



Department of Energy

Washington, DC 20585

Workforce Analysis of Existing Coal Carbon Capture Retrofits

Summary

The Department of Energy (DOE) has developed an analysis of the workforce needs for installing carbon capture equipment on existing coal facilities. This memo assesses the workforce needs of installing carbon capture and storage (CCS) retrofits on existing coal-fired electric generating units (EGUs) in the 2030s, compares it to estimates of current workforce availability by occupation, and summarizes existing mechanisms that DOE and CCS developers are using to proactively invest in workforce development.

Key findings from this analysis:

- 71,400 to 107,100 average annual jobs resulting from project investments—including construction, project management, machinery installers, sales reps, freight, and engineering—would likely be needed over a five-year construction period to deploy CCS at a subset of existing coal power plants. 116,200 to 174,300 average annual jobs would likely be needed for a larger set of existing coal power plants with no retirement date.
- Many of the skills needed to build and operate carbon capture technologies are similar to those used by workers in the electric power generation and fuels industries, including skilled construction labor and machine operation and maintenance.
- The total number of jobs needed for deploying CCS on coal power plants is significantly less than the size of the existing workforce in adjacent occupations with transferrable skills in the electricity generation and fuels industries.
- In addition to the existing workforce with available skills, existing programs and mechanisms exist to expand the workforce. DOE programs, industry workforce investments, and 45Q prevailing wage and apprenticeship provisions provide additional significant support to workforce development, and demonstrate that the CCS industry likely has the capacity to train and expand the available workforce to meet future needs.

Coal Capacity Carbon Capture Retrofit Assumptions

The decision of whether to retrofit a fossil EGU with CCS will be unique to each generating unit, and depends on factors such as the unit age, operating and fuel costs of each unit, the relative costs of other fuels and electricity generation technologies, state, and Federal incentives for CCS, access to CO₂ transportation and storage infrastructure, and other factors.

The Environmental Protection Agency (EPA) National Electric Energy Data System (NEEDS) database includes 73 gigawatts (GW) of coal EGUs with no current firm commitment to retire or convert to natural gas by 2040.¹ While these EGUs all have near term potential for CCS retrofits, the set of coal plants likely to retrofit with CCS may be smaller when accounting for a plant's capacity and age. Coal

¹ The NEEDS data base tracks electricity generation unit information including basic geographic, operating, air emissions, and other data including announced retirement dates. <https://www.epa.gov/power-sector-modeling/national-electric-energy-data-system-needs>

retirements in recent years have tended to come from older units. Specifically, the capacity-weighted average age of coal EGUs scheduled to retire in 2024 is almost 54 years.² Capture costs on a dollar-per-ton basis tend to be higher for smaller capacity coal EGUs. In DOE's National Energy Technology Laboratory (NETL) carbon capture retrofit database, no coal plants 50 MW or smaller operating at 70 percent capacity factor have capture costs less than \$85 per metric ton CO₂ (\$/t CO₂), the incentive provided by the 45Q tax credit.³

This analysis considers two scenarios for coal CCS retrofits:

- **Scenario 1:** Coal-fired EGUs with capacity greater than 50 MW that will be less than 60 years old in 2040 are assumed to install CCS, consistent with data on coal fired EGU retirement age trends and capture cost data. This includes 99 coal fired EGUs at 67 power plants representing 42 GW of capacity. Deploying CCS at these plants could sequester about 229 million metric tons of CO₂ per year.⁴
- **Scenario 2:** All coal EGUs with no firm commitment to retire or convert to natural gas by 2040 install CCS. This includes 206 coal fired EGUs at 109 power plants with 73 GW of capacity. Deploying CCS at these plants could sequester about 400 million metric tons of CO₂ per year.

Coal Carbon Capture Workforce Estimates

In December 2023, Rhodium Group released a workforce analysis commissioned by the Great Plains Institute that identifies the economic impact and workforce opportunities of CCS in the midcontinent region of the United States.⁵ Throughout the region, 87 coal power plants were identified as having near-term potential for retrofitting with carbon capture systems.⁶ The report estimated an annual average of 30,910 to 46,370 construction jobs associated with coal CCS retrofits over a 15 year period. These jobs are reported as in-state jobs, directly associated with carbon capture retrofits, and do not include other jobs at the facilities, nor indirect and induced jobs.⁷

For this analysis, the high and low average annual investment jobs for coal power plant CCS retrofits reported in the Rhodium Group analysis were scaled to the two coal CCS scenarios. These were adjusted to assume that construction on these units would take place over a single five-year period across all

² <https://www.eia.gov/todayinenergy/detail.php?id=61425>

³ This database provides high-level analysis on the incremental costs for retrofitting pulverized coal plants with carbon dioxide capture systems. <https://www.netl.doe.gov/energy-analysis/details?id=e7e822ff-18ac-4bc6-a052-0be3521b8789>

⁴ Assumes the plants operate at 70% capacity factor and a carbon capture rate of 90%.

⁵ Great Plains Institute is a non-profit energy organization and Rhodium Group is an independent research organization. <https://rhg.com/research/carbon-capture-and-storage-workforce-development-state-by-state/>

⁶ Eleven industries are included in the full Rhodium Group analysis: ammonia, cement, ethanol, gas processing, hydrogen, iron & steel, pulp & paper, refineries, waste, coal power plants, and gas power plants.

⁷ The Rhodium Group analysis uses IMPLAN, an economic modeling system that estimates jobs associated with capital investment, supplemented with Bureau of Labor Statistics (BLS) occupational data. For more on Rhodium Group's methodology, see <https://rhg.com/wp-content/uploads/2023/12/Carbon-Capture-and-Storage-Workforce-Development-Methodology.pdf>

plants starting in 2028, under the assumption that cumulative job-years per plant are constant.⁸ For scenario 1, this results in 71,400 to 107,100 average annual investment jobs over a five-year construction period. For scenario 2, this results in 116,200 to 174,300 average annual investment jobs over a five-year construction period. These investment jobs are further categorized by occupation, using the same proportional breakdown of occupations for coal power plants presented in the Rhodium Group report. The occupational job estimates are reported in Table 1.

Table 1. Estimated average annual workforce associated with installing coal CCS retrofits on 42 GW and 73 GW of existing capacity, compared to existing workforce by occupation in the Electric Power Generation and Fuels sector.

	Average annual coal CCS investment jobs		Existing workforce in Generation & Fuels ^{9,10}
	Scenario 1: 42 GW	Scenario 2: 73 GW	
Construction Trade Workers	11,420 – 17,140	18,590 – 27,890	292,526
Executives and Business Operations	8,570 – 12,850	13,940 – 20,920	198,100
Machinery Installers, Maintenance, and Repairers	8,570 – 12,850	13,940 – 20,920	117,200
Sales Representatives	6,430 – 9,640	10,460 – 15,690	156,600
Commercial Freight	5,710 – 8,570	9,300 – 13,940	105,300
Engineers	2,860 – 4,280	4,650 – 6,970	128,100
Other	27,130 – 40,700	44,160 – 66,230	398,600

Available Workforce with Transferrable Skills

Many of skills needed to build and operate carbon capture technologies are similar to those used by workers in the electric power generation and fuels industries, including skilled construction labor and machine operation and maintenance. These skills and experience can be leveraged to support carbon capture implementation at existing facilities, creating jobs for incumbent energy workers.¹¹ Scale up of carbon capture will require technical experts and workers in skilled trades (e.g., electrical, plumbing, and mechanical trades), the energy sector, and manufacturing. The robust infrastructure of training and

⁸ For comparison, the Petra Nova retrofit design, procurement, construction and commissioning of the fully integrated carbon capture, transport, and storage processes and equipment took less than 3 years (July 2014 through December 2016). <https://www.osti.gov/servlets/purl/1608572>.

⁹ Data from *U.S. Energy and Employment Report* (USEER). U.S. Department of Energy. 2023. <https://www.energy.gov/sites/default/files/2023-06/2023%20USEER%20REPORT-v2.pdf>; Electric Power Generation and Fuels is defined using the NAICS classification used in USEER 2016 as the sum of 211 (Oil and Gas Extraction), 2121 (Coal Mining), 213112 (Support Activities for Oil and Gas Operations), 213113 (Support Activities for Coal Mining), 221110 (Electric Power Generation), 324 (Petroleum and Coal Manufacturing), 33313 (Mining and Oil & Gas Manufacturing). Breakout by occupation uses the BLS Employment Projections Table 9. Industry-occupation matrix data, by industry. <https://www.bls.gov/emp/tables/industry-occupation-matrix-industry.htm>. Construction jobs in Generation and Fuels are taken from USEER 2023.

¹⁰ The USEER 2023 report only provides demographic information by overall sector, not by occupation. It notes that for electric power sector workforce overall, women made up a higher proportion of the workforce (32%) than in the overall energy workforce (26%) but lower than the overall workforce average in the U.S. (47%). The proportion of non-white workers in electric power sector was 28%, higher than the national workforce average of 23% and overall energy workforce of 25%.

¹¹ https://liftoff.energy.gov/wp-content/uploads/2024/02/20230424-Liftoff-Carbon-Management-vPUB_update4.pdf

recruitment that creates these skillsets in adjacent industries (largely electric power and fuels industries) can also be used for CCS development.

This analysis compares the estimated coal-fired EGU CCS workforce needs by occupation to the existing workforce in occupations with similar transferable skills to assess the availability of the workforce for CCS retrofit activities. The electric power generation and fuels industry is defined using the North American Industry Classification (NAICS) codes.¹² Breakout by occupation uses the BLS industry-occupation matrix employment numbers for 2022.¹³ This is a conservative assumption as it assumes that only the existing workforce in these specific subsectors have transferrable skills. There are other subsectors with transferable skills such as in trades like electrical, plumbing, and construction management, and as noted below, there are workforce training opportunities, including those incentivized by the Inflation Reduction Act (IRA)¹⁴ tax credits, that will increase the available workforce.

The total number of jobs needed for deploying CCS on coal power plants across both scenarios is significantly smaller than the size of the existing workforce in adjacent occupations with transferrable skills in the electricity generation and fuels industries (Table 1). The actual workforce with transferrable skills would likely be larger when accounting for workers with similar occupations in other industries. Continuing to invest in the current workforce along with expansion of this workforce through government- and industry-led training opportunities, such as those outlined below, will further support a robust domestic carbon capture industry.

Project-level CCS investment jobs estimates

Scaling the Rhodium Group investment job estimates to a unit or project level estimate results in 1,070 to 1,600 average annual jobs per project over a five-year period. These numbers are consistent with available data or estimates from specific coal CCS retrofit projects:

- **Project Tundra** – A project selected in December 2023 to negotiate for up to a \$350 million award under the DOE Carbon Capture Demonstration funding opportunity.¹⁵ The project plans to capture an average of 4 million metric tons of CO₂ per year. The draft Environmental Assessment projects peak labor force to be approximately 600 to 700.¹⁶
- **Boundary Dam** – An existing CCS facility in Canada employed 1,700 people at peak construction.¹⁷
- **Petra Nova** – The Final Environmental Impact Statement for Petra Nova projected approximately 1,100 construction-related jobs and up to 20 jobs for operations.¹⁸

¹² For industry definitions, see DOE (2016) U.S. Energy and Employment Report. <https://www.energy.gov/policy/us-energy-and-employment-report-2016>.

¹³ <https://www.bls.gov/emp/tables/industry-occupation-matrix-industry.htm>.

¹⁴ Inflation Reduction Act, Pub. L. 117-169 (Aug. 16, 2022), <https://www.congress.gov/117/plaws/publ169/PLAW-117publ169.pdf>.

¹⁵ <https://www.energy.gov/oced/CCdemos>

¹⁶ <https://www.energy.gov/sites/default/files/2023-08/draft-ea-2197-nd-carbonsafe-chapters-2023-08.pdf>

¹⁷ SaskPower, “SaskPower CCS.” [Online].

https://unfccc.int/files/bodies/awg/application/pdf/01_saskatchewan_environment_micheal_monea.pdf.

Accessed February 29, 2024.

¹⁸ https://www.energy.gov/sites/default/files/EIS-0473-FEIS-Summary-2013_1.pdf

45Q Prevailing Wage and Apprenticeship Requirements

The prevailing wage and apprenticeship provisions in the 45Q tax credit for carbon capture and storage are estimated to provide additional support for a robust workforce for CCS construction. To qualify for the increased value of the 45Q tax credit, taxpayers must ensure that laborers and mechanics employed in CCS construction are paid no less than applicable prevailing wage rates and must employ apprentices from registered apprenticeship programs for a certain number of hours. By meeting prevailing wage and apprenticeship requirements, taxpayers can increase the base amount of the incentive by 5 times, from \$17 per metric ton of CO₂ for geologic storage (\$12 per metric ton for geologic storage with enhanced oil recovery) to \$85 per ton of CO₂ (\$60 per ton for EOR).¹⁹

The prevailing wage and apprenticeship requirements tightly link use of the tax credit with opportunity to grow the workforce. By pairing energy investment with the creation of quality jobs, the tax credit investments will help make these jobs more attractive to workers and incentivize the expansion of workforce training pathways into these jobs. The inclusion of registered apprenticeship provisions enables a talent pipeline for developing a workforce, as these include “paid work experience... progressive wage increases, classroom instruction, and a portable, nationally-recognized credential.”²⁰

A registered apprenticeship program is an apprenticeship program vetted and approved by the U.S. Department of Labor (DOL) or a State Apprenticeship Agency. The U.S. apprentice market has more than doubled between 2014 and 2023, growing at an average annual rate of more than 7 percent.²¹ As of March 2024, 39 registered apprenticeship programs support the occupation “Carbon Sequestration Plant Engineer.” Additional programs support the skilled construction trade workforce required for CCS implementation and maintenance.²²

The use of registered apprenticeship programs for training new employees is well-established in the electric power generation sector.²³ An Electric Power Research Institute analysis of IRA found that the supply of apprentices is anticipated to be adequate in the Ohio Valley, Mid-Atlantic, and Texas for taxpayers to meet the requirements of the increased tax credit based on several energy sector projections.²⁴ The same study also found that DOE, DOL, and industry, as incentivized by the IRA, continue to invest in registered apprenticeships, and these investments in workforce development are designed to continue a trend of growing apprenticeship enrollment and support apprenticeship completion to grow the labor pool of skilled trades workers.²⁵ These investments are further outlined in the following section.

¹⁹ <https://www.irs.gov/credits-deductions/prevailing-wage-and-apprenticeship-requirements>

²⁰ <https://www.apprenticeship.gov/inflation-reduction-act-apprenticeship-resources>

²¹ <https://www.apprenticeship.gov/data-and-statistics>

²² <https://www.apprenticeship.gov/partner-finder>

²³ U.S. Energy and Employment Report. (2023). <https://www.energy.gov/sites/default/files/2023-06/2023%20USEER%20REPORT-v2.pdf>.

²⁴ James, R., N. Pilot, A. Kumar. (2023). IRA Supply Chain and Workforce Analysis to Inform Technology Cost Assessments. Electric Power Research Institute. <https://www.epri.com/research/products/000000003002027328>.

²⁵ On trends in apprenticeship see: [What We Know About Registered Apprenticeship: A Systematic Review and Synthesis of 30 Years of Empirical Research - Amber Gallup, 2024 \(sagepub.com\)](https://www.sagepub.com/journalsPermissions.nav?path=/journals/000000003002027328)

The prevailing wage requirement works in coordination with the hiring requirements for registered apprentices. The DOL determines the prevailing wage rates, which include the basic hourly wage rate and any fringe benefits, through a survey of employers. Prevailing wages are specified geographically, typically by county, as well as type of construction and occupation. The effects of prevailing wage on project costs differs by geography and project. Studies show a limited effect of prevailing wage on total project costs.²⁶ This may be especially true in the coal generation power sector where wages are on average well-above the median.²⁷ Existing high labor standards in the electric power generation sector position utilities to benefit even with the potential costs of complying with the requirements for the 45Q increased credit.

DOE and Industry CCS Workforce Development Programs

There are several DOE supported and industry led workforce development programs underway, focused on training and educating the skilled workforce needed for CCS deployment. These programs demonstrate that the CCS industry likely has the capacity to train and expand the available workforce to meet future needs.

DOE is supporting the development of a robust carbon management workforce through a series of dedicated efforts. These include:

- **University Training and Research (UTR) programs:** In November 2023, DOE's Office of Fossil Energy and Carbon Management (FECM) released a Request for Information (RFI) to seek input on various questions regarding workforce development efforts through new curricula on carbon management informed by community knowledge and values.²⁸ Information received from this RFI is expected to be used by FECM's UTR program to develop a pipeline of underrepresented students in the carbon management workforce, broaden the network of higher-education institutions with curricula focused on carbon management, and generate learning materials on how carbon management can be enhanced by incorporating the perspectives of different cultures and communities throughout the United States. Other DOE training programs include the Research Experience in Carbon Sequestration²⁹ and the Mickey Leland Energy Fellowship Program.
- **Registered apprenticeship and apprenticeship readiness:** DOE has supported registered apprenticeships to introduce training in new technologies, and apprenticeship readiness programs to recruit and support workers from groups underrepresented in the skilled trades for apprenticeship completion. For instance, FECM, in collaboration with the DOE's Office of Technology Transitions and ENERGYWERX established the Capacity Building for Repurposing Energy Assets³⁰ initiative that will help energy communities build technical capacity and prepare their workforce to help revitalize energy systems, address environmental impacts, and tackle challenges associated with energy assets (power plants, coal mines, oil/gas well lands) that have

²⁶ <https://journals.sagepub.com/doi/abs/10.1177/0160449X18766398>

²⁷ <https://efifoundation.org/wp-content/uploads/sites/3/2021/03/WageReport.pdf>

²⁸ <https://www.energy.gov/fecm/request-information-growing-carbon-management-education-capacity-minority-serving-institutions>

²⁹ <https://recs-ccus.org/>

³⁰ <https://www.energy.gov/fecm/articles/doe-invests-800000-workforce-development-opportunities-energy-communities-across>

retired, or are slated for retirement. Among the first cohort of selected awards was a grant to the City of Beulah, Department of Economic Development to partner with North Dakota's Building Trades Unions to implement an apprenticeship readiness program.

- **Community Benefits Plan (CBP) framework:** CBPs are required for project developers applying for DOE funding opportunities, and are a key method to promote quality jobs and workforce development through DOE investments.³¹ The CBP framework is based on four priorities: engaging communities and labor; investing in America's workforce through quality jobs; advancing diversity, equity, inclusion, and accessibility; and implementing the Justice40 framework to ensure benefits flow to disadvantaged communities.³² DOE asks project developers applying to DOE programs to meaningfully engage with community and labor organizations and demonstrate how projects support quality jobs and support equitable pathways into employment for workers from groups underrepresented in the energy sector and disadvantaged communities. This framework aims to ensure that projects that receive public funding create tangible benefits for the communities and workers where the projects are located. Investments for carbon capture projects selected for DOE awards include workforce development for skilled and technical jobs through partnerships with universities, on-the-job training through registered apprenticeships, and offering paid internships that provide high quality work with competitive pay.^{33, 34}
- **Regional Economic Development Initiative (REDI):** The Office of Energy Justice and Equity launched the REDI program to focus on collaboratively developing regional benefits that boost workforce and improve environmental and human health. It will be focused on locations with multiple federally funded carbon management projects occurring simultaneously, such as along the Gulf Coast. The program will support the development of Community Benefits Plans that address the unique needs and priorities of each community, ensuring that the benefits of clean energy projects are distributed equitably and contribute to the overall well-being of the region. Of the 67 plants with no retirement dates before 2040, 17 are located in the Gulf Coast states of Texas, Louisiana, Mississippi, Alabama, and Florida.
- **Readiness Accelerator for Major Projects (RAMP):** Led by the Office of Energy Jobs, RAMP fosters broad, inclusive paths to good jobs created through DOE investments. The initiative includes a place-based Community Workforce Fellowship that aims to bolster skills and capacities of community, education, and labor partners to develop effective and inclusive workforce recruitment, retention, and advancement practices in the energy sector by advancing place-based and durable workforce partnerships.

³¹ <https://www.energy.gov/sites/default/files/2023-08/OCED%20CBP%20101%20Factsheet.pdf>

³² Many coal plants with no planned retirement before 2040 are located in Disadvantaged Communities as defined by the Climate and Economic Justice Screening Tool (<https://screeningtool.geoplatform.gov/>). It is important to develop workforce opportunities directed to host communities to support Diversity, Equity, Inclusion, and Accessibility in the carbon capture workforce and to ensure that benefits flow to Disadvantaged Communities as required by the Justice 40 Initiative.

³³ <https://www.energy.gov/oced/articles/oced-selects-three-projects-ca-nd-and-tx-reduce-harmful-carbon-pollution-create-new>

³⁴ <https://www.energy.gov/oced/articles/oced-selects-four-projects-ky-ms-tx-and-wy-advance-technologies-reduce-harmful-carbon>

- **Diversity in workforce development:** DOE has partnerships with several Historically Black Colleges and Universities (HBCUs) and other Minority Serving Institutions (MSIs) through the HBCU-MSI program. In January 2024, FECM announced an investment of over \$17 million for university-projects involving training of students in STEM and humanities disciplines.³⁵ Of the 30 U.S. colleges and universities involved in these projects, 19 are designated MSIs, including HBCUs, Tribal Colleges and Universities, Alaska Native and Native Hawaiian-Serving Institutions, Hispanic-Serving Institutions, and Asian American, Native American, and Pacific Islander-Serving Institutions. For the first time, five projects will establish “visiting scholar programs” involving multi-institution collaborations for student exchanges from MSIs.

In addition to DOE programs, new regional workforce initiatives have been launched by companies in the CCS industry, often in partnership with local schools or unions. Examples include:

- **Vernon Parish School Board Capturing Better Futures Initiative:** A partnership between CapturePoint Solutions LLC and the United Association of Plumbers and Pipefitters (UA) to offer career training and job opportunities to students from across nine Vernon Parish, Louisiana high schools. Students who successfully complete a career training and education program on pipeline construction and maintenance, steamfitting, and pipelaying will be able to join the UA’s registered apprenticeship program after graduation.³⁶
- **Greater Houston Partnership and Houston Energy Transition Initiative:** A membership group focused on growing the CCS industry and supports programs at Rice University, the Energy Institute High School, and other local education and training efforts.³⁷
- **Louisiana River Parish Sequestration:** A partnership with River Parishes Community College to provide curriculum support and guest lecture opportunities to help students better prepare for jobs in energy transition fields.³⁸

³⁵ <https://www.energy.gov/fecm/articles/doe-invests-17-million-university-led-projects-advance-decarbonization-and-net-zero>

³⁶ <https://www.capturepointllc.com/news/capturepoint-solutions-co-sponsors-capturing-better-futures-initiative>

³⁷ <https://htxenergytransition.org/>

³⁸ <https://blueskyinfrastructure.com/river-parish-sequestration/>