to propose solutions to the problems posed by hiring, operators posed several ideas, including advertising hydropower as a well-paid career field with strong demand for qualified workers and expanding

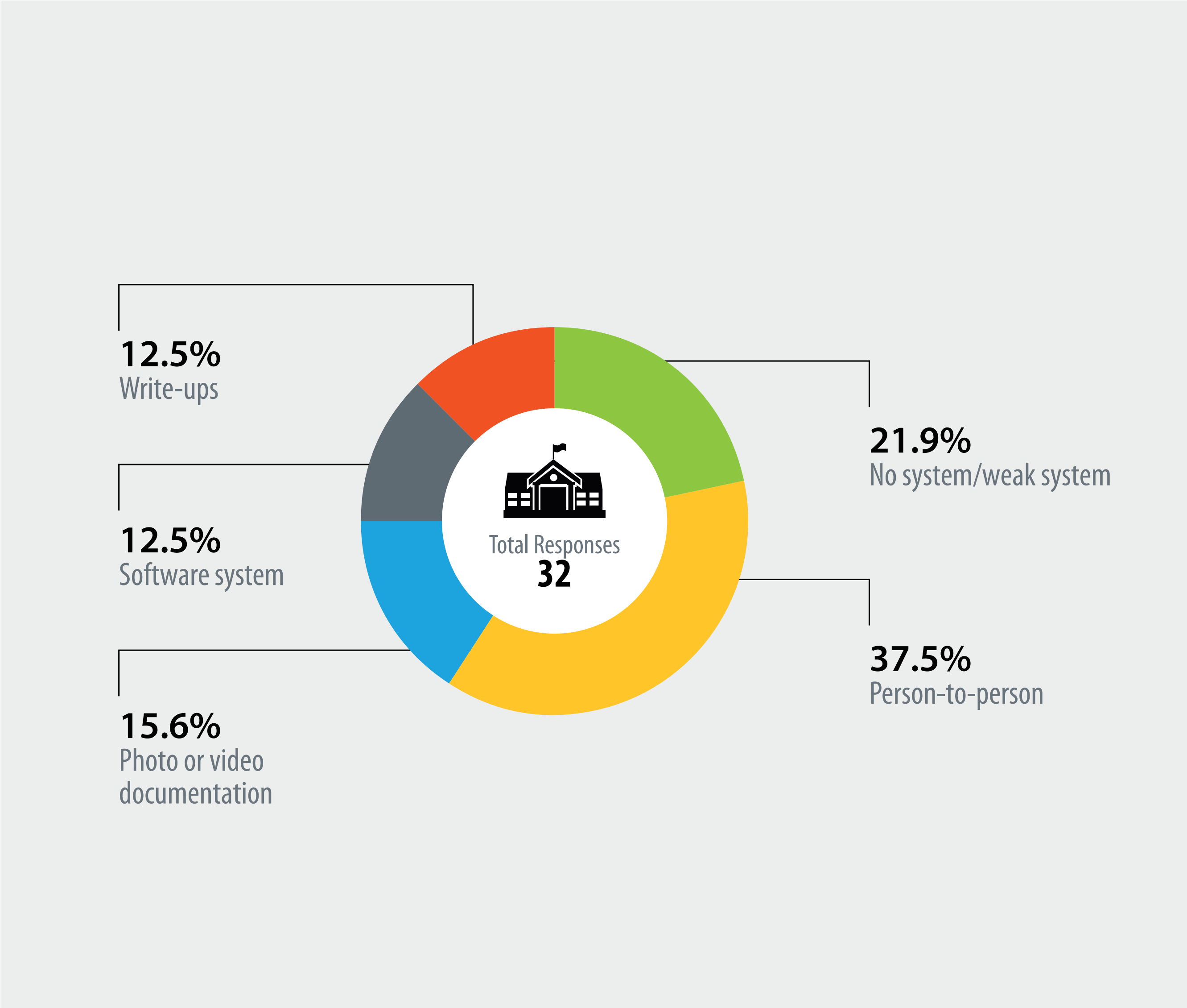


Figure 12. Knowledge Transfer Systems *Source: Paidipati et al. (2017)*

hydro-specific courses across education levels, including postgraduate studies (Paidipati, et al. 2017). Two ways to address these problems were identified: (1) increase awareness among career counselors about the hydropower industry, helping make students and educational institutions aware of these career opportunities; and (2) provide online programs to expand the potential audience without requiring students to relocate to gain a hydropower-specific education. In many cases only one or two courses are necessary, raising the possibility for students to complete a degree at one institution while transferring hydropower-specific credits from another (Paidipati, et al. 2017).

There will be demand for hydropower workers in the future as a result of attrition and/or industry growth. Filling these positions requires pathways for education, training, and knowledge transfer. This is particularly true for positions that are difficult to fill.

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Highlights

- **Long the nation's largest source of renewable energy, hydropower represents a significant portion of the U.S. electricity sector and offers important resiliency and flexibility services to the evolving national grid.**

- **Operating and maintaining hydropower facilities requires highly qualified workers with years of experience and education. Even under scenarios of limited growth in hydropower capacity, more workers will be needed as a result of attrition.**

- **Any increases in the hydropower and pumped-storage fleet will require additional workers for manufacturing the specialized equipment used by the industry, construction, and operation and maintenance of facilities.**

- **Additional education and training programs are likely needed to fill hydropower positions, although the creation of these programs will depend on student interest. Employers can prepare for upcoming workforce changes by communicating employment opportunities and developing knowledge-transfer systems.**

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