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Transforming ENERGY

U.S. Hydropower Workforce:
Challenges and Opportunities

Authors

Jennifer Daw, Jeremy Stefek, Elise DeGeorge, Ritu Treisa Philip, Arielle Cardinal, and Linda Parkhill
National Renewable Energy Laboratory

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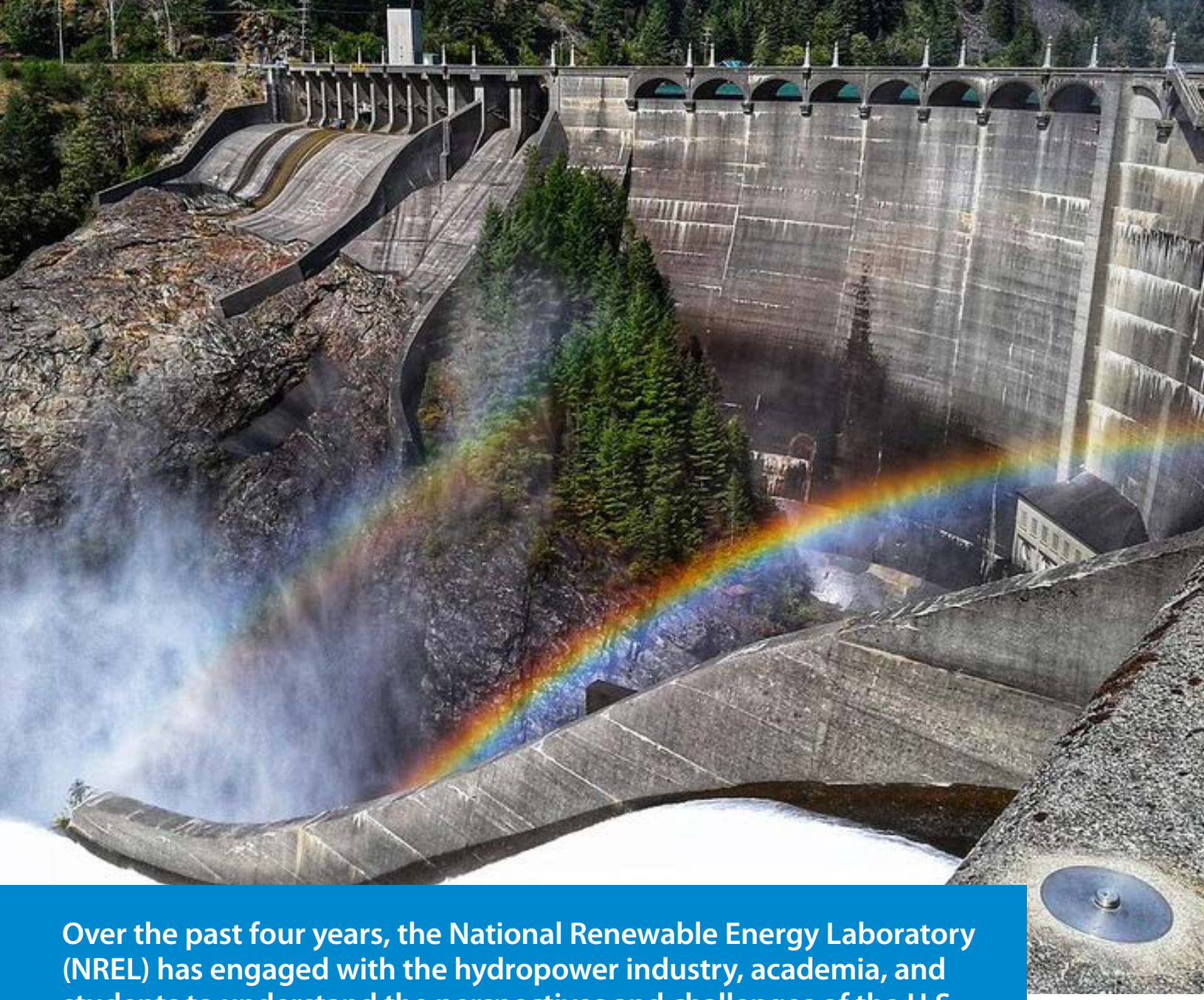
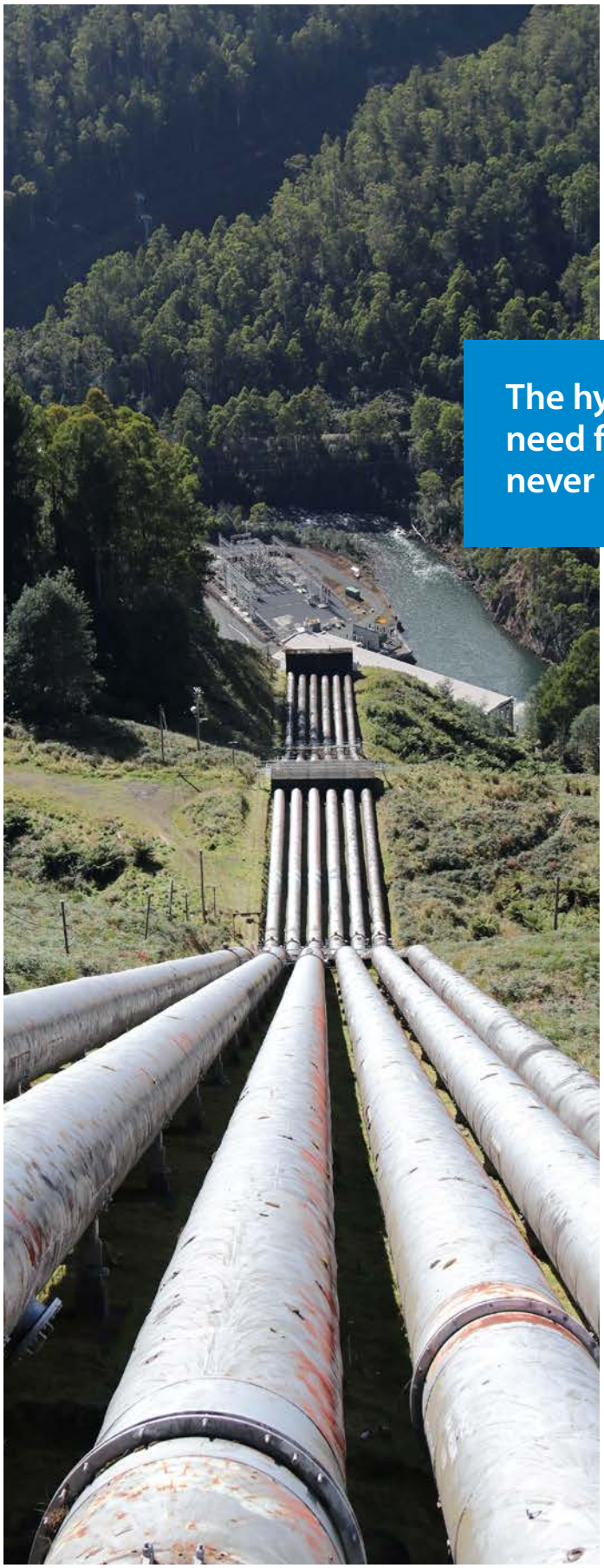
Figures & Tables



Over the past four years, the National Renewable Energy Laboratory (NREL) has engaged with the hydropower industry, academia, and students to understand the perspectives and challenges of the U.S. hydropower workforce pipeline.

This engagement and research were sponsored by the U.S. Department of Energy's (DOE's) Water Power Technologies Office as part of an NREL-led project—**Water Power Science, Technology, Engineering, and Mathematics (STEM) to Workforce**—which has the goal of developing tools and programs to strengthen the water power workforce pipeline. This report shares findings from that research and provides an update on U.S. hydropower workforce trends as a follow-on to NREL's 2019 report, *Workforce Development for U.S. Hydropower: Key Trends and Findings* (Keyser and Tegen 2019). Recent data from NREL's and the Hydropower Foundation's survey efforts and the hydropower industry are also presented.



This is a time of change for the hydropower industry. With more than a quarter of the domestic hydropower workforce over the age of 55 retiring in the coming decade, the need to build a strong workforce pipeline has never been more critical. The number of hydropower workers aging and leaving the workforce is increasing, leading to a higher risk of knowledge loss as more experienced workers in the industry retire (Keyser and Tegen 2019). To be successful, the industry needs new, diverse talent to fill jobs across many different occupations, spur innovation, and support the evolving role of hydropower in the U.S. electrical grid.

The hydropower industry is changing. The need for a strong workforce pipeline has never been more critical.

Hydropower is one of the nation's main sources of renewable energy generation and the largest source of utility-scale energy storage. In 2021, hydroelectricity accounted for roughly 6.3% of total U.S. utility-scale electricity generation and 31.5% of total utility-scale renewable electricity generation, with a little over 80 gigawatts (GW) of conventional net summer generation capacity (U.S. Energy Information Administration [EIA] 2022a). In the same year, more than 23 GW of capacity was generated from pumped storage hydropower in the United States (EIA 2022b). Pumped storage hydropower currently accounts for 93% of all utility-scale energy storage in the United States and is growing nearly as fast as all other energy storage technologies combined (Uría-Martínez, Johnson, and Shan 2021).

Hydropower is already an essential contributor to the U.S. power system in terms of generation and storage, and it also provides critical ancillary services to ensure a flexible and resilient grid. The ability to quickly ramp hydropower generation provides valuable flexibility to meet electricity demands without disruption. Hydropower is also key to increasing the share of electricity generation from variable renewable energy sources, such as wind and solar (Uría-Martínez, Johnson, and Shan 2021). The flexibility and energy storage provided by hydropower enable the integration of other renewables into the grid, delivering a renewable energy source that can help the United States achieve its aggressive climate goals.

The role of hydropower as a "force multiplier" for other renewable energy resources makes it an important asset for an evolving grid. Still, more innovation is needed to enable this evolution. While hydropower is often associated with large infrastructure, most of the nation's hydropower facilities are much smaller than well-known, iconic projects like the

Hoover Dam. Also, fewer than 3% of the nation's 90,000 dams produce power; retrofitting even a fraction of these dams could result in more renewable, reliable power for the U.S. grid (U.S. Army Corps of Engineers 2022).

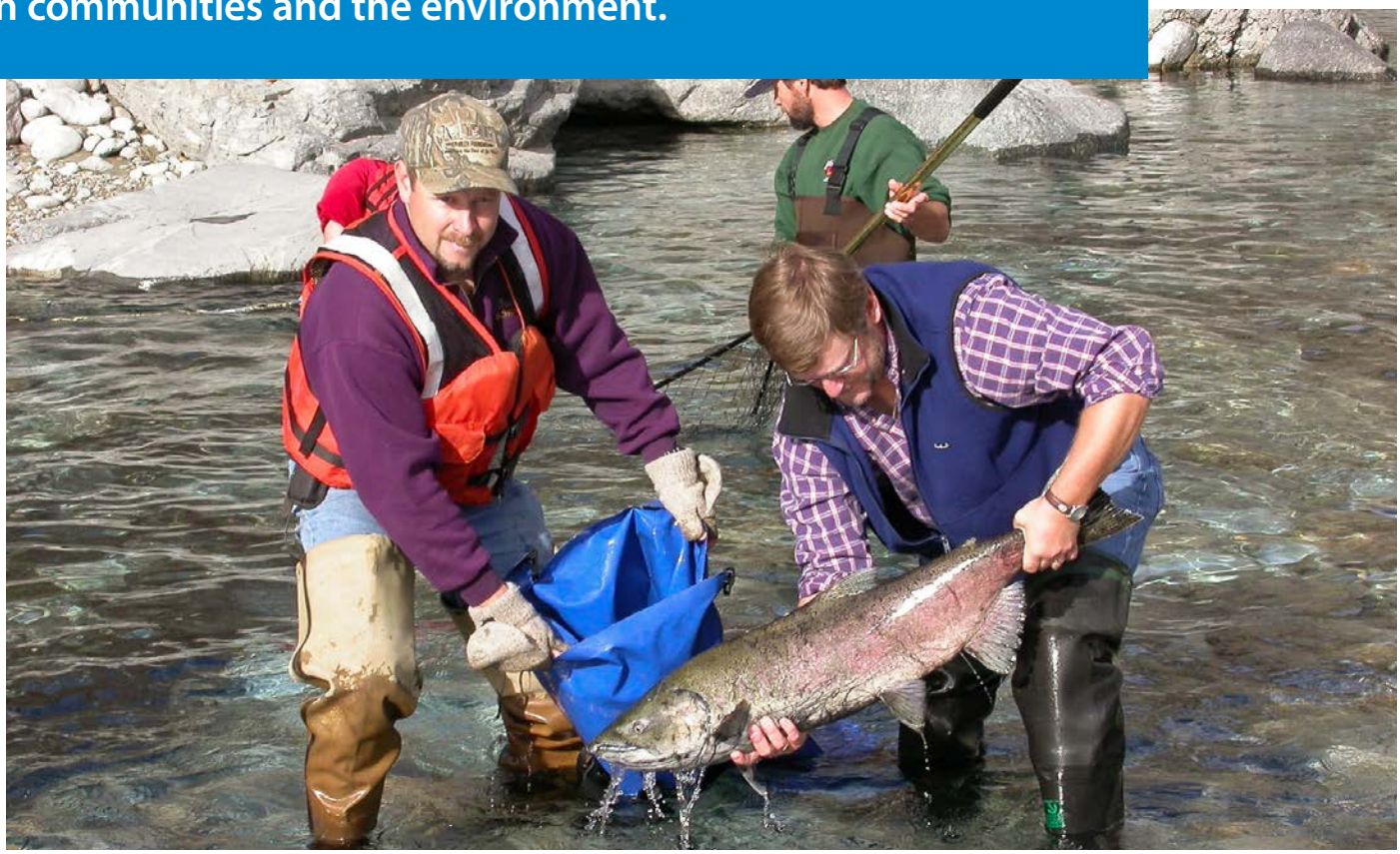
The hydropower industry continues to innovate to leverage opportunities for growth, like retrofitting non-powered dams and adapting operations at existing facilities to mitigate effects on communities and the environment. Innovations such as low-impact hydropower, safe fish passage, and more inclusive planning processes like the Uncommon Dialogues (Stanford University undated) are being used to facilitate more sustainable outcomes for hydropower infrastructure. Research from the Water Power STEM to Workforce project has revealed that many students and potential workers have limited knowledge of the hydropower industry and see it as a "solved problem." However, hydropower is anything but "solved."

As the demand for workers across the energy sector continues to grow, there is a great need to increase awareness of the job opportunities that result from the role the U.S. hydropower industry plays in our decarbonized future. **Competition for workers with other industries and an aging workforce underscore the urgency to strengthen hydropower's domestic workforce pipeline to meet the industry's needs both now and in the future.**

Hydropower Sector Workforce Snapshot

In 2021, the conventional generation hydropower industry employed 64,514 workers across the utilities, manufacturing, professional services, construction, and wholesale trade sectors (Figure 1)—an increase of 1,400 workers from 2020 but an overall decrease of 3,300 workers from 2019. An additional 7,901 workers were employed in pumped storage hydropower in 2021.[1] Workers in the conventional generation hydropower industry represent 7.5% of all workers employed by the electricity sector, higher than nuclear (6.5%) but less than solar (39%), wind (14%), coal (8.3%), and advanced

The hydropower industry is more than large hydroelectric dams—the industry continues to innovate to mitigate impacts on communities and the environment.



[1] The working population is defined as ages 15 and older.

natural gas (8%) (Keyser 2022).[2] Employment impacts were experienced by the energy sector overall as a result of the COVID-19 pandemic; however, the 2021 U.S. Energy and Employment Report reflects a rebound with the addition of 560,000 jobs.

Most conventional hydropower workers (27%) are in the utilities sector, which includes hydropower plant operators, maintenance staff, engineers, and other professionals, followed by the manufacturing sector (25%). There are minor differences observed in these breakdowns in 2021 as compared to NREL's 2019 hydropower workforce report, *Workforce Development for U.S. Hydropower: Key Trends and Findings* (Keyser and Tegen 2019; referred to hereafter as "the 2019 NREL report"), with 1%–2% increases in each of the trade and transportation and utilities categories and a 3% decrease in construction. Most pumped storage workers are in the construction sector (39%), followed by the manufacturing sector (30%), and professional services (17%) (Keyser 2022). Construction jobs represent a larger share of workers in pumped storage than conventional hydropower. There are many career paths in the hydropower industry for technical workers (construction, manufacturing, trade, transportation, pipeline, other services) and nontechnical workers (professional and business services).

There are many career paths in the hydropower industry for workers with a wide range of technical and nontechnical skills.

Throughout the report, we characterize different parts of the hydropower industry:

- **Conventional generation hydropower** (or "conventional hydropower") includes traditional facilities and smaller, lower impact hydropower facilities that use dams, impoundments, or diversions to generate electricity. Examples include conventional hydropower dams, in-conduit hydropower, run-of-river dams, run-of-river bypass, and the powering of non-powered dams.
- **Pumped storage hydropower** includes facilities where excess energy generated from other renewable energy sources can be stored and used at a later time by moving water between two reservoirs of differing elevations. Open-loop hydropower is continuously connected to a naturally flowing water feature, whereas closed-loop hydropower is off-stream and not continuously connected to a naturally flowing water source.

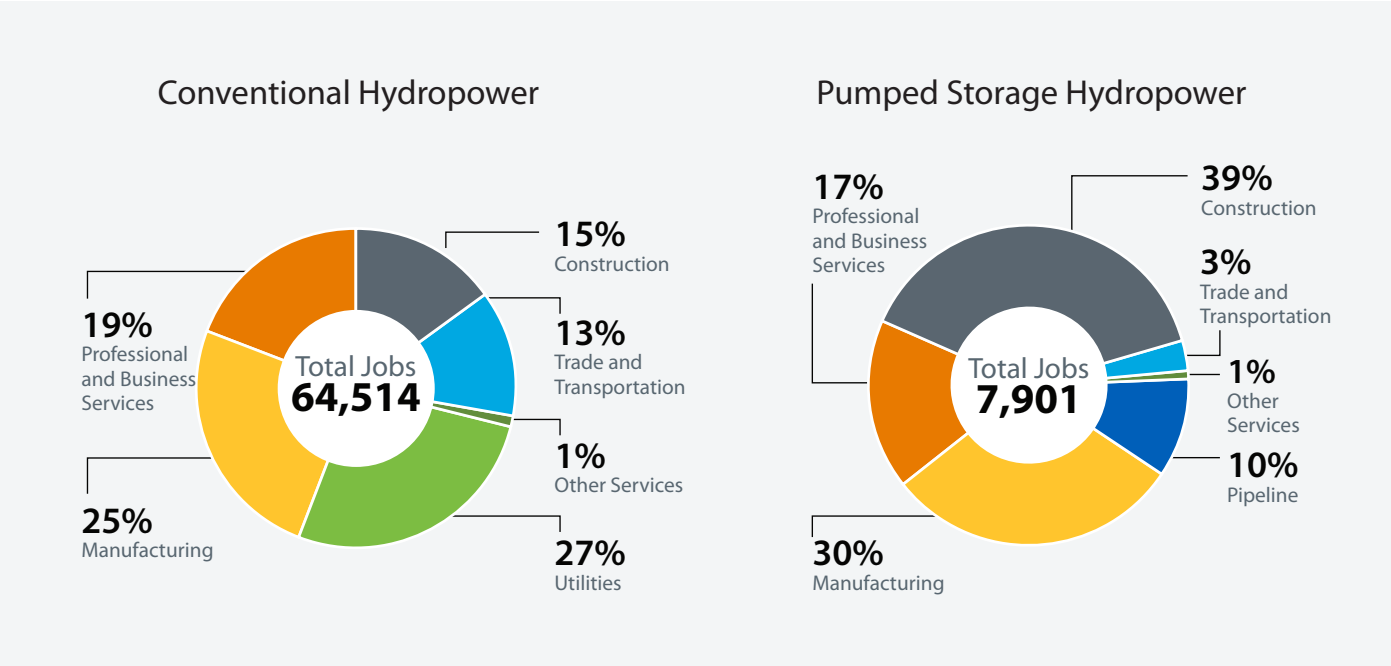
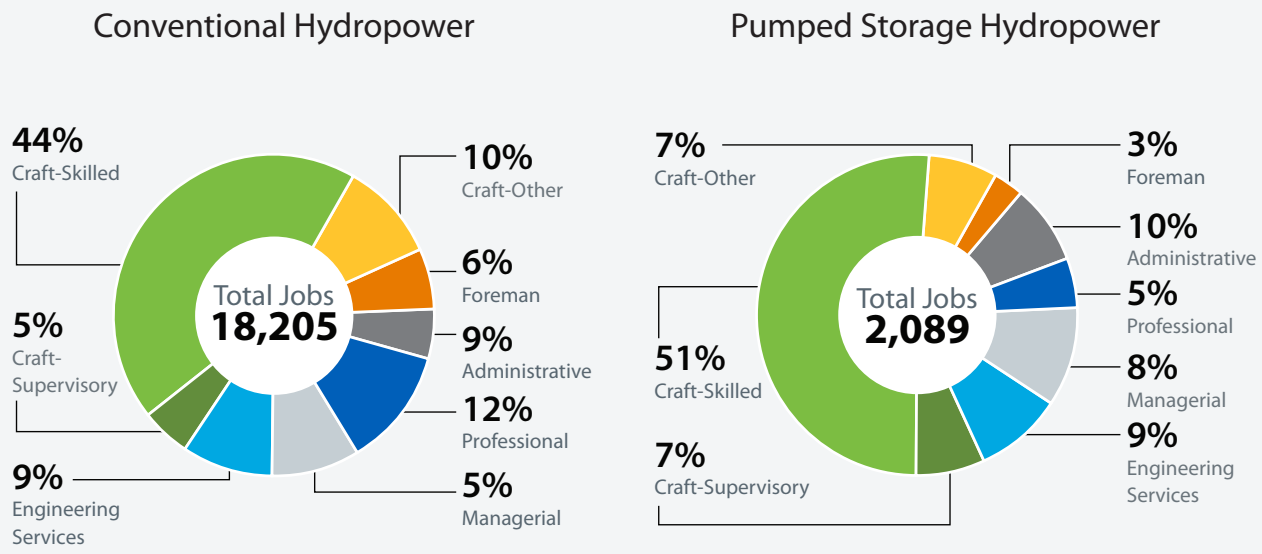


Figure 1. Conventional and pumped storage hydropower sector employment by industry. *Data from Keyser (2022)*

[2] If pumped storage hydropower workers are added to conventional hydropower workers, employment linked to the hydropower industry would be higher than coal and advanced natural gas. However, the U.S. Energy and Employment Report categorizes pumped storage under transmission, distribution, and storage employment, which does not allow for a direct comparison.

A large portion (31%) of the hydropower industry is focused on the operations and maintenance of existing facilities for conventional hydropower generation and pumped storage. Approximately 20,300 jobs are for on-site hydropower workers, who operate and maintain existing conventional and pumped storage facilities (Figure 2); this number does not account for contractual or supply chain jobs.[3] On-site hydropower workers represent eight different occupation categories, as shown in Figure 2. The largest share of on-site workers at both conventional and pumped storage hydropower facilities is skilled craftspeople. As compared to the 2019 NREL report, the number of overall on-site jobs for conventional and pumped storage has decreased by roughly 11.7%.



Job 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
Foreman	Lead worker who oversees 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), drafter, engineering technician, etc.

Figure 2. Number and occupation breakdown of on-site hydropower jobs. *Data from Guidehouse (2019)*

[3] To determine the number of on-site workers, NREL used hydropower job data from 1995 to 2018 (in full-time equivalents for multiple occupations) collected by GKS Hydro Data, a Guidehouse database (Guidehouse 2019), and extrapolated to the nameplate capacity of conventional and pumped storage hydropower facilities using U.S. Energy Information Administration data (EIA 2022c).

The largest share of the current U.S. hydropower workforce (both conventional and pumped storage) are basic and skilled craftspeople, with 58% of the jobs supporting electrical, mechanic, laborer, and custodian activities (Figure 3). Hydropower relies heavily on crafts and tradespeople, and these jobs are also in high competition across the U.S. workforce. In the electric power generation sector in 2022, construction jobs, which include a large portion of basic and skilled craftspeople to support building power plants, had the largest increase (11,300 jobs) but also had the highest hiring difficulty, noted by 92% of respondents to the United States Energy and Employment Report (Keyser 2022).

Hydropower plant operators and control room operators are hydropower-specific roles, which require the knowledge of many basic and skilled trades as well as experience in the job role, often provided through apprenticeship programs and knowledge sharing. The basic requirements for control room operators (70%) and plant operators (61%) are a high school diploma (Guidehouse 2019). These roles rely heavily on knowledge transfer systems and apprenticeship programs to provide the necessary skills and training.

Hydropower relies heavily on crafts and tradespeople and these jobs are in high competition in the U.S. workforce.

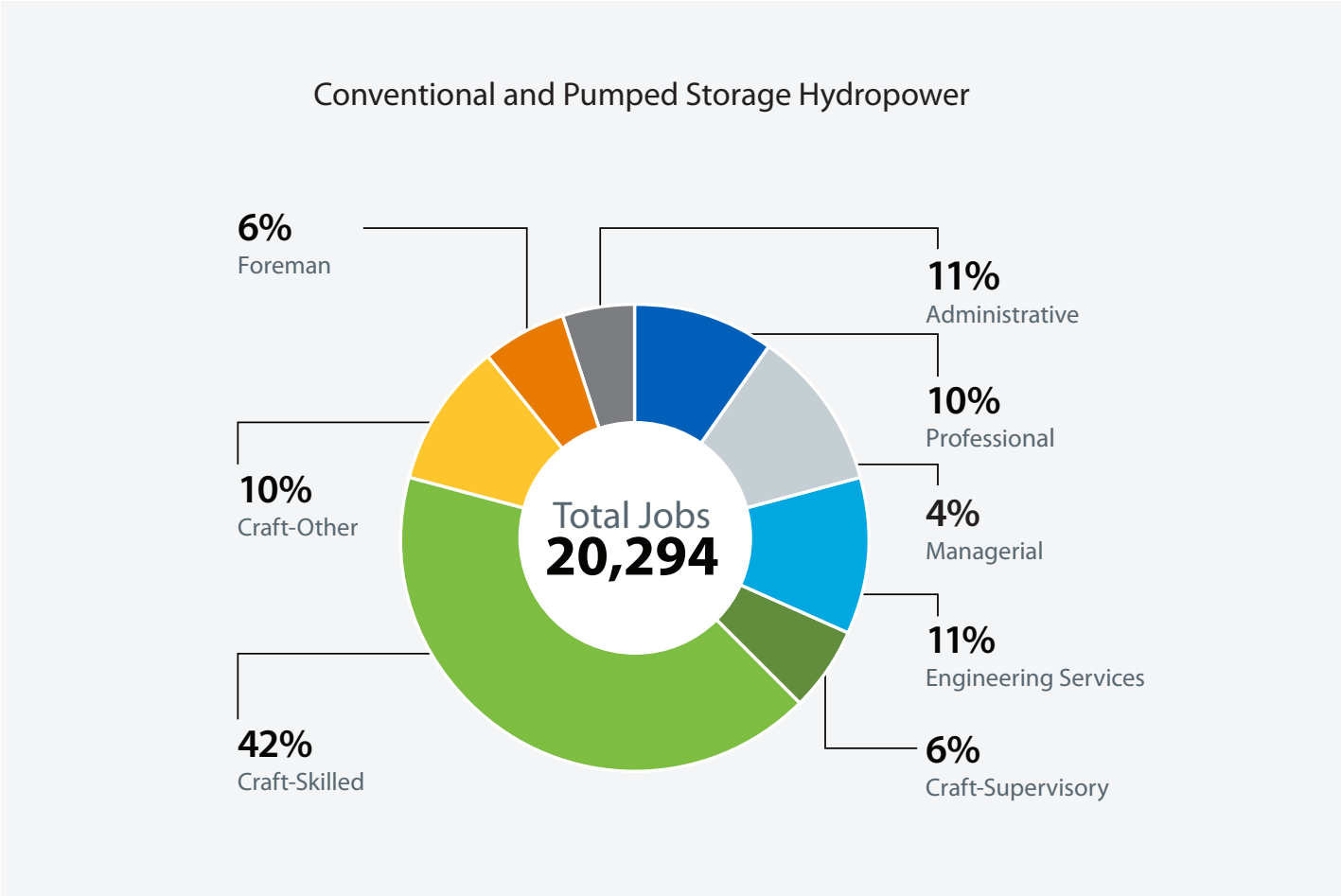


Figure 3. Crafts and tradespeople represent the largest hydropower worker group. *Data from Guidehouse (2019)*

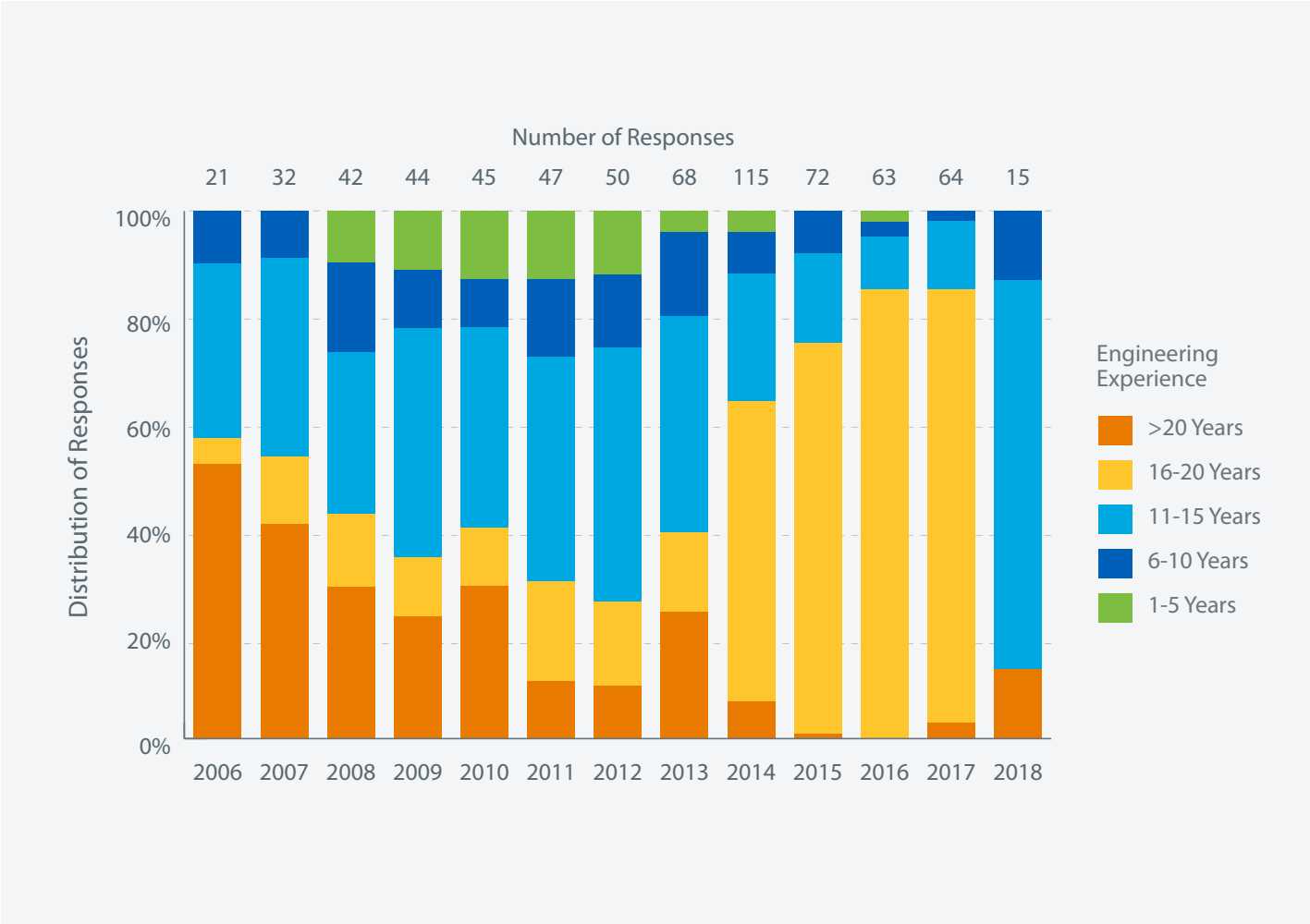


Figure 4. Hydropower workforce engineering experience trends. *Data from Guidehouse (2019)*

The data demonstrate the trend that there are fewer new engineers with less than 5 years of experience entering the workforce.

Engineering services jobs, especially with hydropower-specific experience, represent a large worker group in the hydropower industry. The Generation Knowledge Service (GKS) Hydro data from Guidehouse (2019) show the average experience level of an engineer in the hydropower industry has grown over time (Figure 4). The share of workers with an average amount of engineering experience—in the 16- to 20-year range—grew between 2014 and 2017, whereas the share of new workers with experience in the 1- to 5-year range did not grow. Although the number of responses varies from year to year, the data demonstrate the trend that there are fewer new engineers with 1 to 5 years of experience entering the workforce.

Hydropower facilities can be found in all regions of the United States (Figure 5), and the number of workers in each job classification varies by region and technology. The largest on-site conventional hydropower workforce is in the Pacific Northwest, the area with the most installed hydropower capacity. The largest on-site pumped storage hydropower workforce can be found in the Southwest, while the largest installed capacity is in the Southeast. Similar to the 2019 NREL report findings, the largest percentage of on-site hydropower jobs are in the Craft-Skilled category. The GKS Hydro data demonstrate an increase in demand for craftspeople and tradespeople in the hydropower industry over the past 10 years.

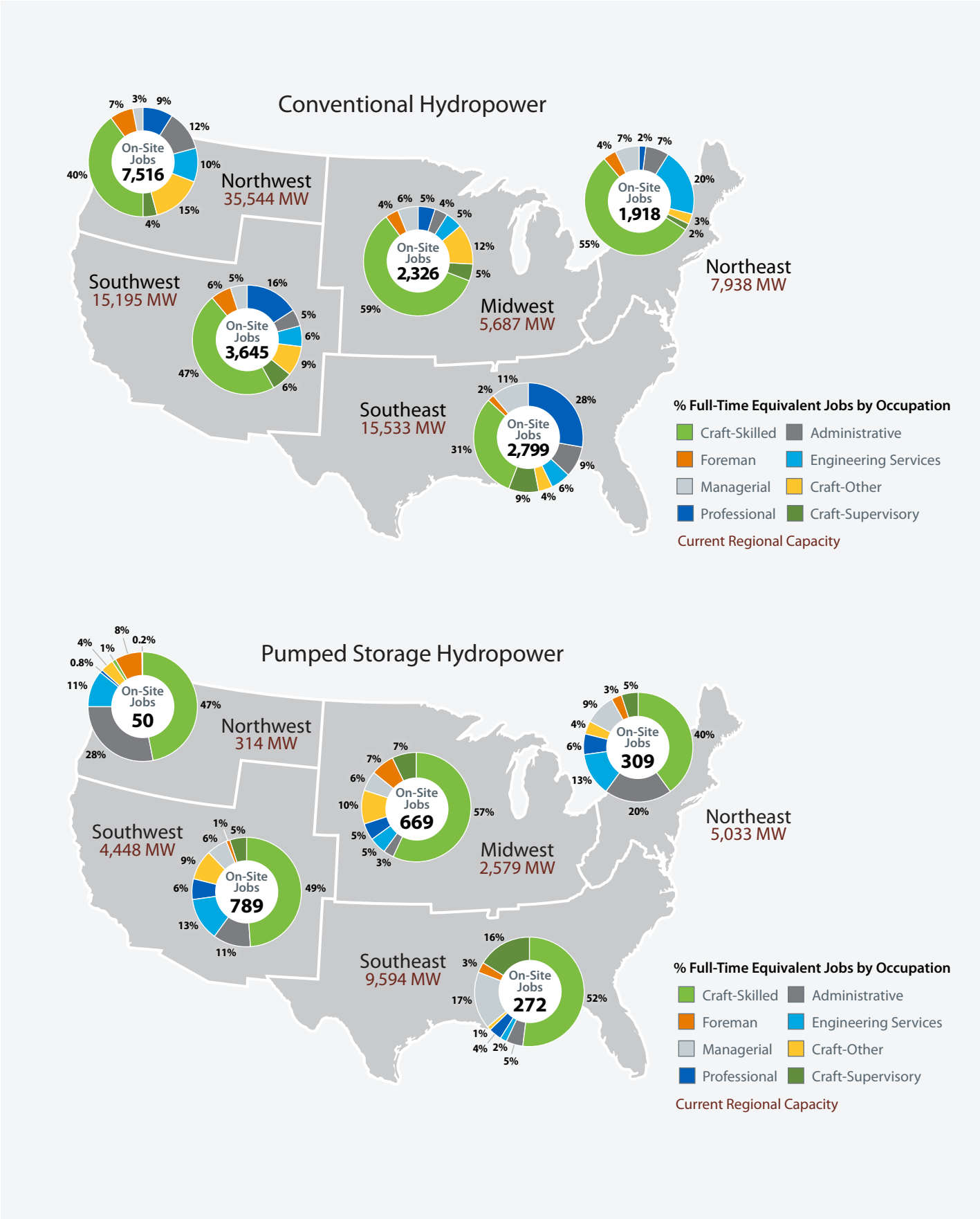
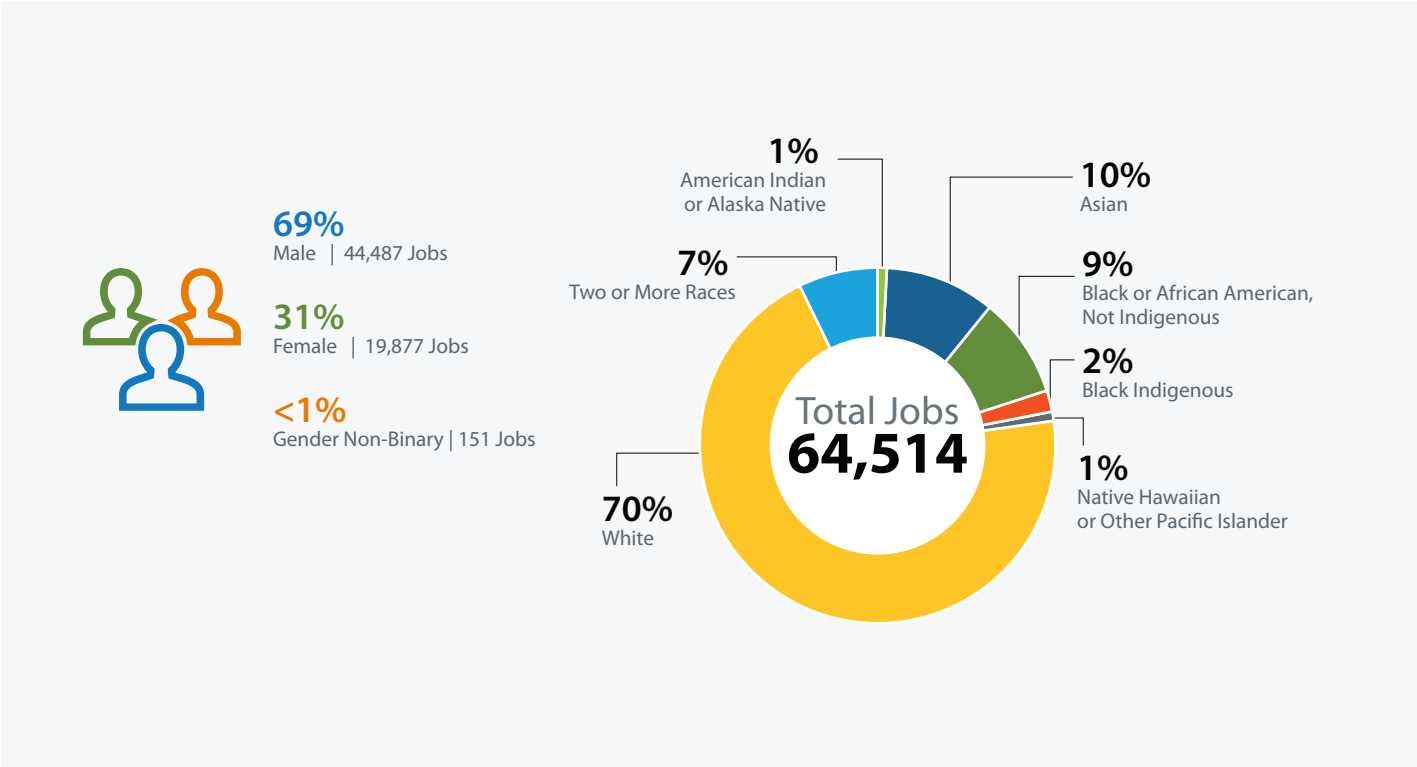


Figure 5. Geographic distribution of on-site hydropower fleet jobs for conventional and pumped storage hydropower. *Data from Guidehouse (2019) and EIA (2022c)*

Demographic workforce data (Table 1) provide insights into the composition and diversity of the hydropower industry: most workers are men (69%), at a similar level to the overall U.S. energy workforce (74%) but higher than the average U.S. working population (53%). Since the 2019 NREL report, the percentage of men working in the industry has increased by 2%. There are slightly more women working in hydropower (31%) when compared to the energy sector as a whole (25%), but far fewer women working in hydropower than the overall U.S. working population (47%). There was a 2% reduction in women in the hydropower workforce from 2019. The share of non-white workers in the hydropower industry is 30%, which is higher than the U.S. energy workforce and general workforce population average; however, the percentage of white workers has increased 2% since 2019. The hydropower industry has a slightly higher concentration of workers represented by a union or project labor agreement (12%) than other energy sectors and the broader U.S. workforce (Keyser 2022). **The most recent demographic data show more work is needed to build diversity in the U.S. hydropower workforce.**

The hydropower workforce is aging. DOE estimates 9,000 workers will leave the industry by the year 2030, increasing to 13,000 workers leaving by 2040 (Keyser and Tegen 2019). By 2030, the number of on-site jobs is anticipated to range from 24,500 to 25,500, and by 2050, on-site jobs are projected to range from 26,000 to 28,000 according to Hydropower Vision scenarios (DOE 2016). The upper estimates assume that the hydropower industry deploys more pumped storage hydropower, small hydropower, and low-impact technologies. These estimates are validated by responses to a 2022 survey of the hydropower industry conducted by the Water Power STEM to Workforce project, which suggest the industry's workforce needs are expected to grow, particularly in the areas of pumped storage hydropower, small hydropower, and low-impact technologies (Figure 6). **The growth of new and lower-impact hydropower technologies will provide more demand for workers with backgrounds in areas like environmental science, biology, and recreation.**

Table 1. Demographics of the U.S. Conventional Hydropower Workforce. *Data from Keyser (2022)*[a]



Demographic	Conventional Hydropower Jobs	% of Conventional Hydropower Jobs	Energy Workforce Averages	% of U.S. Working Population
Male	44,487	69%	74%	53%
Female	19,877	31%	25%	47%
Gender Non-Binary	151	<1%	<1%	insufficient data
Hispanic or Latino	10,272	16%	17%	18%
Not Hispanic or Latino	54,242	84%	83%	82%
American Indian or Alaska Native	794	1%	2%	1%
Asian	6,699	10%	7%	7%
Black or African American, not Indigenous	5,862	9%	8%	12%
Black Indigenous	983	2%	1%	insufficient data
Native Hawaiian or Other Pacific Islander	648	1%	1%	<1%
White	44,990	70%	74%	78%
Two or More Races	4,539	7%	8%	2%
Veterans	5,543	9%	9%	6%
55 and Over	11,238	17%	17%	24%
Disability	1,418	2%	2%	4%
Formerly Incarcerated	1,891	3%	1%	2%
Union Coverage	7,671	12%	10%	6%

[a] Any discrepancies in the data presented may be a reflection of rounding or other anomalies in the source data.

While the on-site hydropower workforce has declined since 2019, the U.S. Hydropower Market Report (Uría-Martínez, Johnson, and Shan 2021) highlights a project development pipeline, especially in pumped storage hydropower, that if constructed would provide new employment opportunities for on-site workers to enter the hydropower industry. The current U.S. conventional hydropower development pipeline of non-powered dam projects, conduit projects, new stream-reach development,[4] and capacity additions are estimated to be 1.49 GW (Figure 7). Based on this development pipeline, NREL estimates conventional generation could add roughly 300 on-site hydropower jobs across the United States based on the current employment levels at existing facilities per megawatt of generation. **The pumped storage hydropower development pipeline is expected to develop more capacity than conventional hydropower in the coming years with an additional 52.8 GW (Figure 7).** Pumped storage hydropower also plays a vital role in enabling other renewable generation on the grid, helping states achieve renewable portfolio standard goals while increasing workforce needs for all renewable energy jobs.
To operate and maintain this additional pumped storage fleet, an additional 8,787 jobs would be required based on the current employment levels at existing facilities per megawatt of generation. These estimates do not include the additional workforce to construct the new projects or domestically manufacture the equipment.

Based on the current hydropower development pipeline, conventional generation could add roughly 300 on-site hydropower jobs, and pumped storage hydropower could add an additional 8,787 jobs.

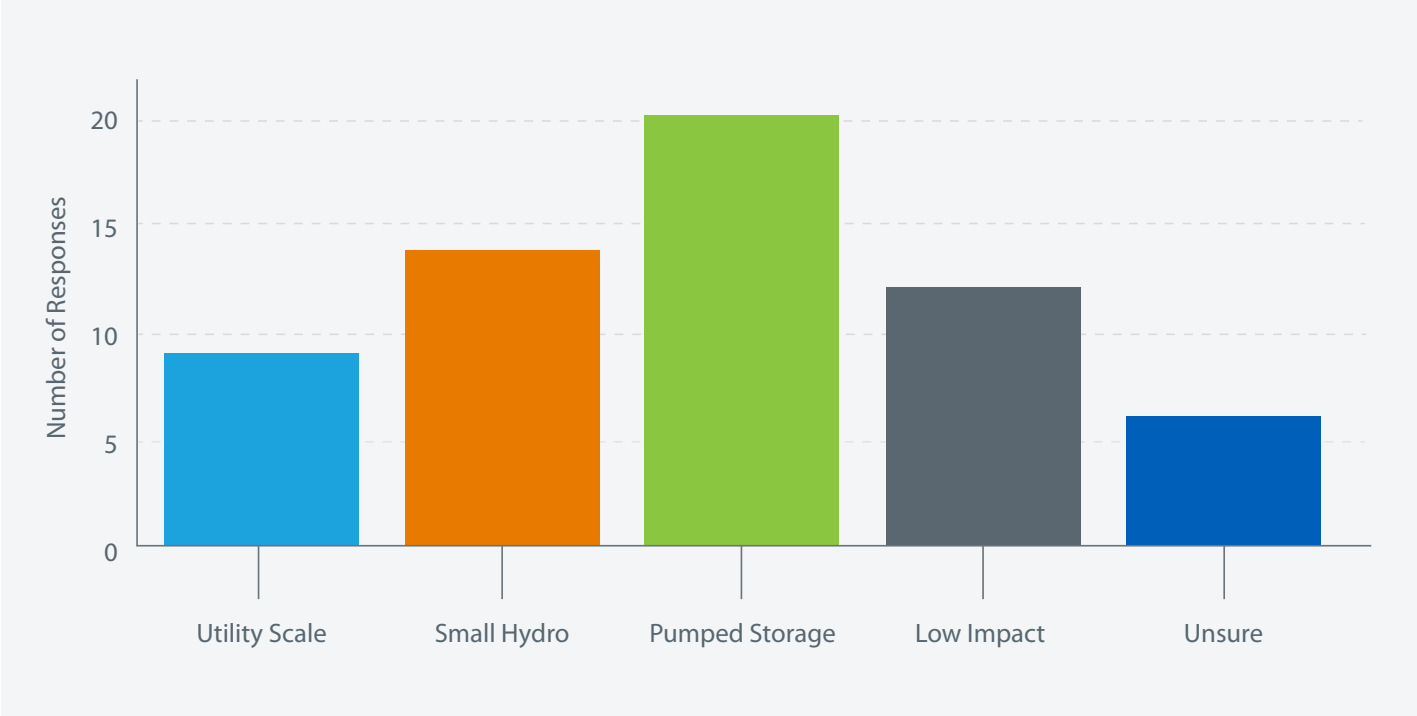


Figure 6. Projected hydropower technology areas for workforce growth

Pumped storage hydropower facilities are where excess energy generated from other renewable energysources can be stored and used at a later time by moving water between two reservoirs of differing elevations. Open-loop hydropower is continuously connected to a naturally flowing water feature, whereas closed-loop hydropower is off-stream and not continuously connected to a naturally flowing water source. **Low-impact technologies** reduce or mitigate environmental or social impacts from hydropower generation. **Small hydropower** describes projects that can capture energy from low-head stream flows or use existing dam or irrigation infrastructure with a capacity up to 30 MW (though capacity limits vary by state). **Utility scale** represents conventional generation facilities that have a capacity of more than 30 MW (though, like small hydropower, the exact definition varies by state).

[4] New stream-reach development includes high-energy-intensity stream reaches, which can potentially serve as areas for hydropower development following an assessment of technical, socioeconomic, and environmental characteristics.

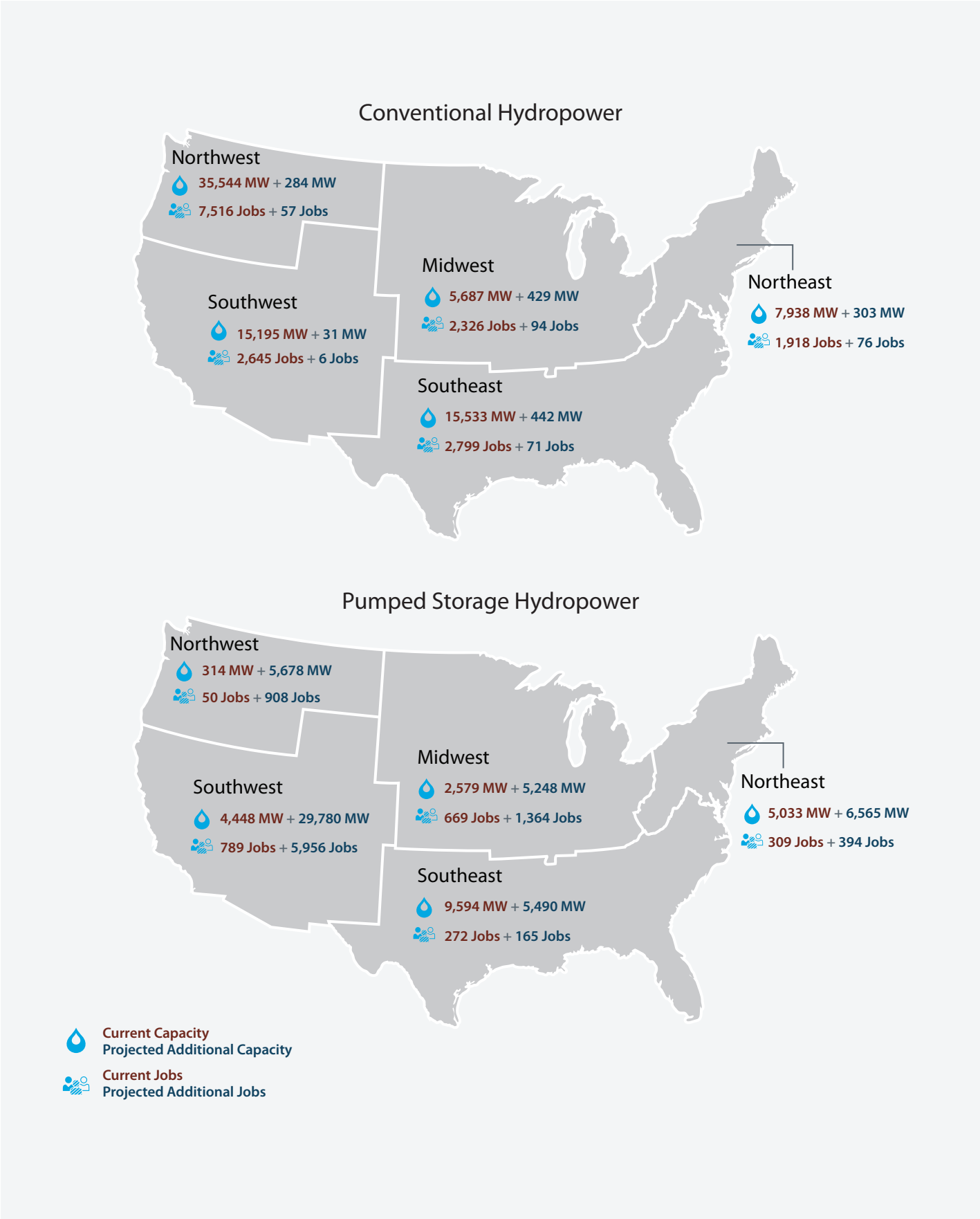


Figure 7. Future U.S. conventional and pumped storage hydropower development pipeline. *Data from Uría-Martínez, Johnson, and Shan (2021)*

Hydropower Education Pipeline

Since the Water Power STEM to Workforce project began, NREL and the Hydropower Foundation have engaged with academia, students, and industry to better understand the strength of the U.S. hydropower workforce pipeline to meet industry needs. The project team conducted a series of surveys[5] to understand the challenges and perceptions of the hydropower industry. The surveys do not serve as an exhaustive representation of the hydropower industry as a whole; rather, they provide anecdotal information that has been used to engage in dialogues with industry, academia, and students and to inform project direction.

Nearly 70% of the U.S. schools surveyed do not offer hydropower degree programs.

Academic Institution Survey

In 2019, NREL and the Hydropower Foundation contacted 26 U.S. postsecondary schools with known courses, programs, or activities in hydropower to document existing educational programs and curricula that could feed the hydropower workforce pipeline. Nearly 70% of the schools surveyed do not offer hydropower degree programs. In some schools, hydropower is included as a topic within other energy courses or can be pursued as an area of specialization. Schools expressed interest in expanding their hydropower programs; however, 34% cited lack of funding as the main obstacle. **In addition, schools expressed that students were unaware of the importance or relevance of hydropower as a growth industry or hydropower as a career path.**

Student Survey

In 2020, NREL and the Hydropower Foundation surveyed 74 students from 20 different high schools and postsecondary schools to understand their perceptions and interest in careers in the hydropower industry. Responses showed that 93% of surveyed students view hydropower as a renewable energy source, ranking it third in interest after solar and wind. Furthermore, 76% of students said hydropower courses

[5]https://hydrofoundation.org/workforce-development/

More than 77% of hydropower industry respondents state recent graduates have limited knowledge of the hydropower industry, with 23% having no knowledge.

would interest them, but many lack access to hydropower curricula in their schools. More than 60% of students indicated they were either unsure or didn't see hydropower as a growing field. Feedback also suggests that many students lack information on the role hydropower plays in the electrical grid and associate hydropower with negative environmental impacts from dams. Finally, 28% indicated they were unaware of the jobs that exist in the industry and lacked understanding of the jobs and skills required. Students most commonly associate hydropower with engineering, project development, and craft and trade jobs.

Industry Survey

In 2021, NREL and the Hydropower Foundation surveyed the U.S. hydropower industry to gauge how prepared students are for hydropower jobs, with a focus on student graduates who recently entered the hydropower workforce. Thirty-two responses were received. More than 77% of respondents said that recent graduates have limited knowledge of the hydropower industry when starting their jobs, with 23% having no knowledge. Only 10% of respondents stated that students are well prepared for jobs in hydropower when entering the industry. Respondents expressed that educating new hydropower workers about the industry often

falls to the employers, with 22% of industry respondents stating that they provide basic hydropower education for new hires. Respondents said that if students had learned about hydropower, it was from internships or prior work experiences.

The 2021 survey also asked hydropower industry representatives about the challenges they experience when recruiting new entry-level workers. Unfamiliarity with hydropower, lack of relevant experience or skill sets to meet job requirements, little interest in geographic location, lack of interest in or misconceptions about hydropower, and the absence of relevant degrees or coursework were all cited as recruiting challenges faced by the hydropower industry. The hydropower industry also struggles to compete with other industries for workers with transferrable skill sets. **Respondents suggested the hydropower workforce pipeline could be strengthened by providing more relevant work experiences, hydropower coursework, and hands-on learning opportunities for students.** Survey respondents also encouraged greater hydropower industry engagement with academia, including providing guest speakers and tours to generate earlier interest and awareness of careers in the industry.

73% of industry survey responses indicated that the hydropower industry has difficulty hiring women, minorities, tribal members, and veterans due to limited interest from those groups and a low number of applicants.

Diversity, Equity, and Inclusion

In 2022, NREL and the Hydropower Foundation reached out again to the hydropower industry to understand workforce-related challenges for operations, maintenance, dam safety, hydropower scheduling, construction, and supply chain jobs and to gather information on diversity, equity, and inclusion initiatives. Thirty-one responses were received from 23 different U.S. hydropower organizations. The survey considered both on-site and off-site hydropower

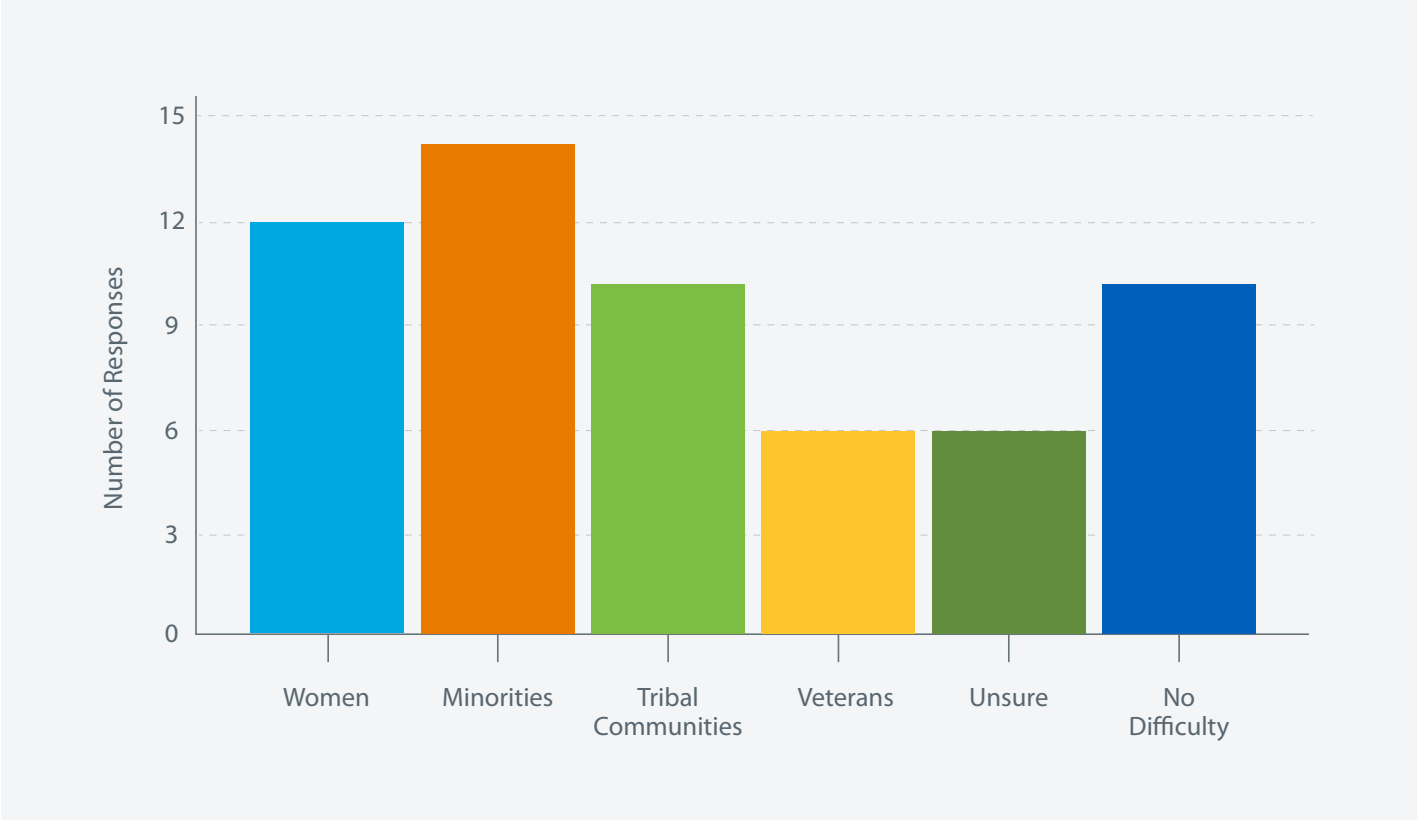


Figure 8. Hydropower industry hiring challenge demographics

jobs ranging from technology, system design, and research and development to project development, regulatory, construction, and operations and maintenance.

Respondents were asked to select the underrepresented groups their organizations have difficulty hiring from—73% of the responses indicated that the industry has trouble hiring women, minorities, tribal members, and veterans due to limited interest from those groups and a low number of qualified applicants (Figure 8). Many of the surveyed organizations have established initiatives to improve hiring from these groups, such as building relationships with minority-serving institutions by attending job fairs and offering internships; establishing internal programs, trainings, and metrics on diversity, equity, and inclusion; and offering hiring preference for veterans.

Retirement, Recruiting, and Knowledge Transfer

Survey respondents stated that the primary jobs experiencing a high retirement rate over the next 5–10 years include skilled crafts and tradespeople (e.g., electricians, mechanics, operators) and engineering services (e.g., engineers, drafters, technicians). In addition, respondents noted significant turnover in engineering services jobs for people who are not retiring but leaving the organization for a new job. Respondents anticipate engineering services jobs will have the largest growth in the industry over the next 10 years; environmental science and skilled craft and trade jobs are also expected to grow significantly.

Increasing retirement and turnover have highlighted the importance of transferring organizational and operational knowledge to new workers.

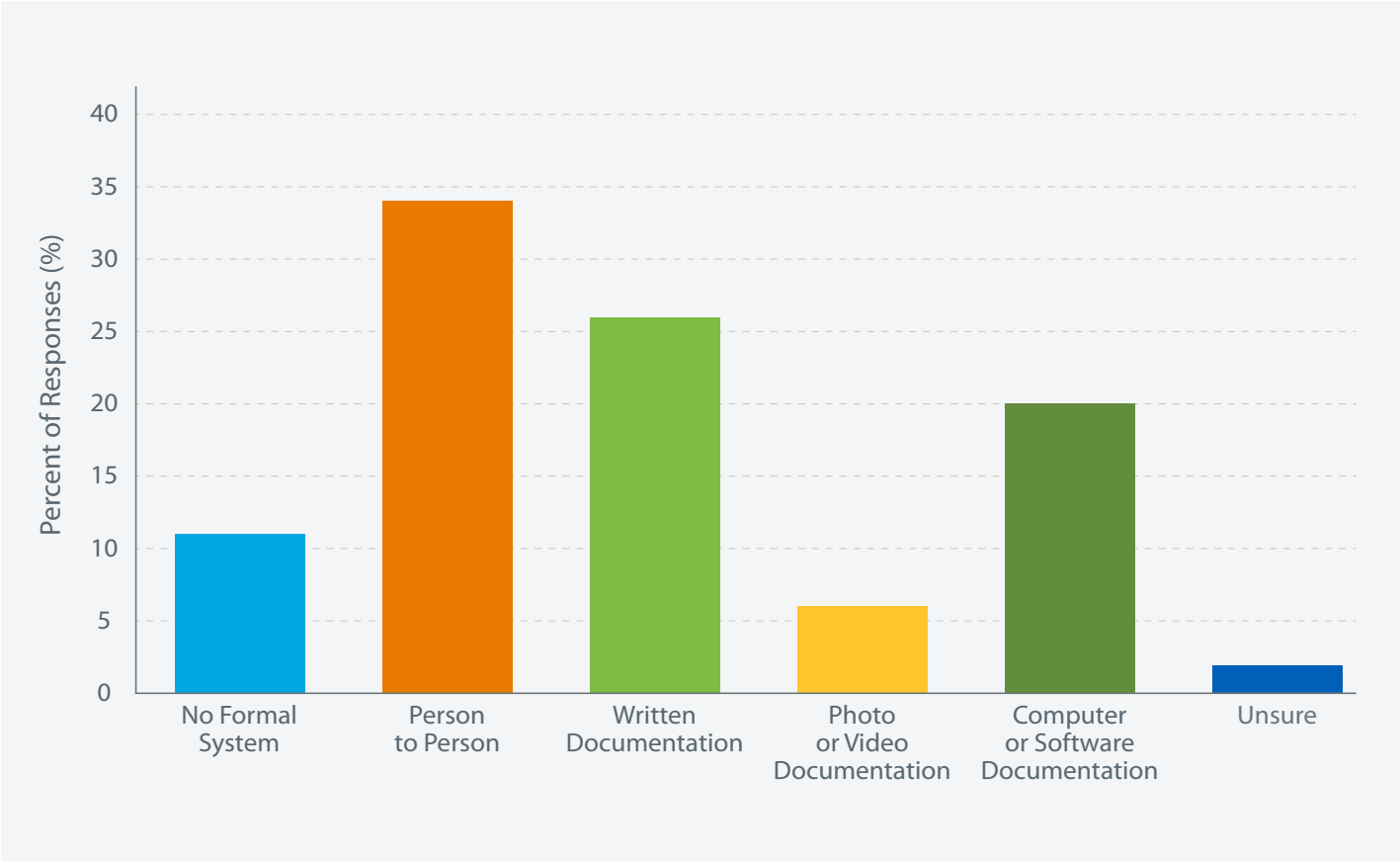


Figure 9. Hydropower industry knowledge transfer systems

Concerns about staff retention, retirement, and turnover have highlighted the need to transfer organizational and operational knowledge to new workers. When asked how their organizations transfer knowledge, 34% of industry respondents said they use person-to-person transfer, 27% use written documentation, and 20% use computer software. A small percentage, 11%, have no formal knowledge transfer system (Figure 9).

The 2022 industry survey respondents indicated that recruiting qualified applicants of any level is challenging for certain hydropower jobs, such as engineering services, skilled crafts and trades, and project management. Recruiting operators is also a challenge, as much of their knowledge is region- or location-specific, which new hires would not have when entering the job. In addition to a shortage of qualified applicants, other issues affect recruiting, including a lack of interest in the hydropower industry, job location, or the types of available jobs; an unwillingness to work for the offered wages; insufficient training, education, or familiarity with hydropower to adequately perform the job; and competition with other industries for transferrable skill sets (Figure 10).

Challenges with recruiting and job-readiness of new hydropower workers could be overcome by expanding technical training, apprenticeships, and educational outreach.

Several solutions were suggested to address these hiring challenges, with nearly one-third of respondents recommending expanding technical training and apprenticeships to improve job readiness through hands-on learning. Other solutions suggested by the hydropower industry to meet its workforce needs include more educational outreach, such as developing shared curricula and educational materials to raise industry awareness with educators, students, and the general public; more funding

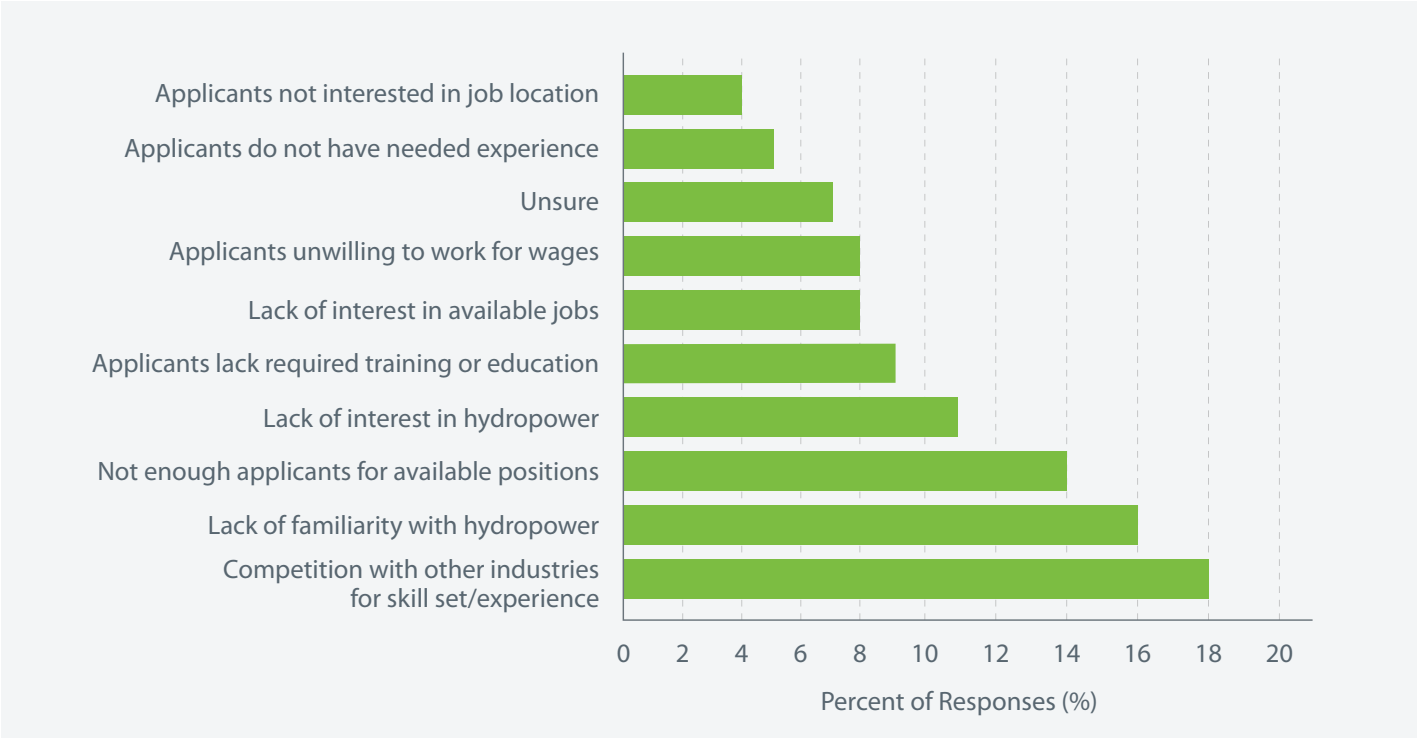


Figure 10. Hydropower industry recruiting challenges

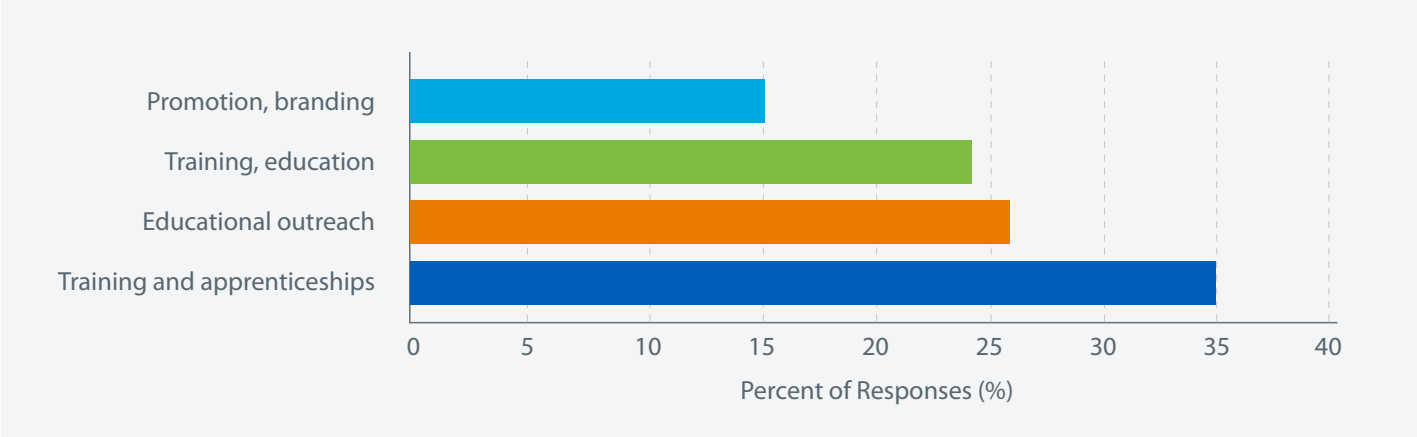


Figure 11. Suggestions to improve hydropower industry recruiting

to support broader hydropower education and research; and campaigns to promote and rebrand hydropower (Figure 11).

Crafts and Trades

The 2022 hydropower industry survey also asked respondents a series of questions specific to craft and trade workers, who are in high demand for their transferrable skills. Respondents said their primary means of recruiting these workers are partnering and outreach with vocational schools (26%), apprenticeship programs (26%), and recruiting from industries with transferrable skills (22%). According to respondents, hydropower's primary competitors for skilled craft and trade workers are the manufacturing sector, other renewable energy technologies, the maritime industry, and the defense sector.

While 28% of hydropower industry survey respondents use unions to help recruit craft and trade workers (citing that unions can be helpful to identify workers with specific skills), 72% of respondents do not leverage unions because there is often no specific union for the job or skill set needed. Partnering with vocational schools and using job websites are the main pathways cited for craft and trade workers to learn about hydropower jobs. Other avenues include formal recruiting programs, partnering and outreach with trade associations, and outreach to the local community.

Mechanics, instrumentation, and controls (I&C) technicians, supervisory control, and data acquisition (SCADA) technicians, and electricians were cited as the craft and trade jobs for which the industry has the most difficulty finding qualified applicants (Figure 12). Respondents indicated that the craft and trade jobs they anticipate having the highest growth over the next 10 years (Figure 13) include instrumentation and controls, SCADA, and computerized maintenance and management systems (CMMS). Mechanics, technicians, electricians, and cyber experts were also highlighted for their potential growth in the industry.

Respondents indicated that the most common knowledge gap for new craft and trade workers is the lack of specific hydropower expertise, noting new job entrants have the basic skills to qualify for the position but often no hydropower industry knowledge. Of the hydropower industry representatives surveyed, 83% said they build needed skills for craft and trade workers through on-the-job training.

It is critical for the hydropower industry to attract new talent, overcome recruiting challenges, effectively transfer knowledge from the older workforce to new workers, and retain its skilled workers.

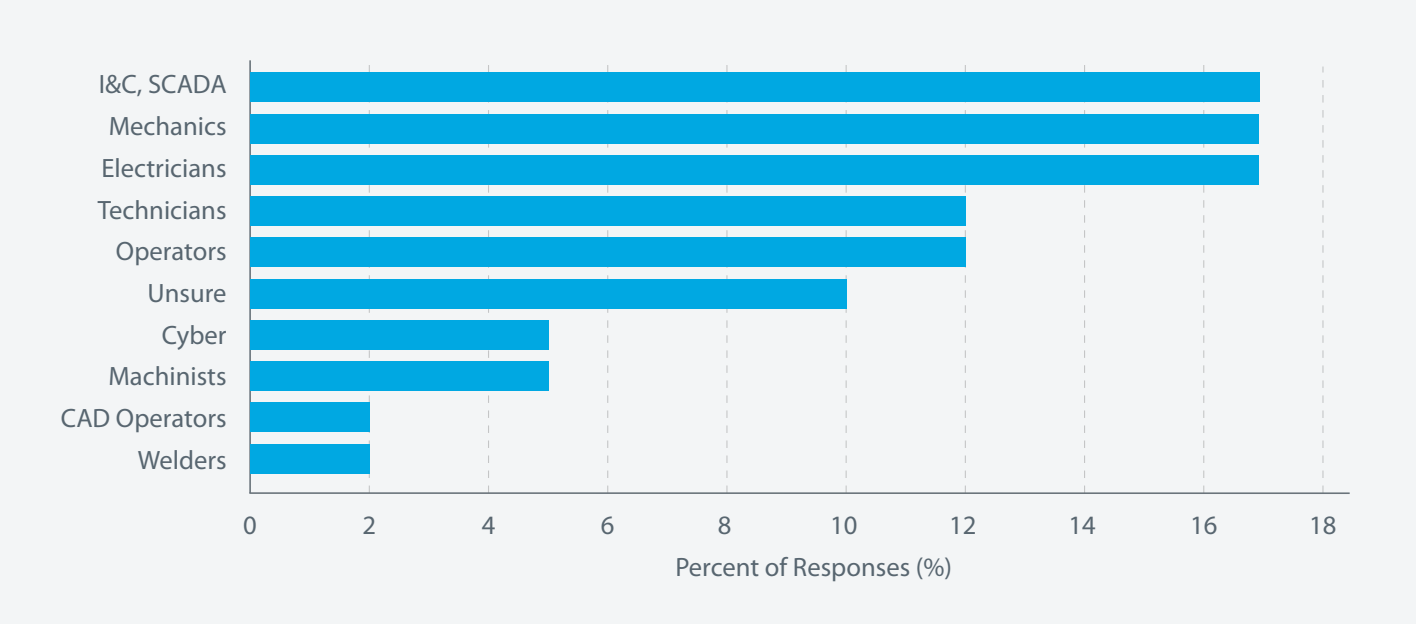


Figure 12. Craft and trade jobs with the greatest hiring difficulty in hydropower

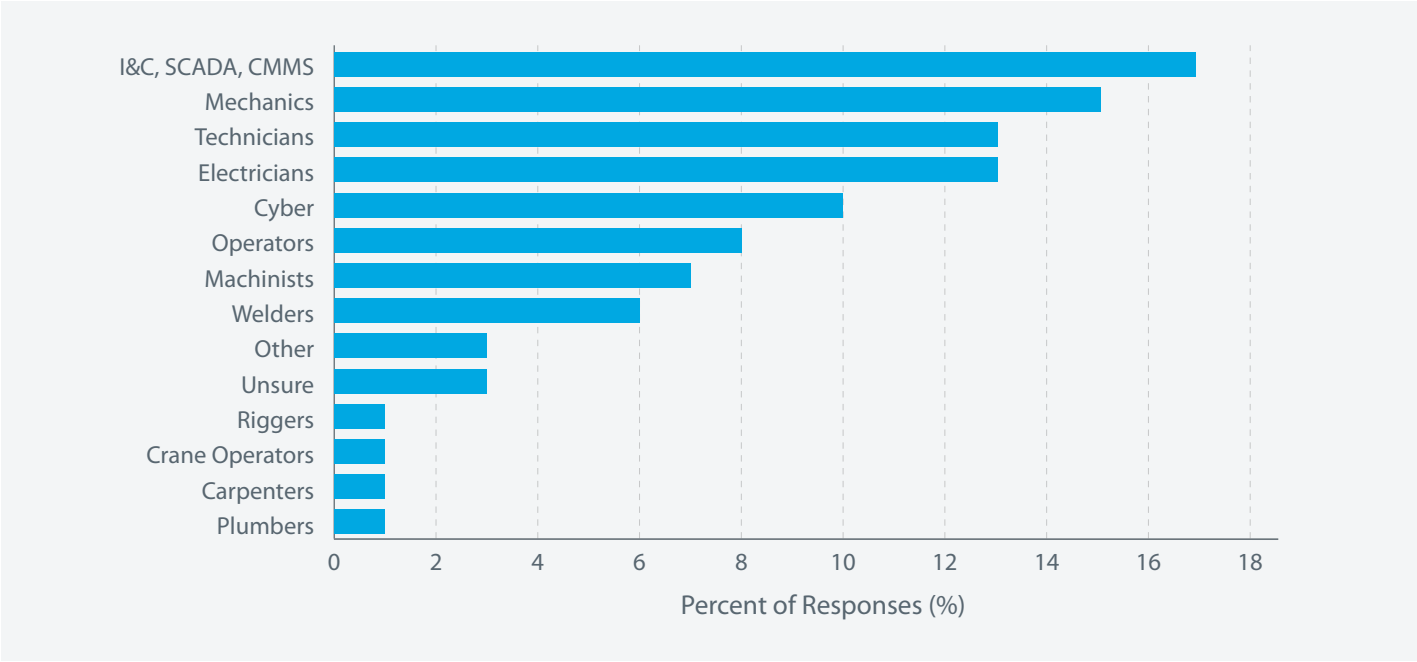


Figure 13. Craft and trade jobs with the largest anticipated growth in hydropower over the next 10 years

Respondents also said they are increasing training on computer skills for craft and trade workers, including SCADA, programmable logic controllers, human-machine interfaces, and electronics.

Pathways to Bridge the Hydropower Workforce Gap

The survey findings from the Water Power STEM to Workforce project provide a glimpse into the challenges the U.S. hydropower industry faces with its workforce pipeline. To ensure a broad understanding of these issues and devise solutions that address them head-on, NREL has actively sought input from and partnership with hydropower industry representatives and relevant educational organizations. Examples include the establishment of an advisory committee with members from industry and academia and partnerships with the Hydropower Foundation, the National Energy Education Development (NEED) Project, the Bonneville Environmental Foundation (BEF), and KidWind. NREL and the Hydropower Foundation have also conducted a series of dialogues with industry, academia, and students to solicit feedback on project activities and identify priorities to strengthen the connection between academic institutions, students, and the hydropower industry. These dialogues have covered a range of topics and have led to:

- The creation of the STEM for Hydropower web portal[6] with educational resources, workforce analysis, and training programs
- The development of career competency maps and "day-in-the-life" videos[7] to support hydropower job entrants
- The creation of the Hydropower Collegiate Competition[8] to engage the next generation of hydropower workers
- The creation of hydropower curricula.

Insights gained from these collaborations have informed the development of STEM activities for a new hydropower workforce, identified needed infrastructure improvements at

Partnerships, open-access educational and training resources, tools for job seekers, hands-on collaboration and engagement opportunities, and an intentional approach to diversity and inclusion can help bridge the hydropower workforce gap.

[6] https://openei.org/wiki/Hydropower/STEM
[7] https://openei.org/wiki/Hydropower/STEM/Resources/Career_Pathways
[8] https://openei.org/wiki/Hydropower/Prizes_and_Competitions/Hydropower_Collegiate_Competition_(HCC)

U.S. educational institutions, and broadened knowledge of the hydropower industry as a viable employment opportunity for students to pursue.

These collective efforts will make a difference in the domestic water power workforce by strengthening hydropower knowledge and industry awareness in recent graduates and potential hires, better preparing them for jobs in water power. The following are descriptions of ongoing and planned activities by the Water Power STEM to Workforce project to support hydropower workforce pipeline expansion:

Clean Energy Talent Hub

Through the Water Power STEM to Workforce project, NREL and BEF have partnered to create a Clean Energy Talent Hub in the Pacific Northwest. The hub's goal is to empower local regions to customize national educational and career-related information to their local context, allowing community organizations to take ownership of region-specific issues. The partnership with BEF enables deep reach within regions to learn about and address local challenges, including those of tribal communities. Over time, the project intends to establish additional regional hubs nationwide to strengthen local connections with the water power industry and address region-specific challenges.

Hands-On Learning

As a result of feedback from educators and students in the Water Power STEM to Workforce project, and with support from the Hydropower Foundation, NREL and DOE established the Hydropower Collegiate Competition, which facilitates real-world hydropower learning experiences for students, opening doors to future industry internships and careers. The competition aims to inspire and grow future hydropower industry workforce leaders. The competition also includes hands-on learning and partnerships between collegiate competitions and K–12 competitions. Feedback from industry and competition participants has already confirmed the value of these collaborations in facilitating industry engagement and introducing hydropower concepts to academia.

Online Learning

The educational materials created by the Water Power STEM to Workforce project are available online and are easy to navigate. The STEM for Hydropower web portal includes educator resources; information on the hydropower workforce, networking, and career-building resources; information on prizes and competitions; links to virtual and in-person hydropower facility tours; and relevant research. The Water Power STEM to Workforce project has also created educational tools such as the Renewable Energy Discovery (REDi) Island to educate and help dispel misconceptions about the hydropower industry. With 3D animated videos of a virtual island powered by renewable energy, REDi Island[9] takes users on a journey to learn about water power technologies and career opportunities. **Through REDi Island, students, educators, and stakeholders can learn about the role of hydropower and current hydropower innovations.**

REDi Island takes students, educators, and stakeholders on a journey to learn about the role of hydropower and current hydropower innovations on a virtual island powered by renewable energy.

Diversity, Equity, and Inclusion

As demonstrated by the U.S. hydropower industry demographics and Water Power STEM to Workforce project survey data, the hydropower industry has room to improve its workforce diversity. Since publication of the 2019 NREL report, there have not been notable improvements to the diversity of the hydropower workforce. Increasing diversity has become an important goal of the Water Power STEM

[9] https://openei.org/wiki/PRIMRE/REDi_Island

to Workforce project and has prompted the project team to conduct dialogues and outreach to identify innovative ways to achieve greater diversity of women and minorities in the hydropower industry. These dialogues have sought to understand the needs and priorities of underrepresented groups and the hydropower industry. To build more diversity in hydropower, partnerships among industry, academia, and underrepresented groups are needed. These partnerships will inform outreach and recruiting to support a diverse workforce by devising approaches and programs to raise industry awareness, share career information, and engage potential workers. Building a more diverse and inclusive workforce will not only bring new perspectives to the hydropower industry, but will also help attract more workers, addressing recruiting and retirement challenges.

Shared Curricula and Certifications

A significant finding of the Water Power STEM to Workforce surveys is that hydropower is not taught in many postsecondary schools and that developing curricula and new programs can be an obstacle for educators due to a lack of time, funding, and credible information on the latest hydropower industry technologies and practices. The Water Power STEM to Workforce project, in partnership with NEED and KidWind, is addressing this challenge by developing and sharing curricula, toolkits, and other educational resources and providing training to educators so they are equipped to teach hydropower. Giving educators the latest information on hydropower technologies and industry trends and providing open access to credible hydropower educational materials will help to build awareness and bolster the hydropower workforce pipeline.

Building on the concept of shared curricula, the Water Power STEM to Workforce project is also exploring formalized partnerships with academic and vocational institutions to offer hydropower certifications targeting crafts, trades, and postsecondary schools. A multidisciplinary hydropower certification can build the knowledge and skills of potential workers by incorporating internships and hands-on training to support their readiness for hydropower industry jobs and ease the training burden for the hydropower industry. The certification would address topics such as technologies, environmental mitigation, power systems, markets, and grid operations, which were identified in the Water Power STEM to Workforce industry survey as areas where new hires lack the needed background.

A more diverse and inclusive workforce will bring new perspectives to the hydropower industry and attract more workers, helping to address recruiting and retirement challenges.

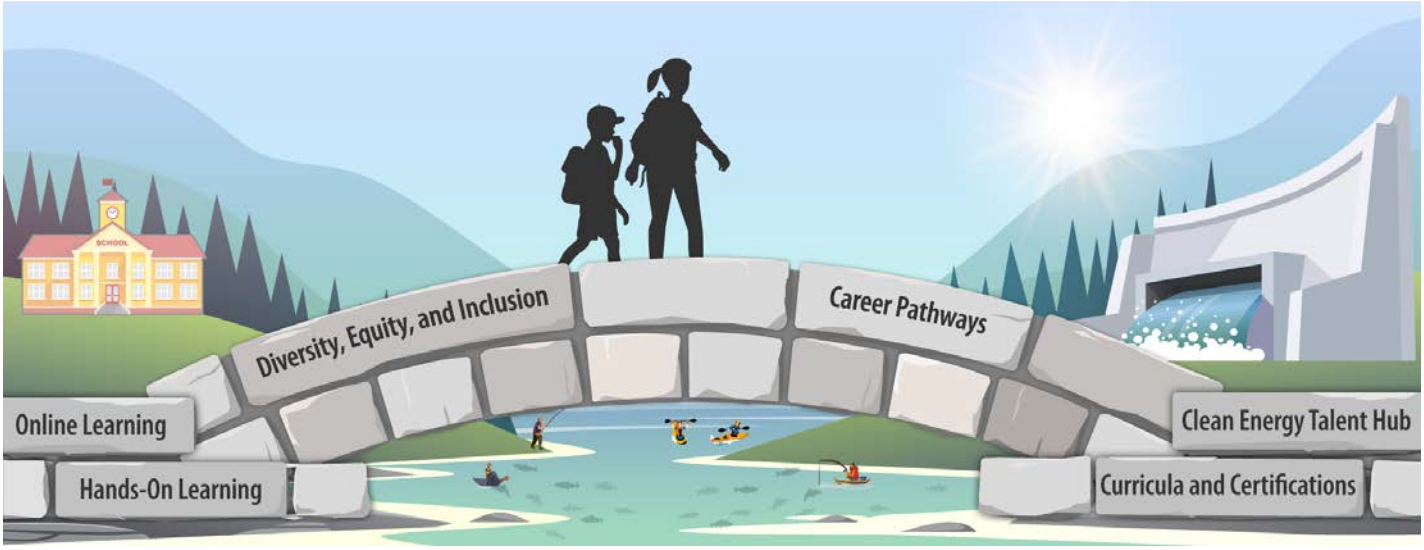


Figure 14. Bridging the gaps in the hydropower workforce pipeline. *Illustration by Alfred Hicks, NREL*

Career Pathways

Career competency maps and "day-in-the-life" videos are being developed to help educators teach students and other job seekers—with backgrounds in both STEM and non-STEM topics—about hydropower careers. These resources will help job seekers from any industry or career stage understand how their skills and education could transfer to a career in hydropower as well as the potential salary range for specific hydropower jobs. Such resources help students and job seekers envision the types of jobs they could pursue in the hydropower industry, addressing challenges faced by educators and students who indicated that the lack of hydropower career path information was an obstacle to working in the industry.

The Water Power STEM to Workforce project is also creating hydropower workforce analysis resources, including the Jobs and Economic Development Impact (JEDI)[10] model, which is a publicly available, user-friendly tool that estimates the economic impacts of constructing and operating power generation plants at the local and state levels. JEDI can be used to analyze the potential job and economic impacts of conventional hydropower along with other energy sources.

The Clean Energy Innovator Fellowship program, which began in FY22, funds recent graduates and energy professionals to work for up to two years with host organizations in the energy field, including electric public utility commissions, municipal and cooperative utilities, and grid operators. Projects may include grid modernization, equitable and affordable access to clean energy and energy efficiency, integration of electric vehicles and building electrification, resilience planning, interconnection, and rate design. The program is funded by several offices within DOE's Office of Energy Efficiency and Renewable Energy, including the Water Power Technologies Office.[11]

Conclusion

The evolving role of hydropower in the modern grid, significant rates of worker retirement, and competition for skilled workers make this a critical time for the hydropower industry. Alongside these challenges, the shortage of hydropower educational programs and limited student awareness of the industry underscore the need to reenergize the hydropower workforce pipeline. The Water Power STEM to Workforce project surveys illuminated academic, student, and industry perspectives—and it is clear more work is needed to meet the needs of the hydropower industry and expand diversity, equity, and inclusion. There is also a broader need to educate stakeholders in hydropower's unique ability to enable a global clean energy transformation. The Water Power STEM to Workforce project endeavors to bridge the gaps identified in this report and to rise to the challenge of strengthening our domestic workforce pipeline to create the next generation of U.S. hydropower. **Now is the time for educators and industry to work together to build a stronger, more diverse hydropower workforce that will help the United States achieve its clean energy and climate goals.**

[10] https://openei.org/wiki/Hydropower/STEM/Workforce_Data_and_Analysis/Jobs_and_Economic_Development_Impacts
[11] https://www.energy.gov/eere/clean-energy-innovator-fellowship

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15013 Denver West Parkway, Golden, CO 80401
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