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Supplying the Unconventional Revolution: Workforce Readiness

Main Report

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About High Road Strategies, LLC (www.highroadstrategies.com)

High Road Strategies, LLC, Arlington, VA, is an economic policy research, analysis, assessment and design consultancy, with a focus on industrial, energy, and workforce issues. Its clients include business, labor, non-profit, academic, and government organizations.

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This report offers an independent assessment of the workforce readiness challenge confronting the unconventional energy supply chain. This research was prepared for the Energy Equipment and Infrastructure Alliance (EEIA).

EEIA represents the unconventional oil and gas supply chain: equipment manufacturers and distributors, construction contractors, service providers, material suppliers, and logistics companies. EEIA members provide equipment, materials, construction, services, logistics and workers to unconventional oil and gas exploration and production, transportation and processing.

IHS and High Road Strategies are exclusively responsible for this report and all of the analysis and content contained herein. The analysis and metrics developed during the course of this research represent the independent views of IHS and are intended to contribute to the dialogue on the role of the unconventional oil and gas supply chain in promoting employment and economic growth.

Executive summary

An IHS study, *Sizing the Unconventional Revolution*, found that unconventional energy development is projected to grow steadily through the next decade.[1] This growth will affect dozens of industries beyond the oil and gas sector, distributed across suppliers from every state. Major capital and operating expenditures by unconventional oil and gas producers flow to a lengthy supply chain that generates upstream, midstream, and downstream activity. Many suppliers in these sectors have lengthy supply chains of their own, multiplying the effect of unconventional energy development.

This rapid growth presents new workforce challenges for employers throughout the unconventional energy supply chain because of the rising demand for skilled workers needed for drilling, extraction, and other supply chain activities. Regions with high levels of unconventional energy development now or in the future seek to maintain and enhance the ability of the local workforce to support this activity to maximize economic development benefits. A shortage of qualified workers in the supply chain could limit the amount of unconventional energy development.

To assess the scale, scope, and nature of the workforce readiness challenge confronting this sector, IHS and High Road Strategies, LLC jointly undertook an extensive study of the unconventional energy supply chain's occupational structure, skill needs, and workforce education and training resources. Specifically the project team:

- Identified and examined the principal workforce challenges confronting the unconventional energy supply chain industries;
- Identified the core occupations of the supply chain industries and determined those in greatest demand nationally and in states with major plays; and
- Identified and examined public and private sector workforce training and education programs and initiatives established for the unconventional energy supply chain.

Methodology and approach

The project team applied quantitative and qualitative methods to assess the workforce challenges. The analyses were carried out for the nation as a whole and for three states with significant unconventional plays—Texas, Pennsylvania, and Louisiana; two states at the early stages of unconventional development—Ohio, and Colorado; and one nonproducing state with significant supply chain activity—Illinois. The analyses drew upon IHS's proprietary economic models and federal employment and occupational statistics (primarily, the Department of Labor's Bureau of Labor Statistics [BLS]), to identify and assess the unconventional energy supply chain's core and high-demand occupations, including employment trends and projections.

The qualitative analysis included interviews of key stakeholders and experts, a survey, and a review of relevant literature and online resources. It was used to help evaluate the statistical employment and occupational data, identify the main workforce challenges, and examine workforce readiness initiatives in response to the challenges.

Specifically, the study involved the following steps:

1. *Identification of core occupations in the unconventional supply chain*, which are those that i) perform essential activities within the economic sectors of the supply chain; ii) can directly affect a sector's level of output if positions remain unfilled; and iii) have specialized education, training, competencies, or skills and experience requirements. The project team identified an initial list of 73 core occupations by applying multiple criteria to the employment by occupation for the North American Industry Classification System

1 IHS Economics. *Supplying the Unconventional Revolution: sizing the unconventional oil and gas supply chain*. September 2014.

(NAICS) industries that comprise the five unconventional energy core supply chain sectors—construction and well services, capital goods, materials, professional and other services, and logistics.

2. *Interviews and survey of stakeholders*, which the project team drew upon to help identify the workforce challenges, validate and refine the list of core occupations and high-demand occupations (HDOs), and identify and evaluate the effectiveness of workforce development programs to meet perceived skill challenges. About 50 individuals representing over 40 organizations in the unconventional energy sector and/or its supply chain provided input, including business and trade associations; supply chain firms (e.g., construction contractors, equipment manufacturers and dealers, material suppliers, transportation), labor unions, workforce education and training providers, and government agencies.

3. *Literature review*, including numerous reports, documents, and articles, especially state assessments of occupational needs and employment growth for unconventional oil and gas development in Pennsylvania, Ohio, Texas, and Colorado by academic research institutes, state agencies, and some oil and gas industry associations.

4. *Identification of HDOs* based on the findings from multiple sources, including statistical analyses, interview, and survey findings, and the relevant literature. The project team identified and evaluated 24 of the core occupations as being in high demand across the supply chain. This list applies nationally and is reasonably consistent across all the major producing states reviewed in the study.

5. *Employment forecasts for core occupations and HDOs* for each supply chain sector. The project team forecast detailed occupational employment by supply chain NAICs sector, drawing on IHS's estimates of total employment for each supply chain NAICS sector in the United States between 2012 and 2025, and applying data from its Business Market Insights (BMI) database.

6. *Replacement needs for core occupations and HDOS*, which supplement the projections of occupational employment growth for the economic growth of the NAICS supply chain industrial sectors. Replacement needs for an occupation refer to job openings resulting from turnover or retirement or other factors, and are calculated by the Bureau of Labor Standards (BLS) for each year in its long-term occupational forecasts.

Workforce challenges

The project team identified eight workforce challenges facing the unconventional oil and gas supply chain, which reflect the difficulties many employers have faced in filling a number of high demand occupations, some within specific sectors and many across the supply chain. While this list is consistent across the six states examined and across the nation, the magnitudes of the challenges vary by state, largely in proportion to their stage of development in the unconventional energy sector. The challenges also vary across industry sectors and occupations.

- ***Shortage of qualified local workers.*** The primary challenge supply chain employers have faced, especially in the early stages of exploration and drilling activity, has been finding enough qualified local workers. Although the training and recruiting of workers from local labor markets has improved, many challenges remain.

- ***Technological change.*** Technological advances in the unconventional energy sector have helped to drive up the demand for higher-skill occupations in the unconventional energy workforce and also have increased the skill requirements in the supply chain.

- ***"Soft skills"*** and behavioral barriers. Aside from technical skills, workers must demonstrate that they have "soft skills" and ability to meet behavioral standards. Soft skills include reporting to work on time, knowing how to dress for the workplace, and the interpersonal skills to interact with people and to work on a team. A major challenge is finding workers able to pass drug-screening tests.

- ***Operator qualifications.*** Confronting oil and gas pipeline contractors is the need for standardizing operator qualifications across the industry, which specify behavioral criteria for workers in the logistics and transportation components of the supply chain, as required by US Department of Transportation regulations.
- ***Working conditions and burnout.*** Many unconventional energy jobs, especially in upstream occupations and in pipeline, road and other construction work, are physically demanding, requiring long hours and sustained periods of work under harsh weather and environmental conditions away from workers' homes. These stressful working conditions can lead to burnout and high rates of turnover.
- ***Attracting youth to skilled trades.*** Aside from difficult working conditions, young people are not attracted to careers in laborer and skilled trade positions, in particular because of a common "cultural bias" against these types of jobs in industries such as manufacturing and construction. They prefer a career path requiring a four-year college degree over one needing career and technical education.
- ***An aging workforce.*** The challenge of maintaining a sufficient workforce in unconventional energy supply chain industries is being made more acute by the looming retirement of aging Baby Boomers working in these fields, or the Great Crew Change, as it is known within the oil and gas industry.
- ***Competition for skilled workers.*** The rapid growth of demand for oil and gas supply chain jobs and the recovery in the US construction and manufacturing sectors have fostered a fierce competition for workers with comparable skills, leading to increased pressure to "poach" workers from other firms within and outside the particular industry.

Core occupations

Although almost 600 different detailed occupations are used by the sectors of the unconventional energy supply chain, the project team narrowed the scope of the study to 73 *core* occupations. These include a wide variety of occupations characterized by different levels of required skills, education, and training. Wage and salary levels range from highly educated petroleum and mechanical engineers, to skilled trades workers such as welders, operating engineers and diesel technicians, to construction laborers, service unit operators and roustabouts.

Some of the core occupations are required in multiple sectors across the supply chain including, for example, *construction laborers*, *operating engineers*, *industrial machinery mechanics*, *mobile heavy equipment mechanics*, *welders*, and *heavy truck drivers*. Other core occupations tend to be concentrated in only a few sectors, such as *rotary drill operators*, *petroleum engineers* and *wellhead pumpers*. At the same time, each of the seven core supply chain sectors tend to employ workers from a relatively small number of core occupations specifically relevant to their supply chain activities. For example:

- Extraction (service unit operators, derrick operators, and roustabouts) and some construction occupations (construction laborers, first-line supervisors) account for the largest shares of the workers employed in well services.

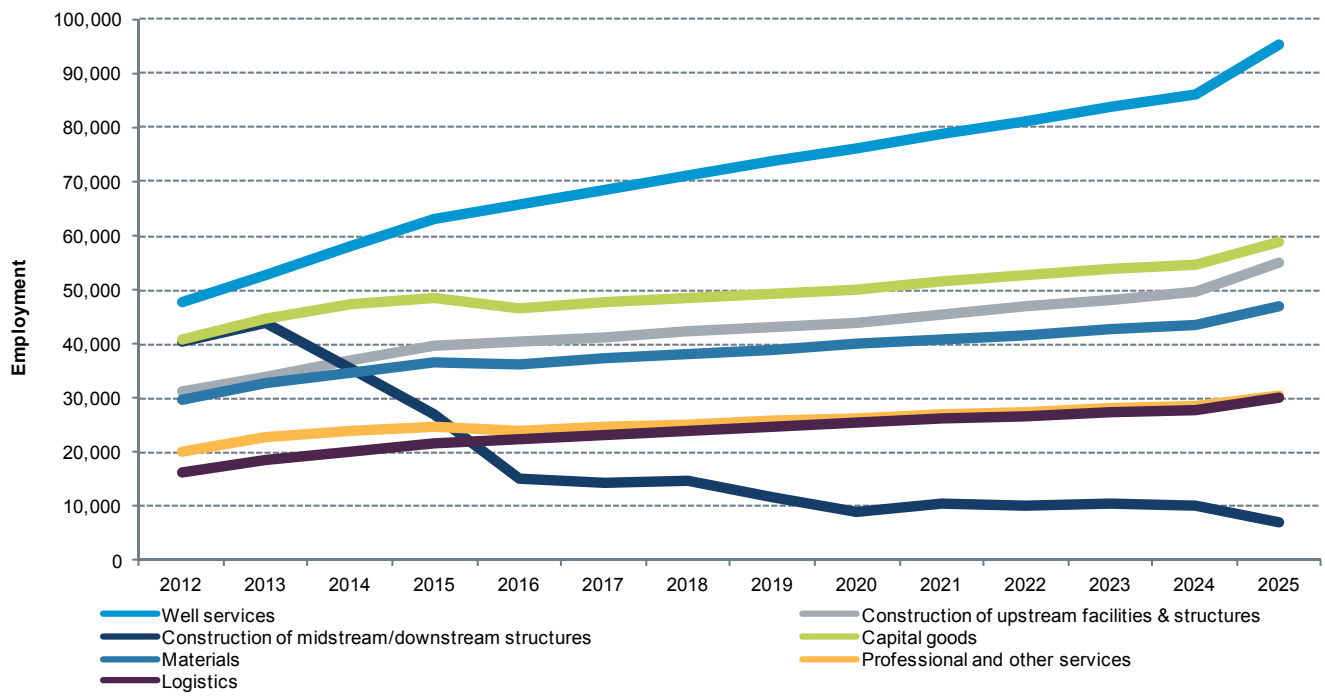
- Construction-related occupations dominate the two main construction subsectors.
- Engineers, scientists and related technicians tend to be concentrated in professional services, though some occupations, especially mechanical engineers, are also important in the capital goods and materials production sectors.
- Production and related occupations (e.g., machinists, welders, industrial machinery mechanics) predominate in capital goods sectors and play an important role, along with some construction occupations such as operating engineers, in the materials sector.
- Heavy truck drivers account for over 90% of logistics sector jobs, though bus and truck mechanics and diesel engine specialists are also important in this sector.

Core occupation projections, 2012–25

The project team forecast employment for each core occupation that would directly support unconventional energy activity across all the supply chain sectors from 2012 to 2025. It found that total employment for all core occupations would grow by over 40% in the forecast period, from 226,300 jobs to over 324,300 jobs. The patterns of core occupational employment reflect IHS's economic forecasts of economic activity in the unconventional supply chain sectors (see accompanying chart):

- Core occupation employment in the well services sector is expected to double by 2025, and in the construction subsector, representing construction of upstream facilities and structures, is projected to grow by almost 75% as the number of wells in operation continue to rise.
- Employment in several occupations in the construction sector, which includes building pipelines, manufacturing facilities and other structures is forecast to rise for a short time and then decline in later years because most of the supporting infrastructure will already have been built.

Trends in core occupation employment by core sector



Source: Bureau of Labor Statistics and IHS

- Core occupation employment is expected to grow at annual rates of 2.9–4.8% in the other core sectors, including capital goods, materials, logistics, and professional services.

Similarly, the employment trends for core occupations grouped by major occupational classification follow projected economic growth for the core sectors:

- Extraction jobs, primarily in well services, are expected to grow at the fastest rate—a 5.3% annual average increase.
- Transportation and materials moving, production, and installation, maintenance and repair jobs are forecast to grow at 4.2% and 3.5% annual rates, respectively.
- Core engineering, scientific; and technician employment in the supply sector, are expected to grow at 3% and 4%, respectively, albeit starting from a smaller base.
- Construction trades employment, in contrast, is expected to rise and then fall, showing only modest growth through 2025, reflecting the economic growth trends in the upstream and downstream construction sectors in the supply chain.
- Management occupations, two of three of which are in construction, correspondingly are expected to have a small net decline.

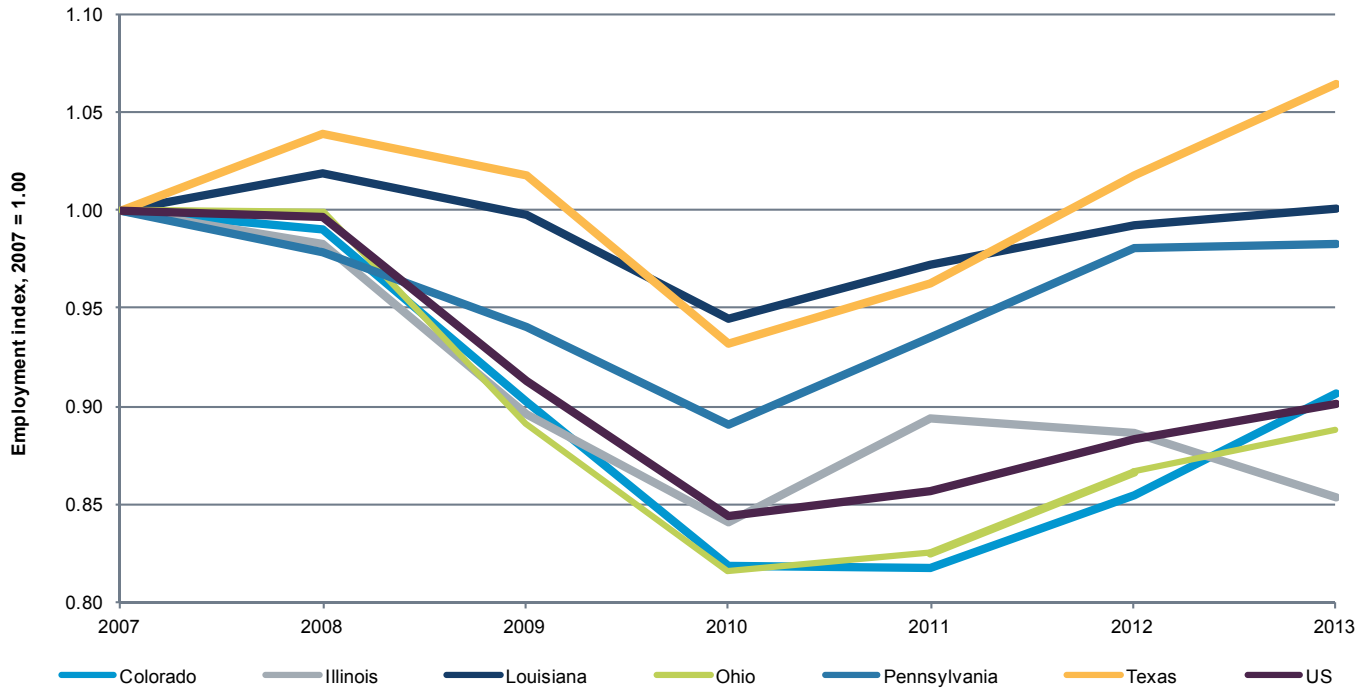
State trends, 2007–13

Analyzing state-level employment trends for core occupations from 2007 to 2013 shows that employment levels of core occupations and their corresponding shares of total employment vary across the states. The differences are due to both their economic structures and the state of development of their unconventional energy activities. It is important to caution that these trends are for *all* workers employed in the core supply chain sectors, not just workers directly supporting unconventional energy activity. Because of data limitations, it is not possible to separate out the latter from workers in the same occupations and sectors that support nonenergy-related activities.

- Texas, Louisiana, and Colorado have relatively high employment shares in core construction and extraction occupations—about 24–33%—reflecting in part their more extensive conventional and unconventional energy production.
- While employment in construction and extraction are also high in Ohio and Pennsylvania, production jobs in core occupations account for the largest share—about one-third—of total supply chain core employment in these states and in nonproducing Illinois, reflecting their high concentrations of manufacturing.

As seen in the following chart, nationally and in all the states the impact of the Great Recession on employment from 2007 to 2010 is clearly evident in the sharp dips in employment in the core occupations. The growth of unconventional production from 2010-2013 in states with large plays has added jobs more quickly in core occupations in supply chain sectors, which contribute to job growth in these sectors overall and to state economies.

Core occupation employment index by state



Source: Bureau of Labor Statistics and IHS

- Texas and Louisiana—two large conventional oil and gas producing states—and Pennsylvania—the nation's largest unconventional producer—lead in total core occupational employment growth, reflecting earlier and greater growth in unconventional energy activities in large plays.
- Core occupation employment in Ohio's manufacturing and construction sectors, hit very hard by the recession, fell steeply after 2007 through 2010 but started a gradual rise afterward, in part driven by growing demand for goods and services for the growing Marcellus and Utica shale plays.
- Colorado has had a similar rebound, although only over the past two years, but could rebound faster and surpass 2007 employment levels over the next few years if it is able to fully develop its unconventional energy resources.
- Only Illinois, also a large manufacturing state, shows a downturn in its core occupation employment, suggesting that the aftereffects of the recession still linger.

High-demand occupations

The project team identified 24 high-demand occupations (HDOs) from the list of core occupations consistently identified as posing the greatest skill shortage challenge for unconventional energy supply chain employers (see accompanying table). HDOs span all the upstream, midstream, and downstream industries comprising the unconventional energy supply chain. Some occupations such as *heavy and tractor-trailer truck drivers*, and *welders* are in high demand throughout the supply chain. Other occupations, such as *construction laborers*, *operating engineers*, *petroleum engineers*, *electrical and electronic engineering technicians*, and *oil and gas service* jobs, are very important only for certain targeted unconventional activities.

HDOs account for nearly three-quarters of total jobs in core occupations engaged in actual unconventional energy supply chain activity, though this share varies for the different core sectors. The share ranges from over

80% of core occupation jobs in well services and construction sectors, to about 60% in the capital goods and materials sectors, to only 47% in the professional services sector, and to almost all core occupation jobs in the logistics sector (mostly heavy and tractor-trailer truck drivers).

The project team also developed profiles for 26 occupations (available in the report's appendix), including most of the HDOs. For each occupation, the profiles describe major activities performed, current employment levels and wages, education and training and certification requirements, and projected employment growth between 2012 and 2025.

HDO employment trends, 2007–13

A comparison of employment trends from 2007 to 2013 shows that HDO employment dips less in the recession years and grows somewhat faster than the total of all core occupations and markedly faster than the nonhigh-demand occupations among core occupations. (Note that these numbers reflect jobs in associated core supply chain sectors, even if they are not in actual unconventional activities.) Although several economic factors contribute to these trends, especially the post-recession rebound of manufacturing and construction, unconventional energy activity undoubtedly contributes, especially in major producing states.

High-demand occupations in the unconventional energy supply chain: 2012

Occupational code	Occupational category	% in supply chain sectors
11–9021	Construction Managers	69.5%
17–2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors	51.6%
17–2171	Mechanical Engineers	53.1%
17–2171	Petroleum Engineers	28.3%
17–3023	Electrical and Electronics Engineering Technicians	42.3%
47–1011	First-Line Supervisors of Construction Trades and Extraction Workers	65.1%
47–2061	Construction Laborers	67.4%
47–2073	Operating Engineers and Other Construction Equipment Operators	69.4%
47–2152	Plumbers, Pipefitters, and Steamfitters	82.5%
47–5011	Derrick Operators, Oil and Gas	88.3%
47–5012	Rotary Drill Operators, Oil and Gas	80.8%
47–5013	Service Unit Operators, Oil, Gas, and Mining	88.0%
47–5071	Roustabouts, Oil and Gas	85.0%
49–3031	Bus and Truck Mechanics and Diesel Engine Specialists	37.1%
49–3042	Mobile Heavy Equipment Mechanics, Except Engines	66.5%
49–9041	Industrial Machinery Mechanics	39.5%
51–4012	Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic	35.8%
51–4041	Machinists	33.3%
51–4121	Welders, Cutters, Solderers, and Brazers	49.1%
51–4122	Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	38.0%
53–3032	Heavy and Tractor-Trailer Truck Drivers	68.8%
53–7032	Excavating and Loading Machine and Dragline Operators	70.5%
53–7071	Gas Compressor and Gas Pumping Station Operators	56.6%
53–7073	Wellhead Pumpers	37.8%
	Total for all high-demand occupations	**61.2%**

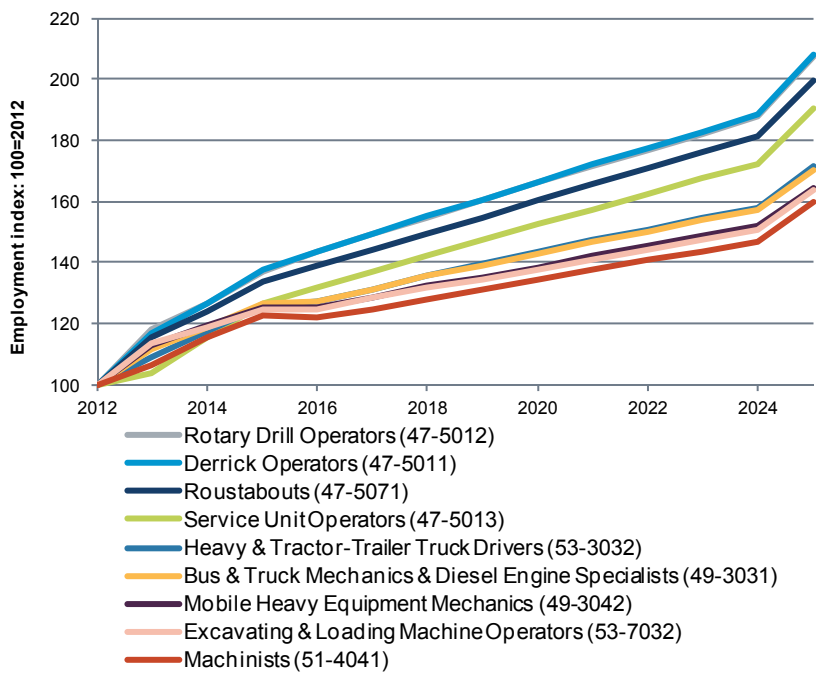
Source: Bureau of Labor Statistics and IHS

Similarly, the HDO employment trends parallel the core occupation employment trends in the six selected states. Texas, Pennsylvania, and Louisiana, with relatively higher levels of unconventional energy development, lead the selected states—and the nation as a whole—in the growth and recovery trends for the high-demand occupations, as they did for core occupations. HDO employment in these three states has grown much faster than for most other occupations, in response to the unconventional energy boom. Ohio and Colorado, reflecting their less-developed unconventional energy sectors, have grown more slowly. Illinois again is an outlier, as its HDO employment level has not fully recovered from the recession.

HDO employment projections, 2012-25

HDO employment projections for 2012–25 parallel the trends for core occupation employment. Total HDO employment is projected to grow by 41.8% from over 167,100 to 237,000 in the forecast period—an addition of nearly 70,000. High-demand occupations predominate, representing at least seven to nine of the top 15 occupations in each unconventional energy supply chain sector. The greatest concentration is in well services, where HDOs account for 12 of the top 15 core occupations.

High growth high-demand occupations employment index



Source: Bureau of Labor Statistics and IHS

The employment projections for individual HDOs over the forecast period reflect the relative demand for occupations due to economic growth in supply chain sectors (see accompanying chart for high-growth HDO projections):

- High growth occupations include well service occupations, machinists in capital goods and materials, heavy-truck drivers, bus and truck mechanics, and mobile heavy equipment mechanics in the logistics and materials sectors.
- Industrial machinery mechanics, mechanical engineers and electric and electronics engineering technicians—prominent in the capital goods, materials and professional services sectors—are expected to show modest but steady growth.
- Employment of construction managers and construction laborers first rises and then falls as midstream and downstream construction is completed, though the employment trend for construction laborers rises after 2020, reflecting a resurgence in demand.
- Employment of operating engineers follows a similar trajectory, but shows a steady growth after 2016, reflecting that HDO's importance in several core sectors.
- Welders present an interesting case, given their important role in construction,as well as in capital goods and materials production: employment dips after 2014, flattens through 2020, before slowly rising through 2025.

Replacement needs

Replacement needs for core occupations is a measure of turnover in the labor force, as workers change employers or occupations, go back to school, retire, or leave the workforce for other reasons. The employment changes in occupations due to economic growth of corresponding supply chain sectors do not reflect the actual numbers of workers that may need to be hired at a given time, because of the turnover in the workforce. Examination of these factors suggests that some high-demand occupations today, especially in the construction sector, may not actually be in high demand by 2025, while others may become in even more high demand because of replacement needs.

Overall, if replacement needs are factored in, supply chain employers could need to fill a total of at least 118,300 new jobs—jobs from economic growth and replacement needs—in HDOs by 2025. Estimated replacement needs for individual HDOs show substantial growth in demand for heavy and tractor-trailer truck drivers, roustabouts, service unit operators, machinists, operating engineers, industrial machinery mechanics, mechanical engineers and welders. The demand growth stems from job openings from economic growth and replacement needs in the forecast period, ranging from a 49% increase for welders to a 143% increase for service unit operators compared with 2012.

- Heavy and tractor-trailer truck drivers will have the largest increase in demand—19,800 jobs due to economic growth and 5,800 openings due to replacement needs.
- Most other HDOs also will have substantial replacement needs in addition to projected job increases due to economic growth.
- Both construction laborer and construction manager jobs are projected to decline by 2025. However, because of replacement needs construction laborer jobs still would have a net increase in demand, but construction manager jobs would still fall because replacement needs would not be sufficient to offset economic-related losses, resulting in a net decline in employment.

Workforce readiness opportunities

The projected growth of employment in HDOs, due both to economic growth and replacement needs, raises questions about the capacity of the nation's workforce education and training system to meet employers' needs over the next decade. The major unconventional oil and gas producing states will have the greatest challenges to provide the workforce programs needed to support local pools of trained workers in HDOs for oil and gas firms and their supply chain.

A large variety of workforce initiatives have been started, expanded, and strengthened with the goal of increasing the supply of skilled workers to meet current and expected growth in demand for HDOs. These efforts take many different forms involving various combinations of private and public sector participation and operating at the local, state, multistate, and national levels:

- Community college, technical college and university programs as well as union apprenticeships frequently operate in partnership with energy-related companies and business trade associations.
- Most companies do some form of on-the-job training but count on third-party providers (e.g., apprenticeships, community colleges) to provide basic technical knowledge and skills to qualify candidates prior to hiring.
- Consortia of workforce stakeholders—businesses, universities, community colleges, and other education and training providers, both on the national and state level—have come together to monitor and promote policies and programs to address the workforce challenges.

It is beyond the scope of the current study to evaluate the capabilities of these programs to meet the projected demands for workers across the spectrum of HDOs. While there is a general consensus about the serious workforce challenges confronting unconventional supply chain employers, the industry so far appears to be keeping up with the demand. However, it remains unclear whether market forces are sufficient to meet the growing workforce readiness needs of the unconventional energy supply chain over the next decade as it rapidly expands. It is possible support from state and federal policies will be required to optimize the economic growth of the unconventional energy sector, which relies on the availability of a high-skilled, well-trained workforce throughout its value chain.

The workforce readiness challenge

The unprecedented growth of unconventional energy development is opening up substantial economic development opportunities in the United States, especially in the regions where there are large shale, tight sands, and tight oil plays. While this energy boom has helped to reverse some of the economic losses resulting from the Great Recession, it has also presented new workforce challenges for employers in the energy sector and the supporting supply chain.

The growing shortage of qualified workers to meet the demand of the rapidly expanding unconventional energy sector has been widely reported. The International Gas Union (IGU) identified people as a "key element for the energy industry to continue its unprecedented growth" and cited surveys identifying "a shortage of talent as one of industry's biggest challenges in the coming years."[2] A major concern is that the current workforce in many of the regions experiencing the unconventional energy boom might not be enough to maximize the burgeoning opportunities in the new energy value chain. For example, a report of the Eagle Ford Shale Task Force in Texas asks, "How do we maintain the manpower needed to supply the growing shale play, and how do we ready the local workforce to take advantage of the near limitless job opportunities presented by the play."[3]

An FMI International study of the energy construction industry indicates that, both domestically and worldwide, the labor demands resulting from unconventional energy production have been adding to strains in the supply of skilled labor in the conventional oil and gas industry, as well as critical supporting sectors such as oil and gas infrastructure construction.[4] The lack of appropriately trained workers in the oil and gas sector could slow development of downstream industrial projects. For example, labor shortages in the Gulf Coast region from the unprecedented rise over the past three years in unconventional oil and gas production are perceived as causing delays in constructing refineries and processing facilities in Texas and Louisiana.[5]

Similarly, in extensive surveys of construction firms in 2013 and 2014, the Associated General Contractors of America (AGC) identified large and growing construction worker shortages in the United States. In 2014, for example, 83% of the over 1,000 US construction firms surveyed reported difficulties in finding enough qualified craft workers, while 61% reported difficulties finding qualified construction professionals. Many of the firms surveyed by the AGC operate within the core construction sectors in the unconventional energy supply chain. The AGC notes that one of the biggest challenges facing these firms is the lack of qualified professional and craft workers as the construction industry continues to recover from a severe downturn that began more than seven years ago.[6]

Many US manufacturers also have long complained about problems finding enough workers with skills they need. For example, the National Association of Manufacturers cited a 2011 survey that found 74% of firms reported deficiencies in the skills of candidates for jobs. On the other hand, a 2012–13 survey of nearly 900 manufacturers by a Massachusetts Institute of Technology research team had more modest results. It found that although most employers did not have extended vacancies, nearly one-quarter of the manufacturers surveyed reported long-term vacancies for which they had difficulties finding workers with the necessary skills.[7] As in the construction sector, as manufacturing recovers from the Great Recession and experiences somewhat of a resurgence from the "re-reshoring" of overseas production, manufacturers, including those in

2 Richard Nemec. "Innovations in Workforce Training, Education." *Pipeline & Gas Journal*. 2014. HighBeam Research. (November 29, 2014). http://www.highbeam.com/doc/1G1-356907037.html.

3 Railroad Commission of Texas (RRC). *Eagle Ford Shale Task Force Report*. Convened and chaired by Railroad Commissioner David Porter. March 2013:12.

4 FMI Corporation. *Skill Shortages in a Booming Market: The Big Oil and gas Challenge*. 2013 (www.fminet.com).

5 Isaac Arnsdorf, Dan Murtagh and Jack Kaskey. "Labor Shortage Threatens to Bust the Shale Boom." Bloomberg.com (April 17, 2014).

6 Associated General Contractors of America (AGC). "Worker Shortage Survey Analysis." Summary. See also AGC, "2013 Worker Shortage Survey Results. National Results." 2014. See http://news.agc.org/2013/09/04/seventy-four-percent-of-construction-firms-report-having-trouble-finding-qualified-workers/.

7 See Suzanne Berger and the MIT Task Force on Production and Innovation. *Making In America, From Innovation to Market*. Cambridge, Massachusetts: The MIT Press, 2013:179-197 (Ch.7).

the unconventional and conventional energy supply chains, are facing increased competition for certain types of skilled production workers.

Along with manufacturing and construction, the challenge of skill shortages exists throughout the unconventional energy supply chain sectors IHS identified in its economic analysis. Supply chain sectors employ workers from a wide range of occupations, from very highly educated petroleum engineers and mechanical engineers, to skilled trade workers such as welders, operating engineers, and diesel technicians, to construction laborers and well-pumpers.

A number of factors underlie the workforce skill challenge in the unconventional energy supply chain. These have been affecting efforts, especially in states with large unconventional plays, to meet the demand for workers with needed skills. Aside from growing competition across and within core sectors, as in construction and manufacturing, some of the most important factors are technological advances that have created new skill requirements; the rapid rise of energy extraction activities that puts pressures on local labor markets; lack of local applicants with appropriate skills and qualifications, including so-called "soft skills"; the rural location and difficult working conditions of unconventional energy activities; the aging and rapidly retiring Baby Boom workforce; and inadequate career education and technical training facilities for HDOs that do not require four-year degrees

Federal and state agencies, companies, industry trade associations, labor unions, workforce education and training providers (including one-, two-, and four-year postsecondary institutions), and community and economic development organizations have been involved in expanding or creating workforce readiness initiatives to address these challenges. These efforts take a variety of different forms, reflecting the needs of different industry sectors and their occupations, and the size of local labor markets. Some efforts are national or multistate, but a large number have been instituted within individual states with large unconventional plays. Whether these initiatives will be adequate to meet the workforce readiness challenge, however, remains uncertain, especially as the unconventional energy sector expands as projected over the next decade.

Assessing the workforce challenge

To assess the scale, scope and nature of the workforce readiness challenge, IHS and High Road Strategies, LLC jointly undertook an extensive study of the unconventional energy supply chain's occupational structure, skill needs, and workforce education and training pipeline. The analysis incudes evaluation of the "upstream" well services, "midstream" construction, professional services, and transport services, and "downstream" suppliers of equipment and materials employed in all phases of unconventional oil and gas production. Relevant activities include predrilling, well-pad preparation, drilling and extraction, transport, and processing of unconventional energy fuels. The study was conducted both at the national level and for a selected group of states with major unconventional energy plays.

Specifically, to accomplish these objectives, the IHS-High Road Strategies project team:

- Identified and examined the principal workforce challenges confronting the unconventional supply chain industries;
- Identified the core occupations of the unconventional supply chain industries, and of these, determined which are in greatest demand, both nationally and in selected states with major plays; and
- Identified and examined the public and private sector workforce training and education programs and initiatives established to address the workforce needs of the unconventional energy supply chain.

The study's approach and the results of this analysis are summarized below, and in the sections that follow.

Methodology and approach

This report used the same definition of the unconventional energy supply chain that IHS identified in our prior economic analysis of the supply chain, consisting of 67 individual economic sectors at the 4-digit and 6-digit NAICs levels For the purposes of the workforce assessment, the 67 individual sectors were divided into seven core groups—capital goods, construction of new nonresidential mfg. structures, construction of other new nonresidential structures, logistics, materials, professional and other services, and well services[8] as shown in the accompanying table. In some of the tables in this report, the well services and the two construction core sectors are combined into a single, larger core sector for ease of presentation.

8 IHS Economics. *Supplying the Unconventional Revolution: Sizing the unconventional oil and gas supply chain*. September 2014.

Unconventional energy supply chain sectors by core group and NAICS Code

Capital goods
3331 Agriculture, Construction, and Mining Machinery Mfg.
332410 Power Boiler and Heat Exchanger Mfg.
332420 Metal Tank (Heavy Gauge) Mfg.
333112 Lawn & Garden Tractor & Home Lawn & Garden Eqpmnt Mfg.
333515 Cutting Tool and Machine Tool Accessory Mfg.
333611 Turbine and Turbine Generator Set Units Mfg.
333612 Speed Changer, Industrial High-Speed Drive, and Gear Mfg.
333613 Mechanical Power Transmission Equipment Mfg.
333618 Other Engine Equipment Mfg.
333911 Pump and Pumping Equipment Mfg.
333912 Air and Gas Compressor Mfg.
333922 Conveyor and Conveying Equipment Mfg.
333991 Power-Driven Handtool Mfg.
334419 Other Electronic Component Mfg.
334512 Automatic Environmental Control Mfg. for Residential, Commercial, and Appliance Use
334513 Instruments and Related Products Mfg. for Measuring, Displaying, and Controlling Industrial Process Variables
334514 Totalizing Fluid Meter and Counting Device Mfg.
334516 Analytical Laboratory Instrument Mfg.
334519 Other Measuring and Controlling Device Mfg.
336112 Light Truck and Utility Vehicle Mfg.
336120 Heavy Duty Truck Mfg.
336510 Railroad Rolling Stock Mfg.
4231 Motor Vehicle and Motor Vehicle Parts
4238 Machinery, Equipment, and Supplies Merchant Wholesalers
Construction of new nonresidential mfg. structures *
2362 Nonresidential Building Construction
2371 Utility System Construction
Construction of other new nonresidential structures **
2373 Highway, Street, and Bridge Construction
2379 Other Heavy and Civil Engineering Construction
2381 Foundation, Structure, and Building Exterior Contractors
2382 Building Equipment Contractors
2389 Other Specialty Trade Contractors

Logistics
4821 Rail Transportation
4831 Deep Sea, Coastal, and Great Lakes Water Transportation
4832 Inland Water Transportation
4841 General Freight Trucking
4842 Specialized Freight Trucking
4861 Pipeline Transportation of Crude Oil
4862 Pipeline Transportation of Natural Gas
4869 Other Pipeline Transportation
Materials
4441 Building Material and Supplies Dealers
4442 Lawn and Garden Equipment and Supplies Stores
3312 Steel Product Mfg. from Purchased Steel
4233 Wholesale Lumber and Construction Materials
4235 Metal and Mineral (except Petroleum) Merchant Wholesalers
4236 Wholesale Electric Goods
4237 Wholesale Hardware, Plumbing and Heating Equipment
4246 Chemical and Allied Products Merchant Wholesalers
212321 Construction Sand and Gravel Mining
325120 Industrial Gas Mfg.
325180 Other Basic Inorganic Chemical Mfg.
327310 Cement Mfg.
327320 Ready-Mix Concrete Mfg.
327331 Concrete Block and Brick Mfg.
331110 Iron and Steel Mills and Ferroalloy Mfg.
331315 Aluminum Sheet, Plate, and Foil Mfg.
332996 Fabricated Pipe and Pipefitting Mfg.
Professional and other services
2213 Water, Sewage and Other Systems
4931 Warehousing and Storage
5241 Insurance Carriers
532412 Construction, Mining and Forestry Machinery and Equipment Rental and Leasing
5413 Architectural, Engineering, and Related Services
5416 Management, Scientific, and Technical Consulting Services
5419 Other Professional, Scientific, and Technical Services
562219 Other Nonhazardous Waste Treatment and Disposal
811310 Commercial and Industrial Machinery and Equipment (except Automotive and Electronic) Repair and Maintenance
Well services
213111 Drilling Oil and Gas Wells
213112 Support Activities for Oil and Gas Operations

* Referred to in the text as Construction of midstream/downstream structures

** Referred to in the text as Construction of upstream facilities and structures

Source: IHS

The project team applied a combination of quantitative and qualitative methods to assess the workforce challenges of the unconventional oil and gas supply chain. The analyses were performed for the US and for four selected states with significant unconventional energy plays – Colorado, Ohio, Pennsylvania, and Texas. The quantitative analyses drew upon IHS's proprietary economic models and federal employment and occupational statistics (primarily from the Department of Labor's Bureau of Labor Statistics [BLS]), especially to identify and assess the unconventional energy supply chain industries' core and high-demand occupations, including employment trends and projections. The qualitative analysis included interviews of key stakeholders and experts, a survey, and a review of relevant literature and online resources. The methodology is summarized below and presented in greater detail in Appendix A.

1. Identification of core occupations. The first task was to identify a set of core occupations in the unconventional supply chain, defined as those that:

- Perform essential activities in the economic sectors that comprise the supply chain;
- Directly affect a sector's level of output, which could be reduced if some of the required jobs in an occupation are vacant; and,
- Have specialized education, training, competencies, or skills, and/or experience requirements.

Based on the occupations used in each of the supply chain NAICs codes, IHS identified an initial list of 71 detailed occupations (out of 840 US Bureau of Labor Statistics occupational categories) as core occupations.

2. Interviews and survey of stakeholders. To validate and refine the initial list of core occupations, IHS solicited feedback from stakeholder organizations through a series of interviews and a short survey. This data was also used to:

- Identify the most in-demand or high-priority occupations, both nationally and especially in the four selected states identified above.
- Identify the main workforce challenges confronting the supply chain sector; and
- Examine the workforce training and development efforts and capacity, especially in the four selected states, to address growing workforce needs of the unconventional supply chain sectors.

Nearly 50 individuals representing over 40 stakeholder groups in the unconventional energy sector and/or its supply chain provided direct input for this analysis. Over 35 individuals from these groups were interviewed, which was the principal source of stakeholders' inputs in the study's analyses. This was supplemented by a survey completed by 33 individuals, several of who also had been interviewed, and many who had not. Based on the surveys and interviews, two additional core occupations were identified, bringing the total to 73 occupations.

3. Review of literature and online resources. The IHS team conducted an extensive review of reports, documents and articles. Of particular value were assessments of occupational needs and employment growth associated with unconventional oil and gas development in Pennsylvania,[9] Ohio,[10] Texas[11] and Colorado,[12] performed either by academic research institutes or state agencies, and some sponsored by oil and gas industry associations.

4. Identification of HDOs. A major objective of the study was identifying the core occupations that are in especially high demand. This was achieved by comparing the findings from multiple sources, including: 1) the statistical analyses; 2) interview and survey findings; and 3) the relevant literature, particularly studies evaluating workforce needs in Pennsylvania, Texas, and Ohio. The IHS team identified 24 occupations that qualify as HDOs. This list applies nationally, and is reasonably consistent across all the major producing states reviewed in the study, although which occupations are in highest demand may vary somewhat by state—reflecting differences, for example, in the stage of development of unconventional energy resources among the states with plays.

5. Occupational employment projections and replacement needs. In its economic study of the unconventional energy supply chain, IHS estimated the total employment for each supply chain NAICS sector in the United States between 2012 and 2025. The sector forecasts were specifically developed for this study and takes into account IHS's best assessment of future demands for inputs from the supply chain due to forecast levels of activity in the unconventional energy sector. IHS then forecast detailed occupational employment for each supply chain sector using data from its Business Markets Insights (BMI) database. We estimated occupational employment growth needed to meet *replacement needs,* defined as job openings due to turnover or retirement or other factors, using the annual replacement rates contained in BLS's long-term occupational forecasts. Gross employment demand for an occupation over time is the sum of the net change due to economic growth plus replacement needs; workforce agencies need to consider both in meeting future labor demand.

Major workforce challenges

There is a broad consensus that unconventional supply chain businesses are currently having difficulty finding qualified workers, especially in the producing states. These challenges are not unique to the unconventional oil and gas value chain, as similar concerns have been echoed by the conventional oil and gas industry and in other industrial sectors such as manufacturing, construction and transportation.

Although the nature of workforce challenges in the unconventional supply chain is similar across the United States, the magnitude of the challenge varies by state, often proportional to the stage of play development within a producing state. For example, in Pennsylvania, where unconventional development is relatively advanced, the state has designed training programs to address the workforce needs of the new companies that began operations in the state to take advantage of the Marcellus Shale resource. Ohio, meanwhile, is at an earlier stage of development of its Utica play and is in the early stages of increasing the capacity of its workforce to meet the expected rise in demand for skilled labor.

This report highlights the nature of the workforce and key issues confronting participants in the unconventional supply chain. The evidence collected for this analysis reflects the national literature and direct

9 See for example, Marcellus Shale Education and Training Center (MSETC; now ShaleTEC). *Pennsylvania Marcellus Shale Workforce Needs Assessment.* MSETC Needs Assessment Series. Summer 2011 (www.msetc.org); Center for Workforce Information & Analysis (CWIA), Pennsylvania Department of Labor and Industry. *Marcellus Shale Fast Fact, July 2012 Edition.* August 7, 2013 (www.paworkstats.state.pa.us); CWIA. *Job Skills Most Needed Across All Occupations by Occupational Group*, December 2013; Pennsylvania Independent Oil & Gas Association (PIOGA). "Careers in Oil and Natural Gas," n.d. (www.pioga.org); Jim Kaufman and Laura Fisher. *Workforce Analysis Report: Energy Sector Jobs in Greater Pittsburgh.* Pittsburgh, Pennsylvania: Allegheny Conference on Community Development and Energy Alliance of Greater Pittsburgh. August 20, 2012 (www.AlleghenyConference.org).

10 Ohio Department of Job and Family Services (JFS). *Ohio Shale, Quarterly Economic Trends for Ohio Oil and Gas Industries,* April 2013 and earlier years. Ohio Oil & Gas Energy Education Program (OOGEEP). *Oil and Gas Careers in Ohio Series, Career Guide.* March 3, 2014 (www.oogeep/industry-workforce/careers/).

11 RRC. *Eagle Ford Task Force*; Center for Community and Business Research (CCBR), Institute for Economic Development, University of Texas at San Antonio, *Workforce Analysis for the Eagle Ford Shale.* October 2012.

12 BCS Incorporated. *Colorado's Energy Industry, Strategic Development Through Collaboration.* Prepared for Colorado Office of Economic Development and International Trade, Colorado Energy Office, Colorado Department of Natural Resources, and Colorado Department of Public Health and Environment. November 2013.

input via the interviews and survey from stakeholders in Pennsylvania, Ohio, Colorado, Texas, Louisiana, Illinois and elsewhere.

Shortage of qualified local workers

- Firms involved with unconventional oil and gas extraction, production and transportation have had difficulties recruiting appropriately trained local workers since the ramp-up of investment in unconventional onshore operations, in part because unconventional energy production spread so quickly in areas with favorable economics for extraction. As operators began installing well pads and pipelines and drilling in areas that had not previously been home to the oil and gas industry, the local supply of adequately trained and skilled workers was inadequate.

- These companies' demand for workers with the requisite experience and skills was often met by recruiting workers from the oil and gas fields where they already had operations (e.g., Texas, Louisiana, and Oklahoma). The problem of recruiting enough local talent to fill the new jobs is exacerbated when companies are operating in rural areas with small populations.[13]

- Further compounding the local workforce shortage is the lag time necessary to develop the skills of local workers required by the industry. Because of the hazards of oil and gas worksites (i.e., combustibles, high pneumatic pressures), the industry often requires more rigorous engineering and occupational safety standards and certifications than for other industries. The challenge, therefore, for local educational and training institutions is to develop appropriate education and training programs to enable local workers to fill more of these jobs, as needed by the various stages of play development and pace of infrastructure expansion. Despite these challenges, the proportion of skilled workers hired from the local labor force in some states has been increasing, although some shortages still exist.[14]

Technological change

Technological change has been an important driver in the demand for higher-skill occupations in the unconventional energy workforce, along with increasing the skill requirements needed for existing jobs. This challenge has been cited frequently both in the literature and by oil and gas industry representatives interviewed by the project team. As a university business professor from Colorado[15] noted, "technology shift is an ongoing thread in the oil and gas industry," not only in the unconventional sector. Similarly, energy reporter Richard Nemec writes, "Technology and innovation have been driving

13 See for example, RRC, *Eagle Ford Shale Task Force*:16. The report cites the "recruiting difficulties for companies in the region, including small rural populations, the shortage of experience labor, and various issues that arise when relocating workers."

14 See MSETC. *Pennsylvania Statewide Marcellus Shale Workforce*: 20. For example, this report notes that, "As the Marcellus Play continues to mature, the industry is moving towards a workforce that contains fewer transient workers and more permanent Pennsylvania residents." It further states that national and international drilling companies, gas field service companies, and gas field construction firms initially brought an external workforce with them to an area, but "are in the process of replacing this workforce with local workers as opportunities arise." It estimates that based on recent interviews and survey data, that although in the early phases of development as many as 70–80% of the employees were from outside Pennsylvania, more recently, "the percentage of new industry hires who are Pennsylvania residents ranges from 50–100% with an approximate average of 65–75% of new Marcellus workers being Pennsylvania residents."

15 Phone interview, Global Energy Management Program, University of Colorado Denver Business School, May 29, 2014.

the US renaissance." For example, "everything from welding to coatings and the composition of today's large diameter pipes involves advanced operations."[16] Gas compression—a critical component at well sites, process plants and along the nation's network of gas pipelines—is another area of technological advance affecting the industry and workforce development needs.[17]

An oil and gas equipment distributor further states that, "there is no change in this industry except for technology. We have had 40 years of unconventional drilling and fracturing. But it is the technology—such as 3D and seismic technology and horizontal drilling—that allows the industry to find the stuff they couldn't find before."[18] The head of a Colorado-based community college oil and gas program adds that the industry is "not just looking for laborers. Jobs in this sector require reading gauges, being computer literate, understanding automation and the programming of PLCs (programmable logic controllers) at the wellhead. They also need to know how processes work, ranging from control-room operations to monitoring the wells."[19] In short, workforce education and training programs geared to the unconventional energy sector and its supply chain need to be able to keep up with technological advances.

"Soft skills" and behavioral barriers

Even if workers have the technical skills needed, workers must also demonstrate to employers they have "soft skills" and ability to meet behavioral standards. Examples of soft skills include reporting to work on time, knowing how to dress for the workplace, and having the skills to interact with people and to work on a team.[20] While this is not unique to the oil and gas industry,[21] finding workers that have a good mix of technical skills, knowledge, and a strong work ethic remains a challenge for energy and supply chain companies.[22]

Several people interviewed for this study highlighted a deficiency of soft skills as a concern for the unconventional energy sector, as it is for the conventional oil and gas industry and for many other industries. As the director of a community college oil and gas program noted, "[The] industry wants us to teach soft skills—be at work on time, know time management and ethics, and team building."[23] Another workforce training expert adds that, "employers see a large skills gap—not just limited to employment in unconventional energy operations, but true for manufacturing, energy and construction. The technical skills (welding, mechanical and electrical systems) and soft skills gap is real, not just perceived."[24]

Another behavioral challenge affecting employers seeking to hire skilled workers, especially in the oil and gas sector, is the large number of job applicants who are unable pass drug screening tests.[25] Several employers and workforce practitioners from the various states indicated that this was an issue for workers they were trying to attract.[26] An oil and gas equipment company official from Texas noted that his industry mandates drug tests and background checks because of safety issues.[27] These regulations exist, he added, because what the industry does "can seriously injure or kill people or have a major environmental impact."

16 Nemec, "Innovations in Workplace Training, Education."

17 Ibid.

18 Phone interview, Wagner Equipment Co., May 14, 2014.

19 Phone interview, Aims Community College Oil & Gas Program, May 29, 2014.

20 Federal Reserve Bank of Cleveland, *Outreach Summary, Workforce Development Challenges in Ohio*. Cleveland, Ohio (2014):6-7.

21 This comes up for a range of sectors, including, for example, the trucking industry. See for example; Jeffrey Short. *WHITE PAPER: Analysis of Truck Driver Age Demographics Across Two Decades*. Atlanta, GA:American Transportation Research Institute, December 2014:3.

22 MSETC. *Pennsylvania Statewide Marcellus Shale Workforce*:6.

23 Phone interview, May 29, 2014.

24 Phone interview, Colorado Online Energy Training Consortium, May 15, 2014. Another in that interview suggested that there also may be a generation gap because younger people entering into the industry have not been taught a strong work ethic.

25 Federal Reserve Bank of Cleveland, *Outreach Summary*:6.

26 However, in at least one case, an interviewee said that it was not an issue in his experience, as most applicants pass the test. Phone interview, June 2, 2014; and phone interview, Career and Technical Education Center (C-TEC) of Licking County, June 3, 2014.

27 Phone interview, Weir Oil & Gas Co., June 5, 2014.

Nevertheless, these and other behavioral screening tests (requiring driving records, performing criminal background checks) have also limited the size of the available workforce. Respondents cited examples of job applicants, despite having the requisite technical skills, being denied employment because of failed drug tests. One workforce program practitioner cited an instance in which drug tests eliminated half the crew from a site.[28]

Operator qualifications (OQ)

The behavior restrictions related to the transportation and logistics component of the unconventional supply chain begin with regulations administered by the US Department of Transportation (DOT) and apply to pipeline installation and maintenance as well as interstate truck drivers and railroad operators. The Pipeline and Hazardous Material Safety Administration (PHMSA) administers the regulations in the pipeline sector, which mandate that workers in the industries and activities under its jurisdiction be drug tested and meet operator qualifications (OQs). OQ programs establish requirements that employees working on pipelines overseen by PHMSA meet technical competency requirements and be able to react to "abnormal operating conditions," which in turn necessitates a great deal of training.

The onus of OQ programs regulated by PHMSA is on the large oil and gas companies, who then pass down these requirements to their contractors and suppliers. A common problem, however, is that the oil and gas companies may interpret the qualifications differently. The result, as oil and gas pipeline contractors explained, is that each company has its own OQ program and no uniform criteria for which a worker must be trained. Workers typically have 15 to 20 days of training for one operator and must undergo additional trainings with each new company.[29] OQ has become an important regulatory issue for which the pipeline construction and installation industry seeks resolution.[30]

Working conditions and burnout

Difficult working conditions were identified as another constraint on finding workers, especially in upstream occupations and in pipeline, road and other construction work in support of oil and gas production. The industry needs workers willing to take jobs that are physically demanding, involve long hours and sustained periods of work, under sometimes harsh weather and environmental conditions, and also willing to be away from home for long periods.

Oil and gas extraction firms and their suppliers typically bring people in on a rotational basis: they work continuously for two to three weeks seven days a week, and 12 hours a day, and then are off for a period of time. One operator observed that the oil and gas industry has always had a culture of mobility,[31] but cited the example of workers being flown in by their company for two weeks at a time to North Dakota to live in "man-camps" near the drilling sites. Meanwhile, their families stayed at home because the remote work was likely to only last for one to two years.[32] Because the drilling locations can be in very rural areas, it also has been hard to attract qualified workers from urban areas to relocate to rural counties where there is little else to do.[33]

These working conditions can be very stressful for workers, leading to burnout and high turnover. At the same time, the shortage of labor puts additional demand on the existing workers to put in additional time on the job. An industry association representative recommended that workers have a more accurate understanding of the demands, the expectations of their companies, and the level of stress in the jobs.[34]

28 Phone interview, Aims Community College Oil & Gas Program, May 29, 2024.

29 Phone interview, Distribution Contractors Association contractors. May 30, 2014.

30 Phone interview, Distribution Contractors Association industry representative. May 30, 2014. Because the regulation is so broad, "everybody has their own spin on this," the industry representative observed. Enforcement by regulatory personnel is not uniform. Some states have their own regulatory groups, other have different compliance programs, while still others don't have any regulations at all. The federal government has its own pipeline safety group. But there is no consistency, and compliance is "specific inspector to inspector."

31 Phone interview, Weir Oil & Gas Co., June 5, 2014.

32 Phone interview, Colorado Oil & Gas Association (COGA), May 22, 2014.

33 Phone interview, Pennsylvania Independent Oil & Gas Association (PIOGA), May 30, 2014.

34 Phone interview, PIOGA, May 30, 2014.

Attracting youth to skilled trades

Difficult working conditions can also further dampen young peoples' interest in pursuing work and careers in laborer and skilled trade positions in the unconventional energy sector. The project team interviewed a large number of representatives of companies and industry associations who mentioned the challenge of attracting young people because of what they perceive as "cultural bias" in the United States against skilled trades jobs in certain industries such as manufacturing, construction and even trucking.[35] One oil and gas equipment supplier employing machinists and welders noted that "not enough people are moving into the skilled trades areas" because "not enough young people are saying that this is an attractive space."[36]

For many students and their parents, and often their high school guidance counselors, there remains a stigma attached to occupations that require vocational education and training. A Federal Reserve Bank in Cleveland report on workforce development in Ohio stated that while "many employers would hire mid-skilled workers who have some secondary school credential that is not a college degree, today's educational system is primarily oriented toward students who plan to go to college, in terms of both curriculum and counseling resources, not on job or career readiness."[37]

However, many of the individuals interviewed agreed that today's skilled jobs in construction, manufacturing and energy sectors require relatively sophisticated skills, and capabilities in STEM (science, technology, engineering and math) remain important. Thus, there is wide agreement that changing the public perception of employment in skilled trades is critical to attracting more young people to careers in these fields.[38]

An aging workforce

The challenge of maintaining a sufficient workforce for high-demand unconventional supply chain occupations is made more acute by the looming retirement of aging Baby Boomers working in these fields, or the Great Crew Change, as it is known within the oil and gas industry.[39] Concerns about the aging workforce cut across multiple industry sectors. Workers in manufacturing, utility, and supply tend to be older than the general working population. For example, in the 2009–10 manufacturing workforce, a Massachusetts Institute of Technology study noted that 17.2% were over 55 years old. BLS projections suggest that even when likely drops in aggregate manufacturing employment are accounted for, there will still be large replacement problems as the current generation of production workers retires.[40]

A National Academy of Sciences study on emerging workforce trends in US energy and mining concurred, noting the "boom in oil and natural gas exploration and production has created a demand for workers and equipment that comes when a large portion of the existing workforce, professional and nonprofessional is less than 5 years from retirement." In fact, although many of these workers are already at retirement age, they continue employment because of the undersupply of experienced workers.[41] For example, half of the oil and natural gas workforce are between the ages of 50 and 60,[42] the average American welder is 55 years old,[43] and about 40% of US utility workers will be eligible for retirement in the next five years.[44] The average age of truck

35 For example, see discussion concerning how decline in vocational education and increased emphasis on academic education will likely draw high school students away from a career as a truck driver: Short. *WHITE PAPER: Analysis of Truck Driver Age Demographics*:16-17.

36 Phone interview, Weir Oil & Gas Co., June 5, 2014.

37 Federal Reserve Bank of Cleveland. *Outreach Summary*: 5.

38 Phone interview, industry specialist, Ohio Oil & Gas Energy Education Program (OOGEEP), May 19, 2014. For example, this informant notes that only 21% of young people go on to get a college degree. So there could be an opportunity to reorient people, to attract many of them into vocational training programs in high-skilled trades occupations, which in fact often pay better than many jobs that require a four-year degree (especially in the burgeoning unconventional energy sector).

39 Federal Reserve Bank of Cleveland. *Outreach Summary*: 5.

40 Berger et al. *Making In America*: 189.

41 Committee on Emerging Workforce Trends in the US Energy and Mining Industries; Committee on Earth Resources; Board on Earth Sciences and Resources; Division on Earth and Life Studies; Board on Higher Education and Workforce; Policy and Global Affairs; National Research Council of the National Academies (NRC). Emerging Workforce Trends in the US Energy and Mining Industries: A Call to Action. Washington, DC: The National Academies Press, 2013:28.

42 John Kemp. "Have you considered a career in petro-engineering?" *Reuters.com* (Jan. 18, 2012).

43 Matthew Philips. "Welders, America Needs You." *BloombergBusinessweek* (March 20, 2014).

44 PricewaterhouseCoopers. *Power and Utilities Changing Workforce, Keeping the lights on.* (www.pwc.com) December 2013.

drivers is also reported to be older than the average age of workers in many other sectors of the workforce. For example, more than 31% of trucking employees in 2013 fell into the 45-54 age group, while about 20% fell in the 55-64 age range, and 6% were 65 or older. The latter percentage is greater than that the 20–24 age group (4.9%) employed in the trucking industry.[45]

The accelerating retirement rates among the energy industry's skilled workforce, combined with rapidly advancing technology, have increased the pressures on industry training and education programs and resources.[46] An oil and gas equipment supply firm executive noted the 15–20-year experience gap between older workers and new entrants. He is concerned about how to transfer the knowledge of people who have been in the industry 20–30 years to less experienced workers. The problem of transferring knowledge to younger workers, therefore, is critical for suppliers to consider in maintaining the right skills inventory to stay competitive.[47]

Competition for skilled workers

Many of the industry and workforce professionals interviewed for this report said that the rapid growth of demand for oil and gas industry and supply sector jobs, along with the recovery in the US manufacturing sector, has fostered a fierce competition for workers with comparable skills. It takes time, sometimes as long as four or five years, to train workers for skilled trades, not to mention professional engineering and management positions. The time lag between ramping up the supply of skilled workers to meet rising demand has increased pressure to "poach" workers from other firms within and outside their own industries, often by offering much higher pay and incentives.

An Ohio community college program representative noted that workers with the engineering and technical skills required for the unconventional energy value chain are also in demand by manufacturing companies. For example, "if you know and can repair motors and compressors, can operate instrumentation and control systems, are a skilled technician, or know and can repair hydraulic systems, then both the manufacturing and the unconventional energy sectors will want you, and the competition bids up the wage levels."[48] Other interviewees had similar stories. A related concern is that some workers in technical training programs sometimes leave before they have finished their coursework, lured by the high wages paid by supply chain and extraction companies.

As the economy recovers and the manufacturing and construction sector improve, new investment in housing, transportation, infrastructure and the energy complex will create increasing competition for workers in the same high-demand occupations. For example, a manufacturing trade association leader noted that, "welders are getting amazing offers from drillers," which reflects the fierce competition for talent.[49] Another interviewee observed that human resources departments of trucking companies complain of troubles retaining drivers because of competition from energy companies. In the end, the fierce competition for immediately deployable skilled workers leads to higher labor costs and "poaching" rather than investment in workforce training that benefits all sectors.[50]

45 Short. *WHITE PAPER: Analysis of Truck Driver Age Demographics*: 10.

46 FMI Incorporated. *Skill Shortages:*4.

47 Phone interview, Weir Oil & Gas Co., June 5, 2014.

48 Phone interview, Zane State College, June 28, 2014.

49 Phone interview, Ohio Manufacturers' Association, May 29, 2014.

50 The trucking industry also has been raising concerns about impacts of competition within the industry on availability of drivers. Short. *WHITE PAPER: Analysis of Truck Driver Age Demographics*:2-3.

Core and high-demand occupations

IHS's economic study of the unconventional energy supply chain includes forecasts of employment levels for the main core supply chain sectors—construction and well services,[51] capital goods, materials, professional and other services, and logistics—and selected NAICS sectors within each group. The IHS-High Road Strategies team took a closer look at these trends, specifically to identify the occupational composition of the workforces in unconventional energy supply chain activities. Applying the methodology above, the team identified the core occupations most important to the core supply chain industries and also those in the highest demand. That is, what are the supply chain occupations in which employers are currently seeing, or expect to see, critical shortages of employees with the necessary skills? This section presents the findings of this analysis.

Core occupations

The accompanying table shows a final list of 73 core occupations in the unconventional supply chain. It consists of the initial set of 71 core occupations identified by the project team, plus two that were added based on the interviews and survey and review of the literature. The table also shows the average annual wages in 2013, and the minimum education and training requirements for each occupation. The occupations are grouped under seven of the major occupational categories (Standard Occupational Classifications, [SOC]) that BLS uses to collect and organize occupational data, based on common characteristics.[52]

Core occupations in the Unconventional energy supply chain

SOC	Occupation	Median annual wage, 2012	Typical education needed for entry	Work experience in related occupation	Typical on-the-job training (OJT) needed to attain competency
Management					
11-3051	Industrial production managers	$89,190	Bachelor's degree	> 5 years	None
11-9021	Construction managers	$82,790	Bachelor's degree	None	Moderate-term
Architecture and Engineering					
17-1022	Surveyors	$56,230	Bachelor's degree	< 5 years	None
17-2041	Chemical engineers	$94,350	Bachelor's degree	None	None
17-2081	Environmental engineers	$80,890	Bachelor's degree	None	None
17-2111	Health & safety engineers, except mining safety engineers & inspectors	$76,830	Bachelor's degree	None	None
17-2141	Mechanical engineers	$80,580	Bachelor's degree	None	None
17-2151	Mining & geological engineers, including mining safety engineers	$84,320	Bachelor's degree	None	None
17-2171	Petroleum engineers	$130,280	Bachelor's degree	None	None
17-3013	Mechanical drafters	$50,360	Associate's degree	None	None
17-3023	Electrical & electronics engineering technicians	$57,850	Associate's degree	None	None
17-3025	Environmental engineering technicians	$45,350	Associate's degree	None	None
17-3027	Mechanical engineering technicians	$51,980	Associate's degree	None	None

(continued)

51 The Construction and Well Services sector can be subdivided into three major subsectors, each with significant levels of employment—well services, construction of new nonresidential manufacturing structures and construction of other new nonresidential structures. Hence, there are a total of seven core sectors comprising multiple four-digit NAICS supply chain sectors for purposes of this analysis.

52 The occupational data used in this study is provided from the Occupational Employment Statistics (OES) program of the BLS, online at www.bls.gov/oes/. The OES program conducts a semiannual mail survey designed to produce estimates of employment and wages for specific occupations. The Standard Occupational Classification (SOC) system is used by BLS and other Federal statistical agencies to classify workers and jobs into occupational categories for the purpose of collecting, calculating, analyzing, or disseminating data. The 2010 SOC system contains 840 detailed occupations, aggregated into 461 broad occupations. In turn, the SOC combines these 461 broad occupations into 97 minor groups and 23 major groups.

Core occupations in the Unconventional energy supply chain (continued)

SOC	Occupation	Median annual wage, 2012	Typical education needed for entry	Work experience in related occupation	Typical on-the-job training (OJT) needed to attain competency
Life, Physical, and Social Scientists					
19-2041	Environmental scientists & specialists, including health	$63,570	Bachelor's degree	None	None
19-2042	Geoscientists, except hydrologists & geographers	$90,890	Bachelor's degree	None	None
19-2043	Hydrologists	$75,530	Master's degree	None	None
19-4031	Chemical technicians	$42,920	Associate's degree	None	Moderate-term
19-4041	Geological & petroleum technicians	$52,700	Associate's degree	None	Moderate-term
19-4091	Environmental science & protection technicians, including health	$41,240	Associate's degree	None	None
Construction and Extraction					
47-1011	First-line supervisors of construction trades & extraction workers	$59,700	HS diploma or equiv.	< 5 years	None
47-2011	Boilermakers	$56,560	HS diploma or equiv.	None	Apprenticeship
47-2051	Cement masons & concrete finishers	$35,760	< High School	None	Moderate-term
47-2061	Construction laborers	$29,990	< High School	None	Short-term
47-2071	Paving, surfacing, & tamping equipment operators	$35,840	HS diploma or equiv.	None	Moderate
47-2072	Pile-driver operators	$48,480	HS diploma or equiv.	None	Moderate-term
47-2073	Operating engineers & other construction equipment operators	$41,870	HS diploma or equiv.	None	Moderate-term
47-2151	Pipelayers	$36,180	< High School	None	Short-term
47-2152	Plumbers, pipefitters, & steamfitters	$49,140	HS diploma or equiv.	None	Apprenticeship
47-2171	Reinforcing iron & rebar workers	$45,910	HS diploma or equiv.	None	Apprenticeship
47-2221	Structural iron & steel workers	$46,140	HS diploma or equiv.	None	Apprenticeship
47-5011	Derrick operators, oil & gas	$46,900	< High School	None	Short-term
47-5012	Rotary drill operators, oil & gas	$49,220	< High School	None	Moderate-term
47-5013	Service unit operators, oil, gas, & mining	$41,970	< High School	None	Moderate-term
47-5071	Roustabouts, oil & gas	$34,130	< High School	None	Moderate-term
47-5081	Helpers—extraction workers	$31,460	HS diploma or equiv.	None	Moderate-term
47-5099	Extraction workers, all other	$38,810	HS diploma or equiv.	None	Moderate-term
Installation, Maintenance and Repair					
49-3031	Bus & truck mechanics & diesel engine specialists	$42,320	HS diploma or equiv.	None	Long-term
49-3042	Mobile heavy equipment mechanics, except engines	$46,050	HS diploma or equiv.	None	Long-term
49-9012	Control & valve installers & repairers, except mechanical door	$50,960	HS diploma or equiv.	None	Moderate-term
49-9041	Industrial machinery mechanics	$46,920	HS diploma or equiv.	None	Long-term
49-9043	Maintenance workers, machinery	$40,620	HS diploma or equiv.	None	Moderate-term
49-9044	Millwrights	$49,510	HS diploma or equiv.	None	Apprenticeship
Production					
51-2031	Engine & other machine assemblers	$36,110	HS diploma or equiv.	None	Short-term
51-2041	Structural metal fabricators & fitters	$35,750	HS diploma or equiv.	None	Moderate-term
51-4011	Computer-controlled machine tool operators, metal & plastic	$35,580	HS diploma or equiv.	None	Moderate-term
51-4012	Computer numerically controlled machine tool programmers, metal & plastic	$45,920	HS diploma or equiv.	None	Long-term

(continued)

Core occupations in the Unconventional energy supply chain (continued)

SOC	Occupation	Median annual wage, 2012	Typical education needed for entry	Work experience in related occupation	Typical on-the-job training (OJT) needed to attain competency
51-4021	Extruding & drawing machine setters, operators, & tenders, metal & plastic	$32,330	HS diploma or equiv.	None	Moderate-term
51-4023	Rolling machine setters, operators, & tenders, metal & plastic	$37,390	HS diploma or equiv.	None	Moderate-term
51-4031	Cutting, punching, & press machine setters, operators, & tenders, metal & plastic	$29,690	HS diploma or equiv.	None	Moderate-term
51-4032	Drilling & boring machine tool setters, operators, & tenders, metal & plastic	$33,940	HS diploma or equiv.	None	Moderate-term
51-4034	Lathe & turning machine tool setters, operators, & tenders, metal & plastic	$36,540	HS diploma or equiv.	None	Moderate-term
51-4035	Milling & planing machine setters, operators, & tenders, metal & plastic	$35,820	HS diploma or equiv.	None	Moderate-term
51-4041	Machinists	$39,500	HS diploma or equiv.	None	Long-term
51-4111	Tool & die makers	$47,000	HS diploma or equiv.	None	Long-term
51-4121	Welders, cutters, solderers, & brazers	$36,300	HS diploma or equiv.	None	Moderate-term
51-4122	Welding, soldering, & brazing machine setters, operators, & tenders	$34,720	HS diploma or equiv.	None	Moderate-term
51-4191	Heat treating equipment setters, operators, & tenders, metal & plastic	$34,010	HS diploma or equiv.	None	Moderate-term
51-4194	Tool grinders, filers, & sharpeners	$34,300	HS diploma or equiv.	None	Moderate-term
51-4199	Metal workers & plastic workers, all other	$31,060	HS diploma or equiv.	None	Moderate-term
51-8031	Water & wastewater treatment plant & system operators	$42,760	HS diploma or equiv.	None	Long-term
51-8091	Chemical plant & system operators	$54,390	HS diploma or equiv.	None	Long-term
51-8092	Gas plant operators	$61,140	HS diploma or equiv.	None	Long-term
51-8093	Petroleum pump system operators, refinery operators, & gaugers	$61,850	HS diploma or equiv.	None	Long-term
51-8099	Plant & system operators, all other	$53,130	HS diploma or equiv.	None	Long-term
51-9011	Chemical equipment operators & tenders	$47,100	HS diploma or equiv.	None	Moderate-term
Transportation and Material Moving					
53-3032	Heavy & tractor-trailer truck drivers	$38,200	Postsec. non-degree award	None	Short-term
53-7021	Crane & tower operators	$47,290	HS diploma or equiv.	< 5 years	Moderate-term
53-7032	Excavating & loading machine & dragline operators	$38,290	HS diploma or equiv.	< 5 years	Moderate-term
53-7033	Loading machine operators, underground mining	$48,420	< High School	None	Short-term
53-7041	Hoist & winch operators	$39,960	< High School	None	Short-term
53-7071	Gas compressor & gas pumping station operators	$51,150	< High School	None	Moderate-term
53-7072	Pump operators, except wellhead pumpers	$44,610	< High School	None	Moderate-term
53-7073	Wellhead pumpers	$45,690	< High School	< 5 years	Moderate-term

"Source: BLS, Table 1.7 Occupational employment and job openings data, projected 2012-22, and worker characteristics, 2012

Not surprisingly, management and professional (engineering, scientific and technician) jobs earn the highest incomes and typically require the highest degree of education. Their median annual wage can range from $45,000–$60,000 for technicians in these fields and upward of $90,000 to more than $100,000 for chemical and petroleum engineers. Science and engineering fields typically require a bachelor's degree, at minimum, and for at least one occupation on the list, a master's degree (hydrologists). Technicians typically require at least an associate's degree.

The majority of skilled trades (e.g., machine and equipment operators, installers and repairers, construction trades, engine and diesel mechanics) in construction, production, oil and gas transport, material transport, and related activities in the supply chain usually require a high school diploma or equivalent. In some instances workers need long-term on-the-job training (OJT) or apprenticeship training to satisfy and maintain the appropriate skill level. Median annual wages are more modest, mostly falling in the mid-$30,000 to mid-$50,000 range, though a couple of occupations rise above $60,000 (gas plant operators and petroleum pump system and refinery operators). Heavy and tractor-trailer truck drivers are a special case, requiring postsecondary nondegree awards such as a commercial driver's license (CDLs).

Workers in the relatively lower-skilled jobs do not necessarily require high school diplomas but do need moderate OJT to attain competency in their occupations. These include construction laborers, cement masons, and a number of field service positions in the oil and gas sector such as derrick, rotary drill, and service unit operators; pipe layers; and roustabouts. The construction laborers' median annual wages may be the lowest, at a little less than $30,000 in 2012. Yet despite their relatively lower educational levels, most of the occupations directly engaged in support services for oil and gas extraction, drilling, and production tend on average to receive annual wages comparable with and sometimes higher than many of the skilled trades, ranging from $40,000 to $50,000.

Occupational distribution by sector

The top 15 occupations ranked by level of employment for each sector are shown in the tables below. Some core occupations are required in multiple sectors across the supply chain, while others tend to be concentrated within only a few. For example, construction laborers, first-line supervisors of construction and extraction, operating engineers, industrial machinery mechanics, mobile heavy equipment mechanics, welders, and heavy truck drivers, fall within the top 15 occupations in terms of employment as a share of total employment in four or more of the major core sectors. By contrast, more specialized occupations such rotary drill operators, geological and petroleum technicians, petroleum engineers, and wellhead pumpers are found in only one or two core sectors.

Each of the core supply chain sectors tend to employ workers from a small number of core occupations that are specifically relevant to its supply chain activities. In addition, although the total number of core occupations associated with a given core sector ranges from 46 (logistics) to 68 (materials), the top 15 core occupations in each sector accounted for between three-quarters (professional services and materials) and 99% (logistics) of employment in 2012.

The first table shows the predominant occupations for the three subdivisions of the construction and well services sector. Not surprisingly, extraction occupations and some construction occupations account for nearly 90% of workers employed in well services industries. Similarly, construction-related occupations, notably construction laborers, first-line supervisors of construction trades, and extraction workers, and operating engineers and other construction equipment operators account for by far the largest number of jobs in the two construction subsectors shown below.

Top 15 occupations in the well services and construction sectors

Well services	Construction of new nonresidential manufacturing structures	Construction of other new nonresidential structures
Service Unit Operators	Construction Laborers	Construction Laborers
Roustabouts	First-Line Supervisors of Construction Trades	Operating Engineers & Other Equipment Operators
Heavy & Tractor-Trailer Truck Drivers	Operating Engineers & Other Equipment Operators	First-Line Supervisors of Construction Trades
Rotary Drill Operators	Construction Managers	Cement Masons & Concrete Finishers
First-Line Supervisors of Construction Trades	Plumbers, Pipefitters, & Steamfitters	Heavy & Tractor-Trailer Truck Drivers
Derrick Operators	Pipelayers	Plumbers, Pipefitters, & Steamfitters
Helpers—Extraction Workers	Welders, Cutters, Solderers, & Brazers	Construction Managers
Operating Engineers & Other Equipment Operators	Heavy & Tractor-Trailer Truck Drivers	Paving, Surfacing, & Tamping Equipment Operators
Construction Laborers	Cement Masons & Concrete Finishers	Structural Iron & Steel Workers
Industrial Machinery Mechanics	Structural Iron & Steel Workers	Mobile Heavy Equipment Mechanics
Wellhead Pumpers	Mobile Heavy Equipment Mechanics	Welders, Cutters, Solderers, & Brazers
Welders, Cutters, Solderers, & Brazers	Millwrights	Excavating & Loading Machine & Dragline Operators
Petroleum Engineers	Excavating & Loading Machine & Dragline Operators	Crane & Tower Operators
Extraction Workers, All Other	Boilermakers	Pipelayers
Geological & Petroleum Technicians	Roustabouts	Reinforcing Iron & Rebar Workers

Source: Bureau of Labor Statistics and IHS

The engineering occupations (petroleum, mechanical, chemical, environmental and mining engineers, and associated technicians) and science professions (environmental scientists, geoscientists, hydrologists, and associated technicians) comprise a relatively small share of the jobs in the core sectors and their associated NAICS supply chain sectors. For example, petroleum engineers were the 13th largest occupation in terms of employment in the well services sector (NAICS 2131); it accounted for about 2% of the workers in that sector in 2012. A much smaller number of petroleum engineers are employed in some of the other sectors, including professional services, materials, and capital goods. The small number of jobs in most of the occupational categories, however, does not diminish the importance of these very high-skilled occupations, which require at least a college degree, in the unconventional energy value chain.

Most engineers and scientists and related technicians tend to be concentrated in the professional services. But some of these occupations also are required in the equipment manufacturers and dealers (capital goods) and materials-producing sectors. For example, mechanical engineering, the largest occupation in terms of employment in this occupational group, is the second- and fourth-largest occupation in the capital goods (more than 2,800 jobs in 2012) and professional services (nearly 2,500 jobs) sectors, respectively.

At the same time, production and related occupations (e.g., machinists, welders, tool and die makers, industrial machinery mechanics) predominate in the capital goods sector and play an important role in the materials sector, which includes quarrying and processing of nonmetallic minerals and fabrication of basic materials such as steel, aluminum, cement and basic chemicals supplied to the unconventional energy sector. Construction-

related occupations (operating engineers, construction laborers, first-line supervisors) are also important occupations in the materials sector.

Top 15 occupations In the capital goods, materials, and professional and other services sectors

Capital goods	Materials	Professional and other services
Machinists	Heavy & Tractor-Trailer Truck Drivers	Water & Wastewater Treatment Plant & Syst. Ops.
Welders, Cutters, Solderers, & Brazers	Operating Engineers & Other Equipment Operators	Mechanical Engineers
Tool & Die Makers	Excavating & Loading Machine & Dragline Operators	Surveyors
Mechanical Engineers	Welders, Cutters, Solderers, & Brazers	Industrial Machinery Mechanics
Computer-Controlled Machine Tool Operators	Rolling Machine Setters, Operators, & Tenders	Heavy & Tractor-Trailer Truck Drivers
Industrial Machinery Mechanics	Industrial Machinery Mechanics	Electrical & Electronics Engineering Technicians
Cutting, Punching, & Press Machine Setters, etc.	Cutting, Punching, & Press Machine Setters, etc.	Environmental Engineers
Welding, Soldering, & Brazing Machine Setters, etc.	Extruding & Drawing Machine Setters, etc.	Environmental Scientists & Specialists, Inc. Health
Structural Metal Fabricators & Fitters	Machinists	Chemical Technicians
Mechanical Drafters	First-Line Supervisors of Construction Trades	Mechanical Drafters
Industrial Production Managers	Mobile Heavy Equipment Mechanics	Construction Laborers
Engine & Other Machine Assemblers	Computer-Controlled Machine Tool Operators	Mechanical Engineering Technicians
Mobile Heavy Equipment Mechanics	Construction Laborers	Mobile Heavy Equipment Mechanics
Lathe & Turning Machine Tool Setter, etc.	Chemical Equipment Operators & Tenders	Plumbers, Pipefitters, & Steamfitters
CNC Machine Tool Programmers, Metal & Plastic	Industrial Production Managers	Construction Managers

Source: Bureau of Labor Statistics and IHS

Heavy and tractor-trailer truck drivers account for over 90% of jobs in the logistics sector, which includes a range of transportation industries (water, rail, general freight, and pipeline). Bus and truck mechanics and diesel engine specialists and mechanics are a distant second and third, respectively, in terms of employment in this sector. Heavy and tractor-trailer truck drivers are also employed in relatively large numbers in the construction and well services, materials, and professional services sectors.

Employment projections 2012–25

The IHS team forecast employment levels for each core occupation used by the unconventional energy supply chain sectors. These projections are intended to be estimates of the number of jobs for each core occupation actually engaged in unconventional energy supply chain activities from 2012 to 2025. These projections are driven by the IHS economic forecasts of unconventional energy supply chain economic growth.

Total core occupational employment that directly supports unconventional energy activity was estimated at 226,300 jobs in 2012 and is forecast to grow by 43%, to nearly 324,300 jobs in 2025. The forecast of core occupational employment in the major core sectors in the unconventional energy supply chain, as shown in that figure and summarized in the table below, reflects the patterns of economic growth for these sectors projected by IHS in its economic study.

Core occupational employment by core sector					
Core sector	**2012**	**2025**	**Difference**	**% Change**	**CAGR***
Capital goods	40,708	58,946	18,239	44.8%	2.9%
Logistics	16,459	30,173	13,714	83.3%	4.8%
Materials	29,565	47,141	17,576	59.4%	3.7%
Professional and other services	20,284	30,641	10,358	51.1%	3.2%
Construction of midstream/downstreamstructures	40,312	7,220	(33,092)	-82.1%	-12.4%
Construction of upstream facilities and structures	31,343	54,997	23,655	75.5%	4.4%
Well services	47,642	95,164	47,522	99.7%	5.5%
Total	**226,312**	**324,283**	**97,971**	**43.3%**	**2.8%**

* CAGR equals compound annual growth rate.

Source: Bureau of Labor Statistics and IHS

- Employment of workers in core occupations in the well services sector is expected to grow substantially as the number of wells in operation continues to rise—doubling over the forecast period, from 47,600 in 2012 to almost 95,200 in 2025, an average annual growth rate of 5.5%.

- Core occupational employment in the construction subsector, which includes upstream construction of upstream facilities and structures, is forecast to grow as well, by three-quarters, rising from about 31,300 in 2012 to just under 55,000 in 2025, an average annual growth rate of 4.4%.

- On the other hand, core occupational employment for the construction of new nonresidential manufacturing structures—including construction of pipelines, rail, marine structures, storage facilities, manufacturing structures, and other facilities—is expected to rise early in the forecast period, but decline rapidly after 2013 because most of the supporting infrastructure will have been built. This downstream construction sector is forecast to shrink dramatically from 40,300 in 2012 to just over 7,200 in 2015, an 82% drop.

- Capital goods and materials are the second- and fourth-largest source of employment in the core occupations, respectively. Between 2012 and 2025, core occupational employment in the capital goods sector is expected to grow by 45%, from around 40,700 to almost 59,000, a 2.9% annual growth rate. Core employment in the materials sector is expected to rise from about 29,600 to over 47,100, a 60% increase in this period, or a 3.7% annual growth rate.

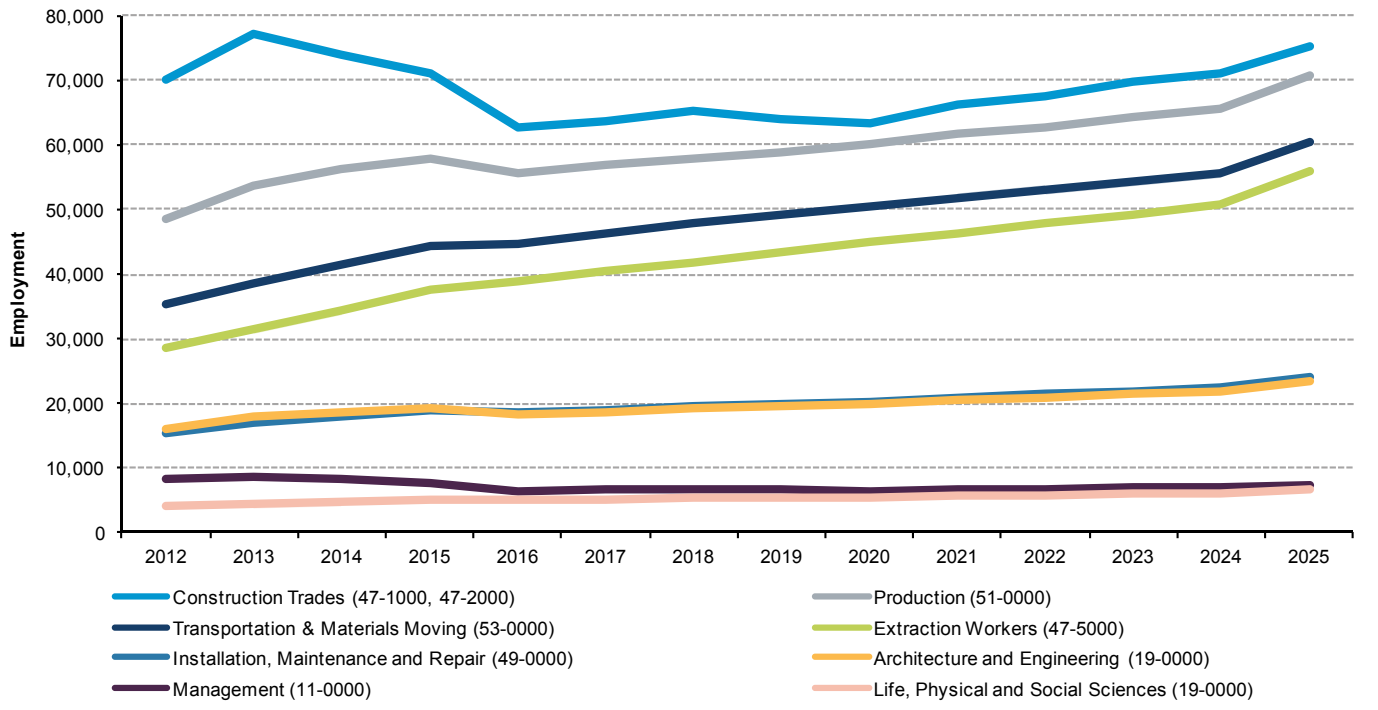
- Finally, core employment in the professional services is expected to increase by 10,400, from 20,300 to 30,700, a 3.2% average annual growth rate. Logistics core occupational employment is expected to nearly double, growing at an average annual rate of 4.8%, from 16,500 to nearly 30,200, over that period.

The figure below shows projections of employment for the core occupations grouped by major occupational classification. The decline in jobs in the core construction occupations after 2014 with a slow rise after 2016 reflects the forecast growth and then decline of construction sector activity related to unconventional energy activity, with rising activity in the upstream offset by declines in midstream and downstream construction.

As expected, jobs in production occupations are expected to show a steady rise through the forecast period, because capital goods are required throughout the supply chain. As the IHS economic study of the unconventional energy supply chain states, "These impacts run throughout the energy value chain and reach deeply into the various equipment sectors responsible for the manufacturing of capital goods."[53] Core extraction and transportation occupational employment also rise steadily, as expected.

53 IHS Economics. *Supplying the Unconventional Revolution*: 21.

Trends in core occupational employment by major occupational category



Source: Bureau of Labor Statistics and IHS

As shown in the table below, while the construction trades are the largest occupational group in terms of core occupational employment, it is expected to grow at only a 0.5% average annual rate, reflecting the build-out of midstream and downstream infrastructure in the first few years of the forecast period. Employment of extraction workers, in contrast, grows much faster, at a 5.3% average annual rate. Transportation and materials moving occupations also grow by over 70%, at an average rate of 4.2% per year. Management occupations, however, have a small net loss over this period.

Core occupational employment by major occupational group

Major occupational code	2012	2025	Difference	% Change	CAGR*
Management (11-0000)	8,308	7,449	(859)	-10.3%	-0.8%
Architecture and Engineering (19-0000)	16,028	23,507	7,479	46.7%	3.0%
Life, Physical and Social Sciences (19-0000)	4,087	6,640	2,552	62.4%	3.8%
Installation, Maintenance and Repair (49-0000)	15,395	24,209	8,814	57.3%	3.5%
Production (51-0000)	48,434	70,783	22,349	46.1%	3.0%
Transportation & Materials Moving (53-0000)	35,276	60,448	25,173	71.4%	4.2%
Construction Trades (47-1000, 47-2000)	70,250	75,350	5,099	7.3%	0.5%
Extraction Workers (47-5000)	28,534	55,897	27,363	95.9%	5.3%
Total core occupation employment	**226,312**	**324,283**	**97,971**	**43.3%**	**2.8%**

* CAGR equals compound annual growth rate.

Source: Bureau of Labor Statistics and IHS

The table below summarizes the employment growth for the top 15 core occupations in the unconventional energy supply chain, ranked according to employment size. Heavy and tractor-trailer truck drivers are the largest occupation in terms of employment across the supply chain sectors. It also has a relatively high average annual rate of employment growth—4.2%—growing by over 19,800 jobs from 2012 to 2025, an increase of over 70%. In contrast, construction laborers, the second-largest occupation, is projected to have a net loss of jobs, one of a handful of other occupations in the construction sectors (for example, construction managers, pipe layers, boilermakers, and structural iron and steel workers), with declining numbers of jobs.

Top 15 core occupations based on 2012 employment

Detailed occupational code and description	2012	2025	Change	CAGR*
53-3032 Heavy and Tractor-Trailer Truck Drivers	27,774	47,578	19,803	4.2%
47-2061 Construction Laborers	26,105	24,703	(1,402)	-0.4%
47-1011 First-Line Supervisors of Construction Trades and Extraction Workers	14,986	16,490	1,504	0.7%
47-2073 Operating Engineers and Other Construction Equipment Operators	14,131	18,330	4,199	2.0%
51-4121 Welders, Cutters, Solderers, and Brazers	11,630	13,598	1,968	1.2%
51-4041 Machinists	8,973	14,314	5,341	3.7%
47-5013 Service Unit Operators, Oil, Gas, and Mining	8,604	16,371	7,766	5.1%
47-5071 Roustabouts, Oil and Gas	8,387	16,739	8,352	5.5%
49-9041 Industrial Machinery Mechanics	6,440	10,266	3,826	3.7%
11-9021 Construction Managers	6,157	4,324	(1,833)	-2.7%
17-2141 Mechanical Engineers	6,064	8,605	2,541	2.7%
47-2152 Plumbers, Pipefitters, and Steamfitters	4,954	5,399	445	0.7%
49-3042 Mobile Heavy Equipment Mechanics, Except Engines	3,530	5,799	2,269	3.9%
47-5012 Rotary Drill Operators, Oil and Gas	3,528	7,306	3,778	5.8%
47-5081 Helpers—Extraction Workers	3,498	6,338	2,841	4.7%

* CAGR equals compound annual growth rate.

Source: Bureau of Labor Statistics and IHS

Several other important construction and production occupations are represented on the list, including first-line supervisors of construction trades and extraction workers, operating engineers, welders, machinists, pipefitters, plumbers and steamfitters; notably, mechanical engineers, which also is the largest professional occupation in the supply chain in terms of employment. At the same time, several extraction-related occupations in the table account for some of the fastest rates of projected employment growth over this period. This includes, for example, service unit operators, oil, gas and mining (5.1%), roustabouts (5.5%), and rotary drill operators (5.8%), reflecting their important roles in the upstream well services sectors in the supply chain. Note that all but the last occupation, helpers-extraction workers, also an upstream well services job, are in bold text, as are several occupations in the earlier occupational tables above. These represent high-demand occupations, which will be discussed in a later section. It is also notable that 14 of the top 15 occupations in employment are also considered high demand.

State comparisons

This section analyzes recent trends in employment in the core and high-demand occupations for states with large unconventional resources—Pennsylvania, Texas, Ohio and Colorado; Louisiana, a large conventional oil and gas producer; and Illinois, a nonproducing state with supply chain industries. The occupational employment estimates presented here include *all* workers employed in the supply chain sectors; they have not been adjusted to indicate *only* the workers that were directly supporting the unconventional energy sector. That is, unlike the occupational employment projections above, not all the jobs support activity in the unconventional energy supply chain. Rather, they represent the total number of jobs in core occupations needed in supply chain sectors across the economy—including jobs in other industries outside the unconventional energy supply chain. For example, equipment manufacturers supplying compressors

to drilling and extraction firms may also produce equipment for nonenergy customers. Similarly, rotary drill operators are employed in the conventional energy sector. Respondents to the interviews and the IHS survey noted that many of the occupations needed in the unconventional energy supply chain have skills that are in demand by other, non-unconventional energy activities in the energy, manufacturing, and construction sectors.

The table below shows employment in the core occupations by major occupational categories for the selected states. Construction and extraction jobs account for 25% of all supply chain sector jobs in the United States and between 24% and 33% in every state except Ohio and Illinois, which are two major manufacturing states. Production jobs account for approximately one-third of supply chain sector jobs in Ohio and Illinois, reflecting the importance of these states' suppliers of equipment and materials (e.g., compressors, fabricated steel tubes) in the overall supply chain. The number of industrial production jobs in the unconventional energy supply chain sectors only slightly outnumbered construction jobs in Pennsylvania, also an important manufacturing state.

Core occupation employment by major occupational category by state: 2013

Occupational category	Texas	Pennsylvania	Colorado	Ohio	Illinois	Louisiana	United States
Management	41,050	11,820	5,180	20,210	11,770	5,820	379,060
Architecture and Engineering	80,960	29,690	16,400	25,300	25,890	12,730	721,500
Life, Physical and Social Science	31,730	10,110	8,160	8,340	6,090	5,500	242,190
Construction and Extraction	358,740	107,780	58,850	75,980	79,540	66,220	2,525,470
Installation, Maintenance and Repair	86,310	37,370	14,010	38,710	31,720	16,820	830,730
Production	187,000	101,290	19,290	125,720	99,030	45,210	1,865,030
Transportation and Material Moving	176,110	78,870	25,150	69,160	68,450	30,090	1,708,920
Total	**961,900**	**376,930**	**147,040**	**363,420**	**322,490**	**182,390**	**8,272,900**

Source: Bureau of Labor Statistics and IHS

The share of each occupation's total employment across all economic sectors that is in the unconventional supply chain varies considerably by occupation. For example, IHS estimates that about 28% of all US employment of petroleum engineers are in the supply chain sectors (keeping in mind that not all petroleum engineers directly support unconventional energy activities), compared to 66% for mobile heavy equipment mechanics and 81% for rotary drill operators in oil and gas production. Overall, about 56% of the total US employment in the core occupations was in the sectors comprising the unconventional energy supply chain in 2012 (recognizing, again, that not all these workers are employed in unconventional energy activities within these sectors).

The employment levels of core occupations, and corresponding shares of total employment, vary across the states reflecting both their industrial composition and scale of the unconventional energy activities. For example, production occupations' shares of total supply chain sector employment in Pennsylvania, Illinois, and Ohio are larger than those of the other states, reflecting the relatively larger manufacturing sectors of these industrial heartland states. Construction and extraction employment in the unconventional energy supply chain sectors is relatively higher in Texas, Louisiana, and Colorado, reflecting in part the more extensive oil and gas production in those states, including unconventional oil and gas production.

State occupational employment trends

Although the absolute employment numbers for supply chain core occupations need to be interpreted with some caution, comparing employment trends for the core occupations across the selected states is instructive. The growth of unconventional production in states with large plays has added jobs in core occupations in supply chain sectors, and this growth has contributed to job growth in these sectors overall and to state economies as well. This point is illustrated in the figure below, which compares the employment index trends (i.e., employment levels over a time period are indexed to the employment level of a base year, in this instance, 2007) for six states and the United States.

The impact of the Great Recession on employment levels for 2008–10 is clearly evident in the sharp dip in employment in the core occupations over this period in all states. This is hardly surprising, as construction and production, which account for 53% of employment in the core occupations, were the two major occupational categories that suffered among the most dramatic losses in the recession.

Of particular interest are the growth rates in employment in core occupations in Texas, Louisiana, and Pennsylvania as the economy rebounded. Exploration and production activity in the large plays in these states was a driver of growth in the core occupations. Employment in the core occupations in Louisiana and Texas has come very close to equaling if not surpassing the prerecession peak—the 2007 base year employment level in the following figure.

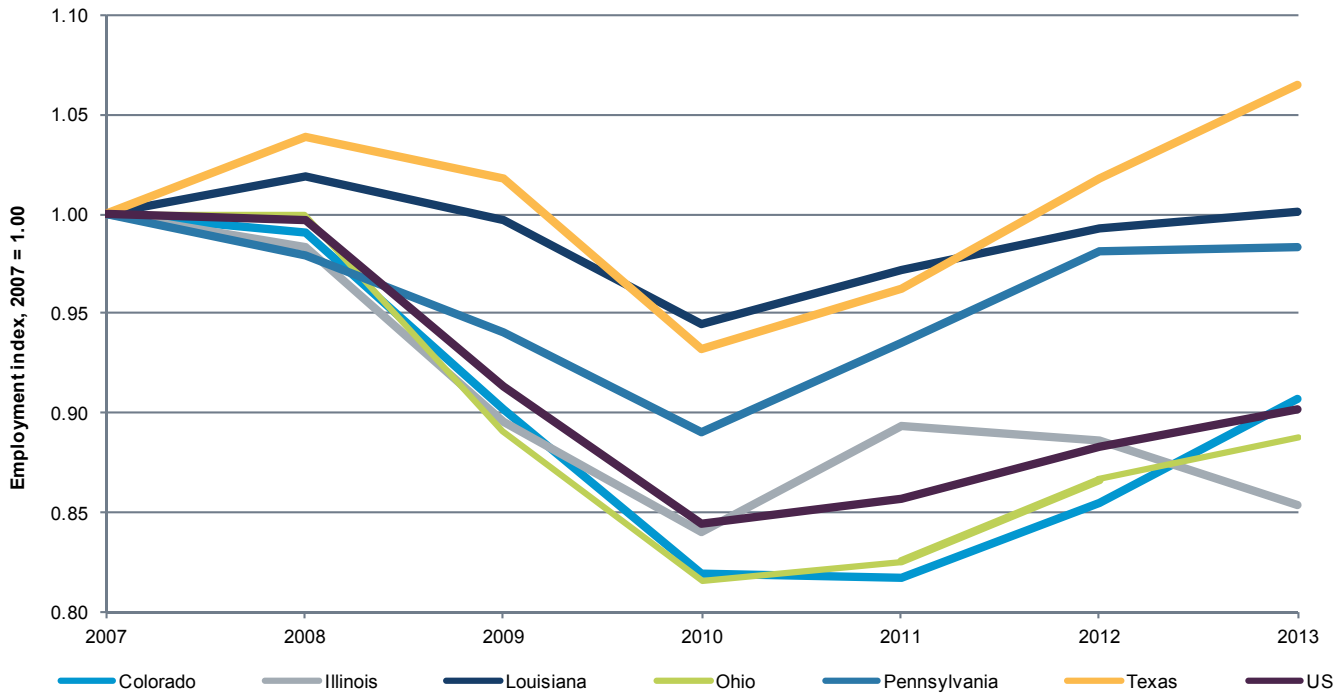
In Ohio, one of the largest manufacturing states in the nation, the manufacturing and construction sectors were hit especially hard by the recession. However, employment in the core occupations, which fell steeply between 2007 and 2010, started a gradual rise in 2011, although the employment level for the core occupations has not yet returned to its prerecession level. Nonetheless, demand for goods and services driven by upstream and midstream capital investment in the Marcellus and Utica shale plays has helped to fuel this trend as development of Ohio's energy complex expands.

Colorado has been showing a similar rebound in its core occupational jobs, but only over the past two years. However, these jobs could rebound faster and surpass 2007 employment levels over the next few years if the oil and gas industry is allowed to fully develop the Niobrara and other unconventional plays in the state.

The outlier is Illinois, also a manufacturing state that suffered significant job losses over the last recession. While Illinois is classified as a nonproducing state, Illinois's employment trends indicate a steady downturn in construction occupations, and stagnant growth in production and transportation and material movement occupations, with relative growth only in the installation and repair jobs. Sharp growth appears only in the combined management and professional occupations in the supply chain.

Job growth among Illinois equipment and goods suppliers to the unconventional energy sector is overshadowed by the larger economic trends in the state. Illinois is the only one of the six states where employment in the core occupations has declined since 2011, suggesting that the aftereffects of the Great Recession still linger, and the partial offset to the decline in manufacturing employment is a function of unconventional oil and gas development.

Core occupation employment index by state



Source: Bureau of Labor Statistics and IHS

High-demand occupations

Having identified 73 core occupations in the unconventional energy supply chain, the project team wanted to know which of them were in especially high demand—those for which employers were having difficulty finding enough workers with the needed skills. First, the project team reviewed the growing body of literature, including several state studies, citing evidence of growing labor shortages in the oil and gas sector and its supply chain, especially for a number of high-demand occupations (HDOs).[54] Additionally, the interviews and survey that the team conducted confirmed that there are labor shortages in many HDOs. The results of this analysis are summarized in the table below, which identifies 24 occupations as being in high demand. (Profiles of these occupations, which discuss their characteristics in more depth, are provided in Appendix C.)

The percentages shown in the table are the shares of the total number of jobs in each occupation in the United States, across all economic sectors that are in the unconventional energy supply chain sectors. For example,

54 See FMI Incorporated. *Skill Shortages.*

69.4% of all operating engineers and other construction equipment operators in the nation were employed in supply chain sectors in 2012. However, as mentioned above, this does not mean that all these operating engineers were engaged in unconventional energy supply chain activities—only that they were working in supply chain industries that may also include non-unconventional energy-related activities.

The HDOs span all the upstream, midstream, and downstream industries comprising the unconventional energy supply chain. Some occupations are repeatedly mentioned as being in high demand throughout much of the supply chain (heavy and tractor-trailer truck drivers with commercial driver's licenses [CDLs]; welders), while others are identified as being very important for certain targeted activities (e.g., construction laborers and managers, and operating engineers; petroleum engineers; electrical and electronic engineering technicians; the oil and gas field services jobs, such as derrick operators, service unit operators and roustabouts).

High-demand occupations in the unconventional energy supply chain: 2012

Occupational code	Occupational category	% in supply chain sectors
11–9021	Construction Managers	69.5%
17–2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors	51.6%
17–2171	Mechanical Engineers	53.1%
17–2171	Petroleum Engineers	28.3%
17–3023	Electrical and Electronics Engineering Technicians	42.3%
47–1011	First-Line Supervisors of Construction Trades and Extraction Workers	65.1%
47–2061	Construction Laborers	67.4%
47–2073	Operating Engineers and Other Construction Equipment Operators	69.4%
47–2152	Plumbers, Pipefitters, and Steamfitters	82.5%
47–5011	Derrick Operators, Oil and Gas	88.3%
47–5012	Rotary Drill Operators, Oil and Gas	80.8%
47–5013	Service Unit Operators, Oil, Gas, and Mining	88.0%
47–5071	Roustabouts, Oil and Gas	85.0%
49–3031	Bus and Truck Mechanics and Diesel Engine Specialists	37.1%
49–3042	Mobile Heavy Equipment Mechanics, Except Engines	66.5%
49–9041	Industrial Machinery Mechanics	39.5%
51–4012	Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic	35.8%
51–4041	Machinists	33.3%
51–4121	Welders, Cutters, Solderers, and Brazers	49.1%
51–4122	Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	38.0%
53–3032	Heavy and Tractor-Trailer Truck Drivers	68.8%
53–7032	Excavating and Loading Machine and Dragline Operators	70.5%
53–7071	Gas Compressor and Gas Pumping Station Operators	56.6%
53–7073	Wellhead Pumpers	37.8%
	Total for all high-demand occupations	**61.2%**

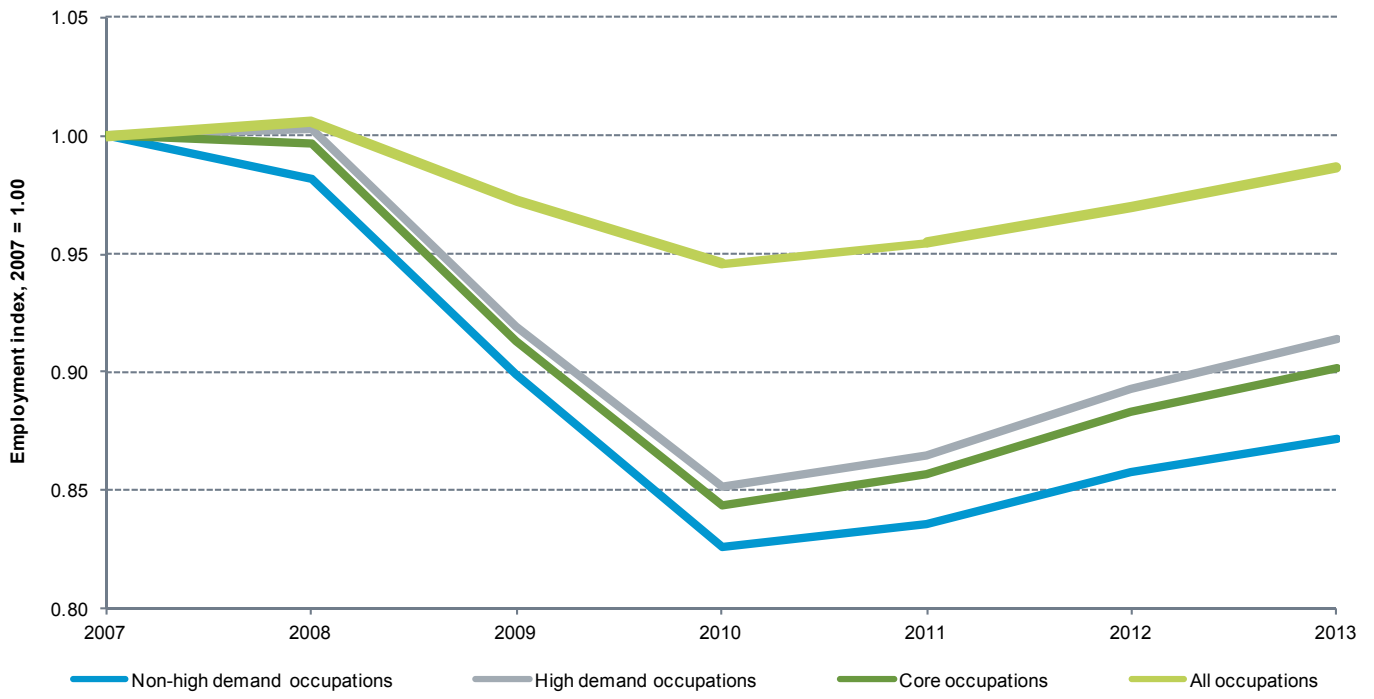
Source: Bureau of Labor Statistics and IHS

HDO employment trends, 2007–13

The figure below compares the employment trends for the HDOs versus trends for core occupations and all occupations in the United States from 2007 to 2013. It also shows total employment for the remaining 49 non-HDOs. Total employment in the core occupations was 8.3 million in 2013, about 6.2% of total US employment in all occupations. Employment in the 24 HDOs totaled 6.0 million in 2013, or 72% of core occupation employment.

Given that the HDOs were in demand by both the energy and manufacturing sectors, their employment levels declined a little less than for core occupations during the recession. Additionally, all of the core occupations—inclusive of the high-demand occupations—dropped substantially less than the noncore occupations. All the employment levels begin to trend upward after 2010, with the total number of HDO jobs growing a little faster than the total number of core occupation jobs.

US employment index by occupational categories



Source: Bureau of Labor Statistics and IHS

- It is important to restate our caution that the employment levels for the unconventional energy sector supply chain occupations are not exclusively workers that support unconventional energy activity. A complicating factor is that even when workers in core occupations are employed by firms supplying goods and services to the oil and gas industry, it is not always possible to distinguish which of those jobs are in unconventional energy development versus conventional oil and gas development. As both the labor shortage literature and the team's interviews point out, there is overlap in the workforce demands created by growth in both the conventional and unconventional energy industries, which require many of the same occupations and purchase inputs from the same industries, especially in the Gulf Coast region.
- Therefore, while the trends show that the HDOs are growing somewhat faster than the core occupations as a whole, and markedly faster than the non-HDOs, several other economic factors contribute to these trends, especially the post-recession rebound in manufacturing and construction. However, the evidence indicates that unconventional energy production is a contributor to these trends, especially in the states with major plays.

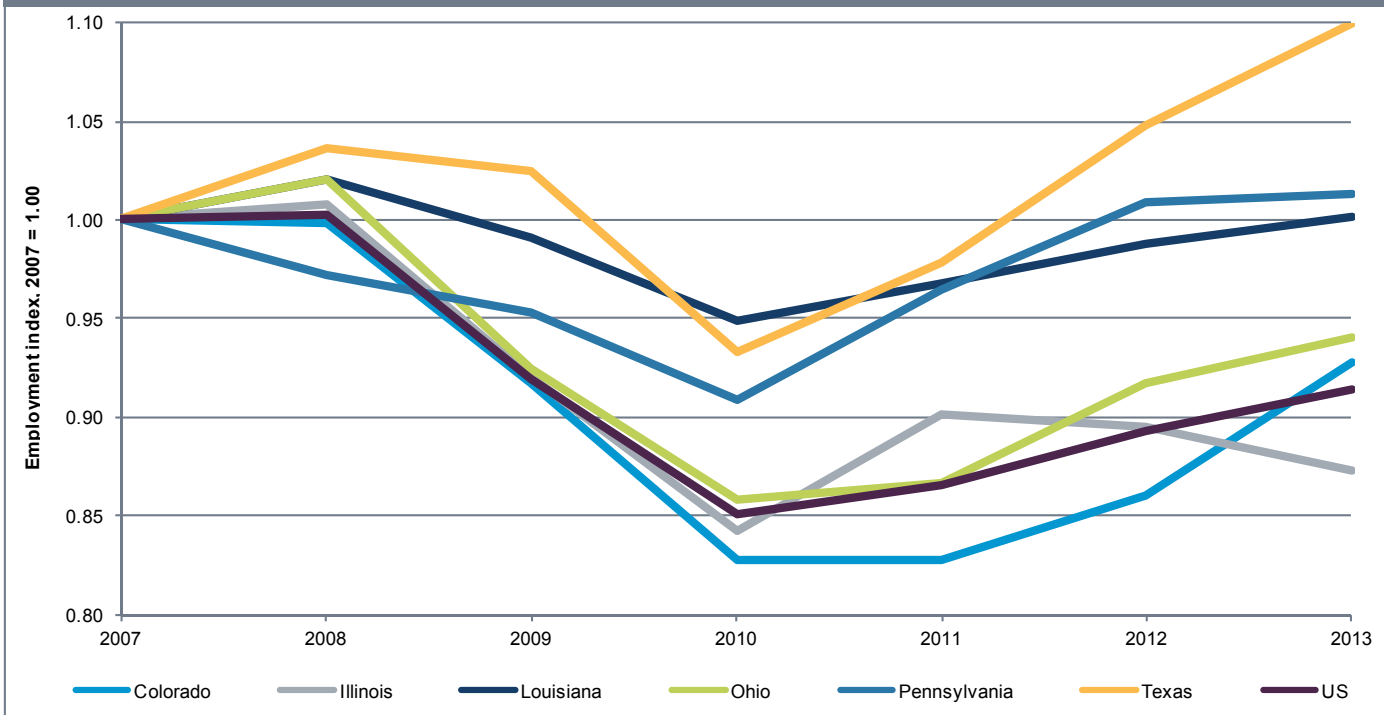
- It also should be emphasized that the exclusion of core occupations from the high-demand list does not imply that they are unimportant jobs in the unconventional energy supply chain. Inclusion on the list reflects a careful consideration of many different factors, based on statistical analyses, stakeholder perspectives reflected in the interviews and surveys, and the literature review. However, the other core occupations also contribute importantly to the various supply chain sectors, often alongside the HDOs.
- As discussed in the section on occupational distribution by sector above, although some occupations are important for multiple sectors, it is possible to discern "clusters" of occupations that are important to a particular sector or functional groups—e.g., construction of pipelines, well pads, and access roads, equipment manufacturing and distribution, professional services, oil and gas field services. In the tables above, listing the top 15 occupations for each core sector, HDOs (in bold text) are prominent, representing at least half of occupations on the lists. The greatest concentration is in the well services sector—12 of the top 15 occupations—and all of the top five—in terms of employment in the sector are HDOs.

State HDO employment trends

The list of core occupations and the subset of HDOs are generally consistent with similar lists compiled by individual states. However, the stage of development of the shale plays within state boundaries can influence which occupations may be of high priority at any point in time. Moreover, the differences may also be more localized to counties or communities in and around the geographic area defining the play. Studies of both the Marcellus Shale[55] and Eagle Ford Shale[56] identified different stages of shale play development, which in turn influences the levels and types of labor demanded by industries involved in exploring the plays.

The figure below compares employment trends for HDOs in the six states. Texas, Pennsylvania, and Louisiana lead the selected states—and the nation as a whole—in the growth and recovery trends for the HDOs, as

High-demand occupation employment index by state



Source: Bureau of Labor Statistics and IHS

55 MSETC. *Pennsylvania Statewide Marcellus Shale Workforce*: 20.

56 RRC. *Eagle Ford Task Force*; CCBR. *Workforce Analysis for the Eagle Ford Shale*.

they did for the full list of core occupations. This reflects their relatively higher level of development of both the conventional and unconventional oil and gas sectors and their associated supply chains. Employment in the HDOs in each state has been growing much faster than for most other occupations, in response to the unconventional energy boom. Thus it is reasonable to expect that the workforce readiness initiatives in Pennsylvania and Texas will be more advanced and developed than those of other states with less developed unconventional energy plays.

In contrast, Ohio and Colorado, as noted, are at earlier stages in the development of their unconventional energy resources. Ohio has gained already from the bordering Marcellus Shale development, and the Utica Shale play is just beginning to take off. Both states have a number of workforce initiatives that have been gearing up to support workforce needs in the unconventional energy sector.

HDO employment projections 2012–25

Drawing on the projections of core occupational employment above, the IHS team estimated employment changes for the HDOs. It used the same methodology that enabled estimates of occupational jobs that were actually supporting unconventional energy activity. In the initial state-level estimates of core and high-demand occupational employment, the figures represented the total number of jobs in an occupation in unconventional energy supply chain sectors, consisting of workers supporting both unconventional energy activity and activity in all other industries such as manufacturing and conventional energy.

HDO share of core occupational employment: 2012

Core sector	Percent
Well services	83.5%
Construction of upstream facilities and structures	82.0%
Construction of midstream/downstream structures	82.0%
Capital goods	57.1%
Materials	60.9%
Professional and other services	46.6%
Logistics	97.7%

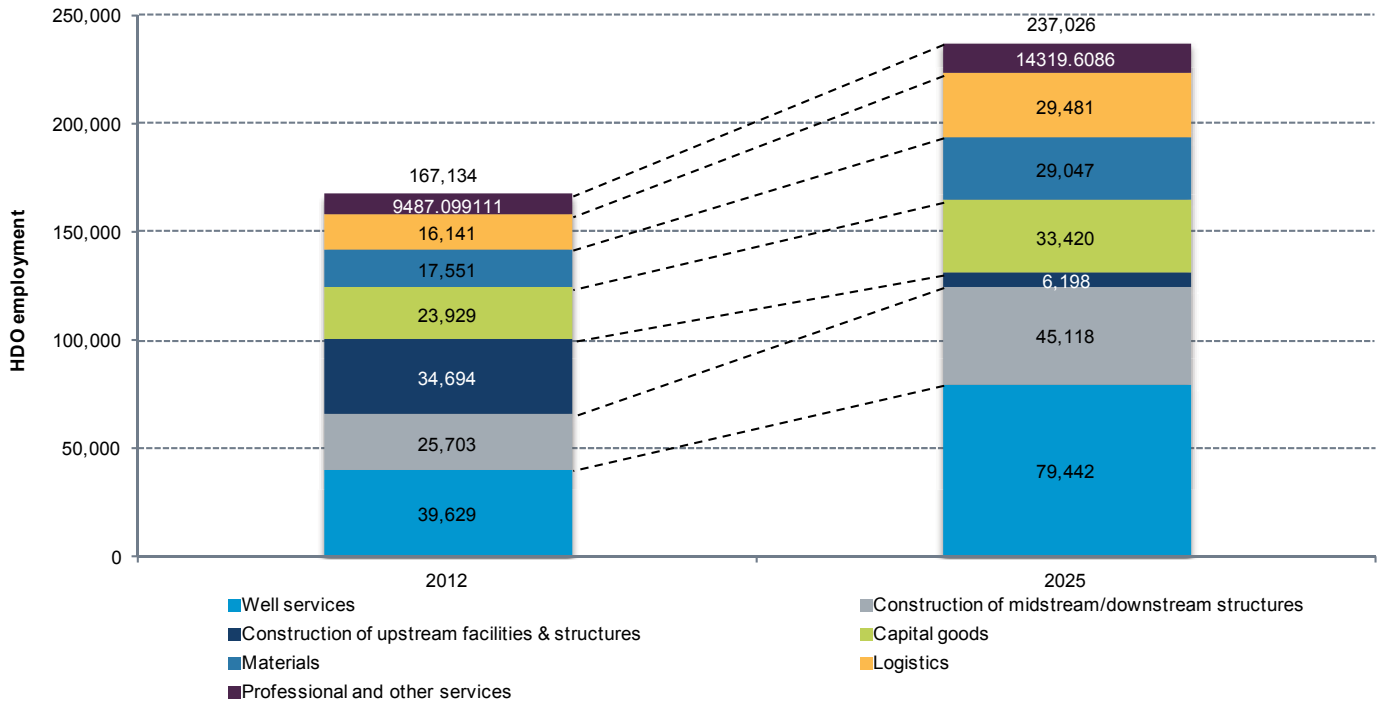
Source: IHS

HDOs accounted for 73% of total jobs in 2012, in core occupations engaged in actual unconventional energy supply chain activity. However, this share varies for the different core sectors, as shown in the table below. For example, the HDO share of core occupation jobs in the well services and construction sectors was in the low 80s in 2012, but was a bit lower in the professional and other services (47%), capital goods (57%) and materials (61%) sectors. On the other hand, in the logistics sector, HDOs account for nearly all jobs in core occupations, primarily because of the heavy and trailer-truck driver occupation, a HD that accounts for 98% of jobs in this core sector.

The HDO shares hold throughout the forecast period, 2012–25, for each core sector. For this reason, the HDO employment projection curves for the core sectors parallel the curves for core employment. Nevertheless, there is a dramatic shift in relative employment across some of the sectors, as illustrated in the following chart. Total HDO employment is expected to increase by 42%, from 167,100 in 2012 to 237,000 in 2025—an addition of nearly 70,000 new jobs are forecast, with an average annual growth rate of 2.8%.

However, while the well services sector is expected to have a doubling of its jobs in HDOs and a 76% increase in HDO jobs in the construction of upstream facilities and structures sector, HDO jobs in the construction of midstream/downstream would diminish by over 80%. HDO jobs, however, would grow substantially in the other core sectors: logistics would grow by 83%, materials by 59%; professional services by 51%; and capital goods industries by 45%.

Core occupational employment by core sectors



Source: Bureau of Labor Statistics and IHS

Although the HDO composition varies across the core sectors, the relative shares of HDO employment within each sector do not substantially change over the forecast period, 2012–25. The table below summarizes the relative shares of individual HDOs in total HDO employment in each core sector in 2025, which also reflects the potential demand for these occupations. The table also illustrates some of the clustering of occupations in the sectors:

- Construction laborers account for the largest number of HDO jobs in the construction and well services sectors, followed by first-line supervisors and operating engineers.
- Extraction occupations, such as service unit operators, also are prominent in this sector.
- Machinists account for the largest number of HDO jobs in the capital goods sector, and production occupations and mechanical engineers account for most of remainder.
- Production and construction occupations predominate in the materials sector, and mechanical engineers will be in high demand in the professional services sector.
- Heavy and tractor-trailer truck drivers account for 93% of jobs in the logistics sector, supported by bus and truck mechanics and diesel engine specialists, which account for 5%.
- The demand for truck drivers across all the sectors is evident, as is the demand across most of the sectors for bus and truck mechanics, mobile heavy equipment mechanics, industrial machinery mechanics, and welders.

HDO share of total HDO employment by core sector: 2025

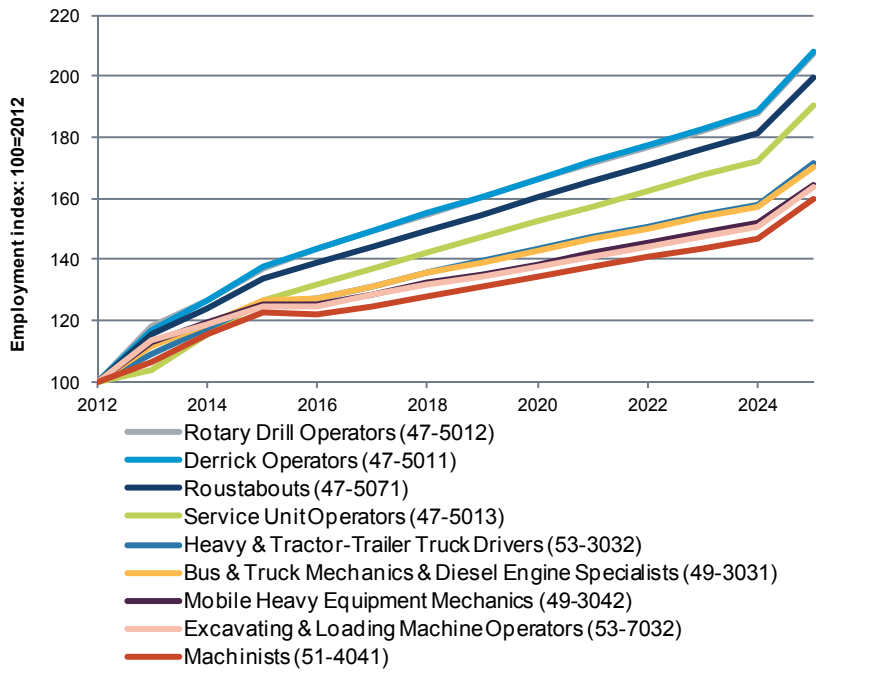
High-demand occupation	C&WS*	CG*	MTLS*	PrS*	LOG*
11-9021 Construction Managers	5.3%			4.4%	
17-2111 Health and Safety Engineers				1.0%	
17-2141 Mechanical Engineers		12.4%	2.5%	23.0%	
17-2171 Petroleum Engineers Total	1.0%			1.1%	
17-3023 Electrical & Electronics Eng. Tech.		2.3%		8.4%	
47-1011 First-Line Supervisors—Construction & Extraction	13.6%		5.7%	3.6%	
47-2061 Construction Laborers	**24.3%**		4.4%	5.5%	
47-2073 Operating Engineers & Other Equipment Operators	11.0%		18.4%	3.3%	
47-2152 Plumbers, Pipefitters, & Steamfitters	4.4%			5.5%	
47-5011 Derrick Operators	3.6%				
47-5012 Rotary Drill Operators	3.8%				
47-5013 Service Unit Operators	8.1%				
47-5071 Roustabouts	8.8%				
49-3031 Bus & Truck Mechanics & Diesel Engine Specialists		1.6%	1.9%	2.7%	5.3%
49-3042 Mobile Heavy Equipment Mechanics	1.4%	5.2%	4.9%	6.1%	
49-9041 Industrial Machinery Mechanics	1.3%	10.3%	7.7%	14.5%	
51-4012 CNC Machine Tool Programmers, Metal & Plastic		3.5%			
51-4041 Machinists		**34.7%**	5.5%	3.2%	
51-4121 Welders, Cutters, Solderers, & Brazers	2.7%	22.2%	8.0%	5.2%	
51-4122 Welding, Soldering, & Brazing Machine Setters, Etc.		4.0%			
53-3032 Heavy & Tractor-Trailer Truck Drivers	6.5%	2.3%	**24.6%**	11.4%	**92.7%**
53-7032 Excavating & Loading Machine & Dragline Operators	1.3%		13.6%		
53-7071 Gas Compressor and Gas Pumping Station Operators					
53-7073 Wellhead Pumpers	1.1%				
Other HDOs	1.9%	1.6%	2.9%	1.2%	2.0%

* C&WS: Construction and well services; CG: Capital goods; MTLS: Materials; PrS: Professional and other services; and LOG: Logistics.

Source: Bureau of Labor Statistics and IHS

It also is instructive to compare the employment projections for individual HDOs. The first figure (see "High growth high-demand occupations employment index") shows the employment projections for the nine HDOs that are forecast to have the highest growth rates over the forecast period. The second figure (see "Low growth high-demand occupations employment index") shows the employment projections for the nine HDOs that will have the lowest growth rates through 2025. For these comparisons, HDOs with at least 1% of the total number of HDO workers employed in the supply chain sectors were selected.

High growth high-demand occupations employment index



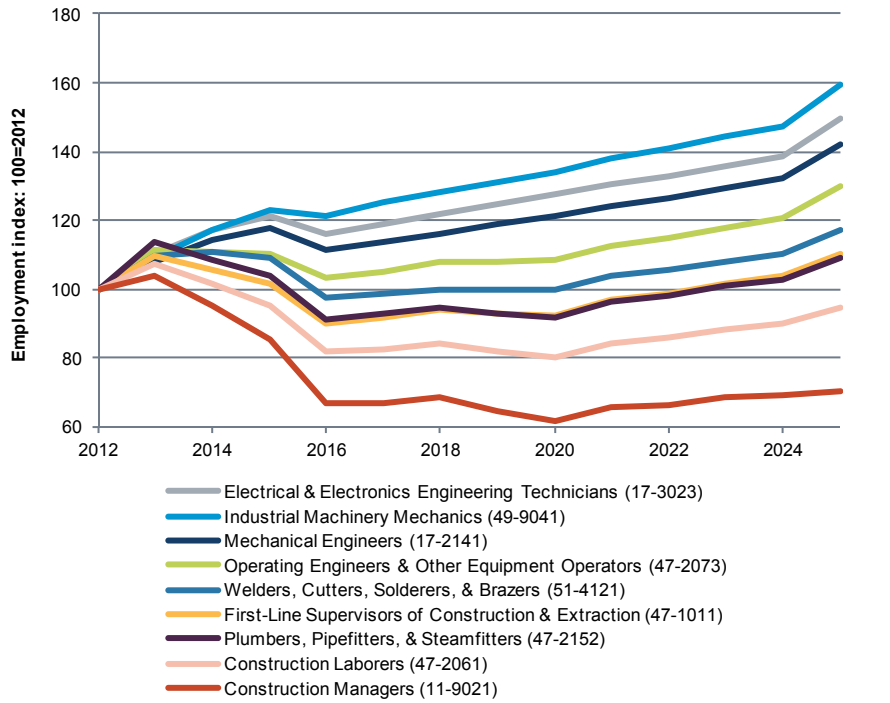
Source: Bureau of Labor Statistics and IHS

The projections shown in the figures reflect the demand for occupations due to forecast economic growth in the supply chain sectors, as discussed before. For example, the high-growth chart includes several well service occupations (derrick operators, rotary drill operators, service unit operators, roustabouts, excavating and loading machine operators) that are expected to grow along with the increase in upstream activity over the forecast period. Heavy-truck drivers, bus and truck mechanics and diesel specialists, and mobile heavy equipment mechanics reflect projected needs in logistics and materials supply chain activities, while machinists' growth reflects the importance of that occupation in the capital goods sectors in the supply chain. Not shown are well-pumpers and petroleum engineers, which start with relatively small employment levels but grow by 125% and 95%, respectively, between 2012 and 2025.

On the other hand, several important construction occupations (construction laborers, construction managers, first-line supervisors, plumbers, pipefitters and steamfitters, operating engineers) show an initial rise, but then fall off—sometimes rapidly—as midstream and downstream construction associated with unconventional energy activities are completed, and more economic activity is associated with upstream construction and well services. All of these occupations, except operating engineers, begin to dip below their 2012 employment levels. In the case of construction managers and construction laborers, employment levels never recover, though the trend for the latter starts to move upward after 2020, reflecting a resurgence in demand for these types of jobs.

Employment of operating engineers follows a similar trajectory, dipping down after 2014, but showing a steady growth after 2016, reflecting that HDO's importance for several core sector industries, especially materials production and transportation, as well as both upstream and midstream-downstream construction. Likewise, industrial machinery mechanics, the fastest growing of this group, show a modest but steady employment gain over the forecast period, reflecting its important role in the professional services, capital goods, and materials supply chain sectors. Mechanical engineering and electric and electronics engineering technician jobs follow similar patterns of growth (as do CNC machine tool programmers, metal and plastic, not shown in the chart).

Low growth high-demand occupations employment index



Source: Bureau of Labor Statistics and IHS

The welders, cutters, solderers, and brazers occupation presents an interesting special case, given its important role in construction, and also the great attention being paid to the perceived shortages for skilled welders—also very important in capital goods and materials production. Employment of welders in the supply chain dips down after 2014 and flattens out through 2020, before slowly ascending through 2025. (The growth pattern for welders, soldering, and brazing machine setters, operators, and tenders, not shown in the chart, is very similar, though employment levels are about one-eighth that of the welders, cutters, solders and brazers occupation.)

Replacement Needs

The forecast growth of employment for HDOs is a response to demand for goods and services provided by the unconventional energy supply chain, which in turn is due to forecast changes in unconventional energy activity. Thus, if employment for a given occupation is expected to grow, for example by 10,000 jobs, this figure indicates the number of net new workers with the skills required in that occupation that would need to be trained/educated and recruited.

However, this figure does not indicate the actual number of workers that may need to be hired at a given time, because of likely turnover in the workforce caused by a variety of factors. There is typically a certain amount of churning in the labor force, as workers change employers or occupations, go back to school, or leave the workforce for different personal reasons. Other factors, such as increased attrition due to retirement, which as noted above could grow to substantial levels as Baby Boomers retire, also increases the number of jobs that would need to be replaced, over and above increased (or decreased) demand due to economic growth (or decline).

The IHS team has estimated the replacement needs for core occupations by adopting BLS replacement needs projections, as described in the methodology section of this report (and elaborated in more detail in Appendix A). The table in Appendix B summarizes the findings of the projected growth and replacement analysis for all the HDO occupations. The table shows the HDOs listed in order of their total employment levels in 2012, with details about their projected growth over the forecast period and estimated job replacements. The table below

summarizes the results in Appendix B by showing the net employment change due to economic growth, and replacement needs for the 12 HDOs with the highest employment levels in 2012.

Overall, the IHS study showed that almost 70,000 new jobs in HDOs would be created between 2012 and 2025 due to forecast economic growth in unconventional energy activity. In addition, if replacement needs are factored in, supply chain employers could need to fill a total of at least 118,000 new jobs in HDOs by 2025.

As the table shows, heavy and tractor-trailer truck drivers are expected to have the largest increase in demand of all the HDOs, 19,800 jobs due to economic growth. However, close to 5,800 additional openings in this HDO are predicted to be created by 2025, for a total increase of nearly 25,600 jobs, a 92% increase over the 2012 employment level in this occupation. Most of the other occupations shown in the table also will have substantial replacement needs over and above the projected increase associated with economic growth.

Employment growth and replacement needs in top 12 HDOs*

High-demand occupations (SOCs)	Employment: 2012	Employment growth: 2012-25	Replacement needs: 2012-25	Demand due to growth & replacement needs: % of 2012
Heavy & Tractor-Trailer Truck Drivers (53-3032)	27,774	19,803	5,774	92.1%
Roustabouts, Oil & Gas (49-9041)	8,387	8,352	2,891	134.0%
Service Unit Operators, Oil, Gas, & Mining (47-5013)	8,604	7,766	4,527	142.9%
Machinists (51-4041)	8,973	5,341	2,671	89.3%
Operating Engineers & Other Equipment Operators (47-2073)	14,131	4,199	4,080	58.6%
Industrial Machinery Mechanics (47-5071)	6,440	3,826	2,417	97.0%
Mechanical Engineers (17-2141)	6,064	2,541	2,691	86.3%
Welders, Cutters, Solderers, & Brazers (51-4121)	11,630	1,968	3,710	48.8%
First-Line Supervisors-Construction & Extraction (47-1011)	14,986	1,504	2,100	24.0%
Plumbers, Pipefitters, & Steamfitters (47-2152)	4,954	445	802	25.2%
Construction Laborers (47-2061)	26,105	-1,402	7,262	22.4%
Construction Managers (11-9021)	6,157	-1,833	1,261	-9.3%

* Top 12 HDOs based on 2012 employment levels.

Source: Bureau of Labor Statistics and IHS

In contrast, the number of construction laborers and construction managers is projected to decline from 2012 levels. In the former case, although the number of laborer jobs is expected to decline by 1,400 by 2025 due to economic growth, replacement needs of close to 7,300 means that by 2025, there still will be net increase in demand of 5,900 new workers. For construction managers, the replacement need for over 1,200 jobs by 2025 will only partially offset the predicted decline of over 1,800 jobs, resulting in a net decline in employment.

Meeting the readiness challenge

This section of the report examines whether the unconventional energy supply chain sectors will be able to meet the workforce readiness challenges associated with rising demand and the increasing competition for skilled workers, which results from the expanding investment in unconventional energy production over the next decade. In the analysis above, the IHS-High Road Strategies team identified the core occupations most directly affected by economic activity in the unconventional energy supply chain. It then identified 24 occupations that are in especially high demand. Workers in these occupations perform important work in the supply chain sectors—some in fact are considered important across multiple core sectors. Many of these occupations require high levels of training and education to provide the requisite skills needed in the unconventional energy supply chain.

The rapid growth of unconventional energy production across the United States is largely concentrated in states with major shale plays, including Texas, Pennsylvania, Ohio, Colorado, and Louisiana, whose supply chains were examined in this study. In addition, the growth of supply chain activities in support of unconventional plays is being felt in nonproducing states with manufacturing, materials, professional service, and logistics businesses that contribute to the unconventional energy supply chain. Correspondingly, as the demand for critical skilled jobs grows around the nation, and in key producing and nonproducing states in particular, concerns have grown about the readiness of the nation's workforce education and training system at the national and state levels to adequately meet the skills needs of the supply chain.

These concerns, in addition, must be considered against the backdrop of a long-term, and growing, concern about labor shortages—i.e., "skills gaps"—in overlapping industrial sectors, such as energy, manufacturing, construction, transportation and professional services. These are sectors, in addition, that employ many workers in the same types of professions as the HDOs. Hence, confronted with growing shortages of these skills, the unconventional energy supply chain sectors will be facing stiffening competition for these types of workers from these other sectors.

Few of the stakeholders interviewed for this study expressed confidence that there will be an adequate long-term supply of skilled workers, given the demands from the continued investment in unconventional oil and gas activity. The large producing states are in particular challenged to provide the education and training programs needed to support a home-grown pool of trained workers for HDOs to service oil and gas operators and their supply chain. Employers, unions, and educational institutions in the large producing states, as well a few national and multistate collaborations, have responded to the challenge by initiating, expanding and strengthening workforce initiatives designed to increase the supply of skilled workers for the future development of unconventional oil and gas and the various elements of the unconventional supply chain.

These efforts take many different forms, involving various combinations of private and public sector participation, operating at the local, state, multistate and national levels:

- Community college, technical college and university programs, as well as union apprenticeships, frequently operate in partnership with energy-related companies and business trade associations.
- Most companies do some form of on-the-job training, but count on third-party providers (e.g., apprenticeships, community colleges) to provide basic technical knowledge and skills to qualify candidates prior to hiring.
- Consortia of workforce stakeholders, involving businesses, universities, community colleges, and other education and training providers—both national and state level—have come together to monitor and promote policies and programs to address the workforce challenges.

Below, a number of different initiatives at the national level and in the selected states are briefly described. The information comes not only from the literature, but also from many of the stakeholder and expert interviews conducted by the IHS team for this study.

Multistate initiatives

ShaleNET, the nation's leading and most ambitious initiative, is a consortium of education and training providers and businesses formed to respond to the natural gas industry's workforce needs. Although its original intent was to create an entry-level training program focused on five HDOs (roustabout, welders' helper, CDL, floor hand and production technician) it now "serves the highest demand occupations in upstream, midstream and downstream activities."[57]

The program was launched in 2010 with an initial $4.96 million Community Based Job Training grant awarded to Westmoreland County Community College (WCCC) in Youngwood, Pennsylvania, by the US Department of Labor Employment and Training Administration (ETA). By the close of the grant on June 30, 2013, more than 14,000 people had been served by 20 training providers in four states. It had trained over 5,000 participants with more than 3,400 finding employment.

In September 2012, ShaleNET received a follow-on ETA grant of $14.96 million through the Trade Adjustment Assistance Community College and Career Training (TAACCCT)[58] program, awarded to the Pennsylvania College of Technology in Williamsport, Pennsylvania. This grant is focused on expanding the initiative's capacity geographically and incorporating a new stackable credential model of training. Pennsylvania College partners with the Allegheny Conference on Community Development[59] to plan and implement the initiative. Other consortium members include Navarro College in Corsicana, Texas; Stark State College in Canton, Ohio; and the Pennsylvania Independent Oil and Gas Association (PIOGA).[60] Employers partnering with and supporting the initiative include Chevron, Shell, Anadarko, Petroleum Corp., Chesapeake Energy, XTO, and Encana.[61]

Gas Compressor Association (GCA) is a professional trade association "dedicated to the enrichment of its members and their industry," which encompasses products and services for the natural gas compressor market. The association includes compressor, driver, cooler and control panel manufacturers, packagers, and rental fleet owners located around the United States. Recognizing its members' need for qualified, well-trained individuals, GCA began partnering with colleges to help develop and maintain programs that will train new mechanics and operators. Using revenues from its annual GCA Expo and Conference, it has awarded $400,000 to its college partners, including Coffeyville Community College, Kansas; Lackawanna College, Pennsylvania; Oklahoma State University Institute of Technology, Oklahoma; Panola College, Texas; San Juan College, New Mexico; Seward County Community College, Kansas; Western Wyoming Community College, West Virginia; and Zane State College, Ohio.[62]

57 See www.shalenet.org.

58 TAACCCT was authorized in 2009 by Trade Act of 1974 as amended by the American Recovery and Reinvestment Act, and authorized to receive $2 billion over four years by the Health Care and Education Reconciliation Act in 2010. The program provides community colleges and other eligible institutions of higher education with funds to expand and improve their ability to deliver education and career training programs that can be completed in two years or less, to prepare workers for employment in high-wage, high skill occupations. http://www.doleta.gov/taaccct/]

59 See www.alleghenyconference.org. Also a ShaleNET partner, the conference was founded in 1944. With its affiliates—the Greater Pittsburgh Chamber of Commerce, Pennsylvania Economy League of Greater Pittsburgh, and Pittsburgh Regional Alliance (PRA)—the conference works to improve the economy and the quality of life in southwestern Pennsylvania. Its strategic is focus to create a more competitive business climate and marketing for the Pittsburgh region for investment, job creation and talent.

60 See www.pioga.org PIOGA, a partner in ShaleNET, is the principal nonprofit trade association representing Pennsylvania's independent oil and natural gas producers, marketers, service companies and related businesses. It represents over 950 members, who drill and operate the majority of the state's crude oil and natural gas, including the Marcellus Shale. These oil and natural gas producers, drilling contractors, service companies, manufacturers, distributors, professional firms and consultants, royalty owners, and other individuals with an interest in Pennsylvania's oil and gas industry.

61 See www.shalenet.org. In addition, ShaleNET is working with 15 Workforce Investment areas and their One Stops targeting 69 counties across Pennsylvania, West Virginia, Ohio, and New York (if/when the moratorium is lifted).

62 For more about the Gas Compression Association see www.gascompressor.org.

Appalachia Partnership Initiative (API) is a $20 million commitment by Chevron USA, Inc., to improve education and technical training to meet the workforce needs of the energy industry and related manufacturing industries in 27 counties across southwestern Pennsylvania, northern West Virginia, and eastern Ohio. Chevron and its partners will work to improve STEM education and technical training programs to develop a skilled workforce that can meet the needs of the energy industry and related manufacturing industries. Specifically, it is expanding its partnership with Project Lead the Way (PLTW), to build STEM programs in K-12 schools in nearly 20 schools in the tristate area in 2014–15. It will work with ShaleNET to develop workforce training programs for the oil and natural gas industry, providing scholarships at four community colleges. Finally, it will fund Carnegie Mellon University to develop an interactive science application to teach middle students about energy resources.[63]

Union apprenticeship programs play an increasingly important role in providing the skilled labor that oil and gas companies and their supply chains need to meet the growing demand driven by the unconventional boom. The energy companies originating in the Gulf Coast region in particular have historically not looked upon unions with much favor. However, pragmatic considerations and rising pressures to find workers with the requisite skills have increased the willingness of many employers to work with labor unions, especially to strengthen the workforce resources for unconventional energy development. Indeed, many of the employers interviewed have been working with union labor and depend on the unions' apprenticeship programs to ensure the availability of workers trained and tested in the skills required for the job.

Operating engineers represented by the International Union of Operating Engineers (IUOE) and construction laborers represented by the Laborers' International Union of North America (LIUNA) go through rigorous training programs run jointly by unions and employers. It is notable, for example, that in 2012, IUOE local unions and their employers invested approximately $107 million in apprenticeship and training programs.[64] The system usually combines on-the-job (OJT) and classroom training, and is generally regulated by the Department of Labor's Office of Apprenticeships or through state apprenticeship councils. This is the general workforce development model in place for these workers and for the other construction trades.

In addition to existing union apprenticeship programs, there is growing interest in increasing the number and availability of other types of apprenticeship programs that can help meet the growing demand for skilled workers in the United States. A report of the Center for American Progress argues that apprenticeship programs are "underutilized training tools in the United States." It notes that the US Department of labor administers a small system of 375,000 registered apprentices with about 100,000 new apprentices per year. By contrast, England starts with about 3 million apprentices per year.[65]

An important US program is the National Institute for Metalworking Skills (NIMS), which has worked closely with metalworking experts from firms and trade associations to develop industry-driven national skills standards and training curriculum for metalworking occupations. Employers can today offer a NIMS- Certified Registered Apprenticeship Program in 16 occupations, including machinists, toolmakers, and CNC setup programmers,[66] all highly relevant occupations for the unconventional energy supply chain.

Private-sector training programs are operated by private firms with histories of providing specialized training relevant to the energy sector, including its supply chain. Examples include"

- *Hobart Institute of Welding Technology* founded in 1930 in Troy, Ohio, is one of the best-recognized training programs for training in welding. The nine-month program graduates 300 students each year, 83% of whom have a job when they leave.[67]

63 See http://www.chevron.com/articledocuments/latest/news_206085/845c371c-7f48-4f3f-b071-bb509d373081/API-Fact-Sheet.pdf.cvxn.

64 Jeffrey Soth. "Testimony submitted by Jeffrey Soth, International Union of Operating Engineers to the Natural Gas Caucus, US House of Representatives." Washington, DC (March 26, 2014); Dan Shingler. "Union's Dirty Business Grows." Crain's Shale (www.SHALEmagazine.com) Spring 2014:18-20.

65 Sarah Ayres, "National Standards for Strong Apprenticeships." Center for American Progress, Washington, DC. August 26, 2014:2

66 Ibid.:4.

67 Philips. "Welders, America Needs You." See also the Hobart Institute of Welding Institute website, www.welding.org.

- *The Gas Technology Institute (GTI)* in Des Plaines, Illinois, is a research, development and training organization addressing energy and environmental challenges. Over its 70-year history, it has trained about 65,000 employees in a broad array of energy topics. GTI offers a full curriculum of gas distribution, gas transmission, marketing, and gas supply courses. It also conducts training in some junior colleges throughout North America on shale gas for individual companies and some of their new employees/service companies.[68]

- *Retrain America*, founded in 2009, provides technical and safety programs to the oil and gas industry focused on unconventional shale exploration and extraction. This includes training of existing employees (from entry level to engineer) on the latest safety standards and operational procedures, to retraining blue-collar workers and veterans for a new career path. Other programs include certification programs in shale exploration, shale engineering and rig safety.[69]

There are other initiatives aimed at addressing the need for training and certifying skilled workers more generally. For example, the Manufacturing Institute, an affiliate of the National Association of Manufacturers, has introduced a system of nationally portable, industry-recognized credentials called the Manufacturing Skills Certification System. This initiative involves 12 industry organizations that offer certification of specific skills in areas including machining, welding, fabrication, automation, fluid power mechatronics, and transportation.[70]

State programs

Businesses, unions, education and training providers, and government agencies in the large producing states, especially, have responded to the workforce challenges with a variety of initiatives:

- State agencies and university researchers track the growth of the unconventional energy sector, evaluate its economic impacts, and assess the workforce needs and challenges associated with the growing industry.

- Consortia and associations comprising business groups, education and training providers, community and economic development organizations, and other stakeholders have been formed to support initiatives to meet growing workforce demands associated with the development of regional shale plays.

- Businesses and unions have collaborated on strengthening apprenticeship programs in the HDOs needed by industry.

- Career and technical centers, community colleges, and universities have been building up their capacity to provide education and training programs, either as participants in consortia or in partnership with companies and industry organizations.

While the energy-producing states examined in this report are very active in expanding and growing new programs to train workers for core and high-demand occupations, they are at different phases and levels of development with regard to unconventional energy, which is reflected in the scale and types of workforce readiness initiatives they are engaged in. In any case, several of the more important workforce readiness or related initiatives in the four selected states—Texas, Pennsylvania, Ohio and Colorado—are reviewed, below. In addition, short summaries of the report's occupational results and workforce readiness initiatives for each state are available in Appendix D.

Texas workforce initiatives

Shale production has become the largest source of natural gas produced in Texas, rising from 1,264.7 billion cubic feet (Bcf), or 18% of gross natural gas production in 2007, to 4,017.3 Bcf, or 49% of gross natural gas

68 See www.gastechnology.org. GTI has locations in Washington, DC, Texas, Pennsylvania, Alabama, Massachusetts, and California.

69 See www.retrain-america.com.

70 Ayres. "National Standards":3.

production in 2013.[71] The Barnett Shale was the nation's earliest unconventional play and remains one of the largest producers of natural gas in the United States today. Production of natural gas from horizontal drilling and hydraulic fracturing took off in 2005, and natural gas production from Barnett wells increased from 380 Bcf to 1,911 Bcf in 2012. However, most of the excitement in Texas over shale energy in the past few years has been around development of the Eagle Ford Shale, which has included a great deal of attention to workforce challenges that could affect the full development of the play.

The Eagle Ford play encompasses 14 Texas counties directly and 20 counties indirectly, and is one of the largest oil and gas developments in the world. Assessments of the existing and projected workforce needs for the Eagle Ford have been carried out by Center for Community and Business Research (CCBR), Institute for Economic Development, at the University of Texas at San Antonio (UTSA),[72] and as part of a report by the Eagle Ford Task Force convened and chaired by Commissioner David Porter of the Texas Railroad Commission.[73]

Consistent with the IHS-High Road Strategies project team's findings, these assessments have noted that most in-demand jobs are for skilled labor or trades, with a significant need for technicians, gas measurement, welders, pipefitters, oilfield services, hydraulic machinery operators, and other service workers. As a Houston Chronicle article reports, "Machine shops, diesel repair shops, tire shops, truck sales, all infrastructure companies, and any company associated with the industry is seeing a major spike in demand for jobs."[74]

Industry, government, and the state's education and training system have responded by building on existing workforce programs as well as starting new initiatives bringing together stakeholders, and numerous community colleges are expanding their programs, all to help remedy potential labor shortages in a variety of high-demand occupations.

The Eagle Ford Shale Task Force was created by Texas Railroad Commissioner David Porter in 2011 to promote economic activity and establish best practices across the play. Throughout 2011 and 2012 it sought to address concerns and challenges that accompany the growing economy across South Texas. The Task Force comprises a diverse group of community leaders, local elected officials, water representatives, environmental groups, oil and gas producers, pipeline companies, oil services companies, landowners, mineral owners, and royalty owners. The findings of a report of the group published by the Texas Railroad Commission includes a major chapter on workforce development[75]

The Eagle Ford Consortium[76] comprises South Texans who seek to collaborate and maximize the benefits to the region and their communities of the Eagle Ford Shale development. Partners in this project include leaders in education and workforce development, industry, community and economic development, infrastructure and natural resources, community investment, and communications. Its stated objectives include developing and fostering effective lines of communications with oil and gas industry and local communities such as public schools, workforce training and education providers, and others; coordinating workforce and education efforts to improve employment of dislocated and underemployed workers; helping procure public and private resources to benefit workforce and community development efforts; and maximizing the economic opportunities to communities in the Eagle Shale region.

Workforce Solutions of the Coastal Bend[77] is a collaborative statewide network to assist both employers and employees during the recruitment and hiring process. Its network of partners and providers offers a wide range of no-cost and low-cost opportunities for employers and job seekers. One of its important efforts has connected employers with skilled workers in the Eagle Ford Shale.

71 See http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_stx_a.htm.

72 CCBR. *Workforce Analysis for the Eagle Ford Shale.*

73 RRC *Eagle Ford Task Force.*

74 Rebecca Maitland. "Oil and gas industry shows demand for skilled labor." Houston Chronicle (March 22, 2013). http://www.chron.com/jobs/article/Oil-gas-industry-shows-demand-for-skilled-labor-4377638.php .

75 RCT. *Eagle Ford Shale Task Force Report.*

76 See.www.eaglefordconsortium.org.

77 See www.workforcesolutionscb.org. Its services include recruitment services, job search assistance, training, child-care support, educational initiatives, and much more.

Texas community colleges are the backbone of the state's workforce development system (as in many other states). They seek to provide training and credentials to skilled technical and trades workers, with many programs geared toward preparing them for careers in energy. A sampling of these programs includes:

- *Alamo Colleges – San Antonio Area* offers associate degrees, certificates and licenses in programs that prepare students for jobs and four-year degrees;[78]
- *Coastal Bend College* has partnered with several organizations to provide field training to students who take various petroleum industry training courses, from CDL certification and petroleum safety and environmental hazards, to technology/ technician management and oil spill response.[79]
- *Laredo Community College* offers degrees and certifications in electrical technology, diesel engine mechanics, and an oil and gas industry specialization;[80]
- *Southwest Texas Junior College* offers associate degrees and technical certifications in diesel technology and welding.[81]
- *Del Mar College* offers various associate degrees, certifications, and continuing education, including training in a number of industrial skills.[82]
- *Victoria College* offers associate degrees and technical certifications in business, welding, and instrumentation technology.[83]

Other community colleges involved in energy sector workforce development include Navarro College, a partner in ShaleNET, and Panola College, an academic partner in the Gas Compressor Association (see above).

Major universities are also involved in training students for professional careers in the oil and gas and related sectors, such as petroleum engineering. These include Texas A&M International University (TAMIU),[84] the University of Texas at Austin, and the University of Texas at San Antonio (USTA). USTA also is home to CCBR, which has produced several studies assessing the economic and workforce impacts associated with the Eagle Ford.[85]

Pennsylvania workforce initiatives

The Marcellus Shale is the largest shale formation in the United States, spanning six northeastern states, including Pennsylvania. Since the first well was drilled in 2004, the Marcellus has helped make Pennsylvania the third-largest natural gas producer in the United States, after Louisiana and Texas. The state's gross natural gas production mushroomed from 182.3 Bcf in 2007 to 3,259.0 Bcf in 2013, mostly due to the Marcellus; shale gas production in the state rose from zero in 2007 to 3,048.1 Bcf in 2013.[86]

Concerns about finding adequately skilled workers for the burgeoning industry sector has spurred a great deal of activity in the state to monitor employment impacts and trends, identify and assess high-demand occupations associated with Marcellus development, and support workforce education and training in response to the rapid growth in demand for skilled labor. Pennsylvania businesses, universities and community colleges are actively participating in ShaleNET, which got its start at the Westmoreland County Community

78 See www.alamo.edu.

79 See www.coastalbend.edu.

80 See www.laredo.edu.

81 See swtjc.edu.

82 See www.delmar.edu.

83 See www.victoriacollege.edu.

84 See tamiu.edu.

85 See utsa.edu.

86 http://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_a.htm.

College and, now centered at the Pennsylvania College of Technology, is run with the help of the Allegheny Conference on Community Development. Other notable programs and initiatives in the state include the following:

Pennsylvania's Labor and Industry Departments' Center for Workforce Information and Analysis (CWIA) provides information and performs studies on the workforce requirements of the Marcellus Shale industry, including identifying and tracking supply and wages in key occupations. CWIA prepares an annual update each May on Marcellus Shale key facts, identifying key occupations and industry sectors by a six-digit NAICs code. It also puts out a quarterly publication *Marcellus Fast Facts*, which provides a quick snapshot of the labor market for Marcellus Shale industries and related economic activity. CWIA is not a job training organization but works closely with organizations such as Workforce Investment Boards, community colleges, etc., including ShaleNet, to supply labor force data that help them in their work.[87]

Shale Training and Education Center (ShaleTEC) is a collaboration between Pennsylvania College of Technology and Pennsylvania State Extension to serve as a central resource for workforce development and education needs of the community and the oil and natural gas industry. Its central operations are located in the Center for Business and Workforce Development on the main campus of Pennsylvania College in Williamsport. It changed its name from the Marcellus Shale Education and Training Center (MSETC) to ShaleTEC in the fall of 2012, because of the center's current and future industry expansion into other shale and tight-sand formations. ShaleTEC's main goals are to provide concise and accurate information for the public; offer workforce-development services to assist with the anticipated large increase in workforce needs of the industry; and to serve as a central access point for the industry to the resources of Pennsylvania State and Pennsylvania College.[88]

Pennsylvania College of Technology became an affiliate of the Pennsylvania State University in 1989, after establishing a national reputation for education supporting workforce development, first as a technical institute and later as a community college. Today, Pennsylvania College is committed to applied technology education. Located in Williamsport, Pennsylvania College enrolls nearly 6,000 students in bachelor, associate, and certificate programs relating to more than 100 different career areas. It also manages the state's largest worker training program through its Workforce Development and Continuing Education unit. Pennsylvania College is a founder and partner with Pennsylvania State Extension in ShaleTEC, and a member of ShaleNET.[89]

Westmoreland County Community College (WCCC), founded in 1970, and located in Youngwood, operates six off-campus education centers serving all of Westmoreland, Armstrong, Greene, and Indiana counties. Its enrollment includes approximately 6,600 full- and part-time students pursuing associate's degree, diploma, and certificate programs with options that prepare students for careers or transfer to baccalaureate degree programs at four-year institutions. WCCC led the consortium of educators and industry members to create ShaleNET in 2010, with an initial grant of nearly $5 million, for training programs for entry-level jobs in the Marcellus Shale industry.[90]

Ohio workforce initiatives

Ohio historically has been a moderate producer of oil and gas.[91] Its total annual natural gas production, primarily from conventional wells, peaked at nearly 160 Bcf in the 1980s, but has declined since, to 80–100

87 See www.paworkstats.state.pa.us.

88 See www.shaletec.org. ShaleTEC offers several short-term, noncredit, workforce training programs that meet specific industry needs and provide opportunities for local residents to train for positions in the industry: Classes include defensive driving; Fit 4 natural gas pre-employment training (roustabout); commercial driver training; API 1104 downhand welding; SafeLand USA; Certified Operations Technician; OSHA Rough Terrain Forklift Training; natural gas development and production overview; and OSHA 10-hour construction.

89 See www.pct.edu.

90 See www.wccc.edu. WCCC's Public Safety Training Center also has received $3.14 million in federal funding to support a natural gas training program

91 See US Energy Information Administration (EIA) state profiles: http://www.eia.gov/state/?sid=OH. EIA reported that Ohio had the seventh-largest crude oil refining capacity in the nation in 2013.

Bcf today.[92] Current interest in Ohio oil and gas exploration has shifted to two Ohio shale plays—the Marcellus Shale and the Utica Shale. The Marcellus Formation thins under Ohio, and its impacts are limited to the eastern counties. The Utica covers most of the eastern half of the state and is expected to have a larger impact across Ohio. However, shale oil and gas drilling has only recently begun to accelerate. Natural gas gross withdrawals from Ohio shale gas wells were initially very small (only about 10-17 million cubic feet [Mcf] between 2007 and 2010), but has recently taken off, reaching nearly 88 Bcf by 2013.[93]

While still small, the growth in shale gas production over the past few years is already having economic impacts, opening up thousands of new shale-related jobs, according to the Ohio Department of Job and Family Services (JFS). Compared to Pennsylvania and Texas, public and private sector efforts to assess and take advantage of these opportunities are only just getting started. As in the other states, state agencies such as JFS have been working closely with workforce investment areas, community colleges, other post-secondary educational institutions, and employers to identify the HDOs needing workers for the unconventional energy sector and to put in place appropriate training programs. Some of the more important of these initiatives are summarized below:

The Ohio Oil and Gas Energy Education Program (OOGEEP) is a statewide education and public outreach program. Created in 1998, OOGEEP provides a variety of programs throughout the state. These primarily focus on teacher workshops, scholarships, student education, firefighter training, industry training, workforce development, research, landowner and guest speaker programs. Providing factual information about the crude oil and natural gas industry, many programs have related curriculum and materials that meet state and national standards. OOGEEP is funded by Ohio's crude oil and natural gas industry through an assessment on the production of all crude oil and natural gas produced in Ohio.

Zane State College,[94] in Zanesville and Cambridge, offers a wide variety of two-year associate degree programs, certificate programs, workshops, and occupational skills training. Its EPIC program (Energy Exploration, Production, Innovation, Collaboration), launched in 2011, is a collaboration of educational institutions, public and private businesses, and government and community-based organizations with the goal of ensuring that Ohio is adequately prepared to meet the growing workforce needs in the energy field. It offers several two-year associates degree programs in technical trade areas, (e.g., oil and gas engineering technology, electrical/electronic engineering technology, welding and fabrication, and industrial maintenance technology), an energy maintenance technician certification, and several short-term certificates and courses commonly pursued in energy programs. Zane State is an academic partner of the Gas Compressor Association (see above).

Stark State College,[95] in Canton, provides associate degrees, certificates, and professional development. A ShaleNET partner, Stark State offers training programs in demand by oil and gas companies, along with their suppliers and support systems. These can include a wide range of credit and noncredit training programs, including many one-year certificates in ShaleNET programs (e.g., industrial process operation technology, petroleum industrial mechanics technology, petroleum technology, pipeline technician, production technicians). It also offers two-year associate degrees and one-year certificates in many related fields.

Career and Technology Education Center (C-TEC) of Licking County **is a state and federally funded one-year career and technical school** serving Licking County since 1974. There are 56 schools like C-TEC in Ohio. It offers some certificate programs for high-demand skilled trade jobs in the unconventional energy and supply chain sectors. C-TEC also receives industry funding. It has a partnership with Ariel Corporation, a privately owned gas compressor manufacturer, to provide training in precision assembly to build natural gas compressors. Ariel has built a new lab and equipment and C-TEC is helping train about 450 of Ariel's workers in a program for machinists and precision assembly at their company.[96]

92 Ibid.

93 Ibid.

94 See www.zanestate.edu.

95 See www.starkstate.edu/oilandgas.

96 Phone interview, C-TEC, June 3, 2014.

Central Ohio Technical College (COTC),[97] in Newark, offers a wide range of degree and certificate programs. In response to growing industry demand for skilled workers in the unconventional energy supply chain sector, COTC has expanded its training programs, adding 70 people to its welding program and 50 for machinist training. Certificate programs are designed by energy supplier companies that contribute to their costs.

Colorado workforce initiatives

Colorado's vast fossil fuel resources include the Niobrara Shale, with resource estimates as high as 2 billion barrels of oil. In 2013 it was the sixth-largest natural gas producer and seventh-largest petroleum producer in the nation. From 2007–13, crude production in the state rose by 146% and marketed natural gas production grew by 29%.[98] Much of the crude oil production is reported by the US Energy Information Administration (EIA) to be increasing with the use of horizontal drilling and hydraulic fracturing technologies. However, while total natural gas production also has been growing, only a relatively small fraction of that is from shale gas wells. Of the 1,604.9 Bcf of natural gas produced in Colorado in 2013, only 247.0 Bcf, or 15%, was produced from shale wells. In 2007, 138.3 Bcf was produced, 11% of total gross natural gas withdrawals.[99]

Energy is one of Colorado's most significant sources of economic activity with more than 122,000 people employed in the industry in 2012. Oil and natural gas extraction produced more than $12 billion in revenues and created more than 35,000 new jobs from 2003–13.[100] However, there does not yet seem to be the same level of concern about being able to fill high-demand positions in Colorado's energy and supply chain sectors as there is in the other states.

Nevertheless, Colorado's large and expanding oil and gas sector continues to fuel interest in initiatives to increase the supply of skilled workers to meet the workforce needs of the industry. For example, a Colorado energy industry report states, "Colorado's energy industry has an opportunity to increase the number of 'homegrown,' highly educated, skilled workers." It recommends that the industry partner closely with educational institutions to "encourage the education of a workforce that meets its needs."[101] Several initiatives with a focus on the workforce needs of upstream, midstream, and downstream energy-related industries are summarized below:

Colorado Online Energy Training Consortium (COETC)[102] was founded with a grant of $17.3 million from the Trade Adjustment Assistance Community College and Career Training Grant program of the US Department of Labor. The project is led by Community College of Denver and includes 14 other colleges across Colorado.[103] The consortium focuses on enhancing current energy-related programs with the goal of training highly qualified workers for businesses. The funds are being used for curricular redesign and technology to bridge the gap between existing workforce skills and emerging energy industry needs. The project also facilitates partnerships among energy-related businesses, community colleges, and local workforce centers to train unemployed and underemployed workers with skills for placement. The Colorado Department of Labor and Employment, representing its 10 regional workforce centers, is supporting the project. Employer partners include Chevron Alaska MidContinent, DCP Midstream, Anadarko Petroleum, Colorado Springs Utilities, San Isabel Electric, Platte River Power Authority, Next Era Energy, and several others.

97 See www.cotc.edu.

98 More than 87% of oil and gas activity in Colorado is concentrated in five counties, and 31 counties represent the remaining 13% of activity. See EIA state profile for Colorado: http://www.eia.gov/state/?sid=CO.

99 See http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_sco_a.htm.

100 Colorado Department of Natural Resources, Colorado Energy Office, and Colorado Department of Public Health and Department. *Colorado Energy Report 2014*. 2014 Colorado State Energy Plan, Denver, Colorado (www.colorado.gov):5.

101 BCS Incorporated. *Colorado's Energy Industry:21*.

102 See https://www.cccs.edu/partnering-for-success/trade-adjustment-assistance/taa-coetc/.

103 These include Aims Community College, Colorado Mountain College, Front Range Community College, Northeastern Junior College, Red Rocks Community College, Trinidad State Junior College, Pueblo Community College, Arapahoe Community College, Community College of Aurora, Community College of Denver, Lamar Community College, Otero Junior College, Morgan Community College, Pikes Peak Community College, and Colorado Northwestern Community College.

Aims Community College, with support of a $2 million grant in 2012 from the Department of Labor, has built and is operating a training facility to teach skills for the oil and gas production industry. Areas of study include oil and gas production; process technology; energy technology; team building; safety and loss prevention. Its advisory committee includes Noble, Encana, Halliburton, Anadarko, some smaller service companies, and the Weld County workforce center.[104]

Front Range Community College **(FRCC)**[105] offers associate degree and certificate programs that train students for careers in well-established and emerging industries. This includes Associate of Applied Science degrees and certificates in electromechanical and electrical power technology and welding technology. The former involves more than two dozen Colorado businesses and organizations. FRCC also has a welding program and also trains student in entry-level knowledge, job safety, and the "soft skills of teamwork and communication."

The Global Energy Management (GEM) Program at the University of Colorado Denver Business School is a hybrid-online Master of Science (MS) degree program designed to develop future leaders in the energy industry. Students who want an "energy MBA" enroll in GEM because it offers graduate business courses (accounting, finance, strategic management, marketing, economics, etc.) focused on the energy industry. The impetus for GEM, which is now 5 years old, was that key companies in Denver (Encana, DCP, etc.) saw potential leadership challenges tied to market growth, baby boomer retirement, and a smaller demographic of people getting into the energy industry.[106]

Colorado School of Mines, Colorado State University, University of Colorado, and University of Denver, which are the state's major research institutions, have engineering programs aimed at meeting the Colorado energy industry's workforce needs. Colorado ranks fifth in the nation in the share of its workforce engaged in engineering occupations, and the Colorado School of Mines is among the top 10 schools graduating petroleum engineers. In 2010, an estimated 9,288 students graduated with an engineering degree or certificate from Colorado academic institutions. In addition to training engineers, these research universities are also doing research relevant to the unconventional energy industry, in which students gain research experience that enables them to go into research and development positions within industry. For example, the Colorado Energy Research Institute at Colorado School of Mines has many student researchers working on developing cleaner solutions to unconventional energy production, including better management of produced water and methane emissions capture and control.[107]

104 See www.aims.edu/academics/aet/oil-gas/ The grant runs out at the end of September 2014, however. Phone interview, Aims Community College, May 29, 2014.

105 See www.frontrange.edu. Also, phone interview, May 27, 2014.

106 See www.ucdenver.edu/academics/colleges/business/degrees/ms/gem/Pages/ Overview.aspx. GEM's hybrid-online delivery method allows professionals from around the world to earn their master's degree. At the beginning of each quarter, GEM students travel to Denver for four days (Friday-Monday) to meet for classes. Students then return home and complete the remainder of their coursework in online collaboration.

107 Phone interview, May 30, 2014.

Conclusion

The IHS study, *Sizing the Unconventional Revolution*, found that unconventional oil and gas development is projected to grow at unprecedented levels through the next decade. Building on this work, the IHS-High Road Strategies project team examined the workforce implications of this growth, in response to employers across the supply chain increasingly concerned about the difficulty of finding workers with the needed skills. In particular, the team identified and evaluated major workforce readiness challenges, the critical occupational and skill shortages confronting employers throughout the supply chain, and the workforce development and training programs—public and private—initiated at the state and federal levels to address these challenges.

Workforce challenges

First, the project team identified eight workforce challenges that affect the ability of many unconventional oil and gas supply chain employers to fill high-demand occupations. The primary challenge is finding sufficient numbers of qualified *local* workers. Although state and local workforce readiness capacity has grown to meet rising demand for upstream skilled workers since energy firms first started drilling, a number of challenges still limit the availability of qualified local workers in many key occupations. In addition, as the economy recovers, supply chain employers face increasing competition for skilled workers from employers in other oil and gas and nonenergy-related construction, manufacturing, and transportation industries.

While the list of challenges is consistent across the states examined, the magnitude of the challenges varies in proportion to the stage of unconventional energy development in a producing state. The challenges also vary across industry sectors and occupations in the supply chain. Several challenges are not unique to the unconventional energy sector. Finding workers with "soft skills" and able to meet behavioral criteria, replacing an aging and retiring workforce, and the "cultural bias" in educational attitudes favoring four-year college degrees over career and technical education for trades workers, are commonly reported problems in the energy, construction, manufacturing and transportation, sectors that include key industries in the unconventional energy supply chain. Other challenges are more specific to unconventional energy supply chain activity, such as rapid technological change, difficult working conditions and worker burnout, and the standardization of operator qualifications.

Core and high-demand occupations

Second, the project team identified and evaluated 73 *core occupations* out of a wide spectrum of occupations throughout the unconventional oil and gas supply chain. These core occupations are defined as those most *directly* affected by changes in economic activity in the five core supply chain sectors; they encompass a wide spectrum of skill levels, education and training requirements, and wage and salary levels. While several core occupations are required in multiple sectors across the supply chain, others are concentrated in only a few. At the same time, in each core sector, a small number of occupations specifically relevant to its activities account for the bulk its employment.

The project team then identified 24 occupations that pose the greatest skill shortage challenge for supply chain employers. These *high-demand occupations* (HDOs) span all the upstream, midstream, and downstream industries in the unconventional energy supply chain. They account for most of the top-employing occupations in each of the five core sectors and nearly three-quarters of total jobs in the core occupations, though this share varies widely across sectors. Well services have the greatest concentration of HDOs, including *service unit operators*, *derrick operators*, *roustabouts*, *rotary drill operators* and *first-line supervisors*. Some occupations such as *heavy and tractor-trailer truck drivers* and *welders* are in high demand throughout the supply chain. Others, such as *construction laborers*, *operating engineers*, *petroleum engineers*, and *electrical and electronic engineering technicians*, are mainly found in specific sectors.

State occupational trends

- The composition of the core occupation and HDO lists are consistent nationally and across the states. However, the project team found that, in comparing states with large unconventional plays—Pennsylvania, Texas, Ohio, Colorado, and Louisiana—and Illinois, a nonproducing state—the employment levels of core and HDOs vary according to the state's industrial composition and stage of unconventional development. For each state, total HDO employment fell less than non-HDO employment in the recession years, 2007–10, and grew much faster after, 2010-2013. These trends reflect, first, the impact of the Great Recession on energy, manufacturing, and construction industries, and then the post-recession rebound in these sectors. The growth of unconventional activity clearly contributed to these trends, as well.
- Texas, Pennsylvania, and Louisiana, with higher levels of unconventional energy development, lead the states in core occupation and HDO employment growth.
- HDO employment in Ohio and Colorado, with less developed unconventional energy activity, has grown more slowly, and in Illinois it has never fully recovered from the recession.
- Texas, Louisiana and Colorado have higher employment in core construction and extraction occupations, reflecting both conventional and unconventional energy activity.
- Production jobs account for the greatest share of unconventional energy supply chain employment in the large manufacturing states of Ohio and Pennsylvania and nonproducing Illinois.
- It should be noted that these trends are for *all* workers employed in the core upstream supply chain sectors (four-digit NAICS), and not just workers directly engaged in unconventional energy supply-chain activities.

Employment projections and occupational demand

The methodology used by the project team in its employment forecasts over the 2012–25 period allows for a better estimate of occupational employment patterns at the national level than used to calculate recent employment trends, as the estimate reflects jobs *directly* engaged in unconventional energy supply chain activities. Total core occupation and HDO employment are each projected to grow by over 40% in the forecast period, the former from about 226,000 to over 324,000 jobs, the latter from about 167,000 to over 237,000 by 2025: an increase in demand for 70,000 new workers in HDOs.

The patterns of core and HDO employment reflect the patterns of economic growth for the core supply chain sectors projected by the IHS economic study. For example, jobs in well services—primarily extraction and some construction occupations—and in the construction of upstream facilities are expected to grow substantially, as the number of new wells continues to rise. Jobs in the other core supply chain sectors—capital goods, materials, logistics and professional services—will also grow at healthy rates. In contrast, employment in occupations engaged in the construction of pipelines, manufacturing facilities, and other structures is expected to decline after 2016, by over 80%, as most of the supporting infrastructure will have been built.

The employment forecasts for individual HDOs also reflect the relative demand for these occupations due to economic growth in the core sectors:

- Employment for well services, machinists in capital goods and materials, and heavy-truck drivers, bus and truck mechanics, and mobile heavy equipment mechanics in the logistics and materials sectors are projected to grow at the fastest rates.
- Employment for industrial machinery mechanics, mechanical engineers and electric and electronics engineering technicians—prominent in the capital goods, materials and professional services sectors—are expected to show modest but steady growth.

- Employment for construction managers and construction laborers will initially rise and then fall off as midstream and downstream construction is completed.
- Employment for operating engineers follows a similar trajectory, but will show a steady growth after 2016, reflecting that HDO's importance in several core sectors.
- Employment for welders—important in the construction, capital goods and materials sectors—high initially, falls after 2014, flattens through 2020, and grows slowly after.

The team's projections show that demand for most HDO jobs will grow because of *replacement needs* over the forecast period. Replacement needs is a measure of turnover in the labor force, as workers change employers or occupations, go back to school, retire, or leave the workforce for other reasons. Overall, supply chain employers might need to fill at least 118,000 new jobs in HDOs—from economic growth and replacement needs—by 2025. Heavy and tractor-trailer truck drivers would have the largest increase in demand—20,000 jobs due to economic growth and 6,000 openings due to replacement needs. Most other HDOs also will have substantial replacement needs in addition to projected job increases due to economic growth. However, some HDOs today, especially in downstream construction, may not be in high demand by 2025. For example, construction laborer and construction manager jobs are expected to decline, though because of replacement needs the former would see a net increase in demand, but the latter would still fall because of greater economic losses.

Workforce readiness challenge

The projected growth of employment in HDOs, due to both economic growth and replacement needs, raises questions about the capacity of the nation's workforce education and training system to meet employers' needs over the next decade. The major unconventional oil and gas producing states are especially challenged to provide the workforce programs needed to support local pools of trained workers in HDOs to service oil and gas firms and their supply chain.

A large variety of workforce initiatives have been started, expanded and strengthened, designed to increase the supply of skilled workers to meet current and expected growth in demand for HDOs. These take many forms, involving various private and public combinations in the unconventional energy sector, including employers, trade associations, labor unions, educational institutions, government agencies, and private workforce practitioners. Many are sponsored and operate at local and state levels, some are multistate, and a few are federally supported. Occupations targeted range from professional occupations (petroleum and mechanical engineers), to skilled construction and manufacturing trades (welders, machinists, operating engineers, pipefitters), to construction and extraction jobs (laborers and service unit operators), to transportation (truck drivers, diesel mechanics).

It was beyond the scope of the current study to evaluate the short, middle, and long-term capabilities of these programs to meet the projected demands for workers across the spectrum of HDOs. While there is a general consensus about the serious workforce challenges confronting unconventional energy supply chain employers, the sector so far appears to be keeping up with the demand. However, it remains unclear whether market forces are sufficient to meet the growing workforce readiness needs of the unconventional energy sector over the next decade, or whether some support from state and federal policies will be required to optimize the economic growth of the unconventional energy sector, which relies on the availability of a high-skilled, well-trained workforce throughout its value chain.

Appendix A: Methodology and approach

Identify core occupations

The first stage in our analysis was to identify a set of core occupations in the unconventional supply chain, defined as those that:

- Perform essential activities within the different economic sectors that comprise the supply chain;
- Directly affect a sector's level of output, as it would be reduced if some of the required jobs are not filled; and,
- Have specialized education, training, competencies, or skills, and/or experience requirements.

There is no standard, quantitative method for identifying core occupations because local labor conditions vary across the major unconventional energy formations. Most of the recent assessments of workforce needs in the unconventional energy sector, primarily done at the state level,[108] indicate that their lists of relevant occupations are primarily for the core drilling and extraction firms, though the assessments also identify some occupations in the upstream part of supply chain, usually referred to as ancillary industries. These assessments also add a caveat that their assessment does not include jobs in midstream industries that supply equipment, materials, or services used by upstream firms engaged in unconventional energy drilling, extraction and production.

For example, a 2011 assessment of workforce needs associated with the Marcellus Shale in Pennsylvania by the Marcellus Shale Education and Training Center (now the Shale Training and Education Center, or ShaleTEC) estimated that over 420 workers from nearly 150 different occupations are needed to perform all the operations required to produce gas from a single Marcellus Shale well.[109] It then notes that while its estimate may include most of the occupations directly associated with the drilling and completion process, it "does not include many of the indirect jobs that will be created in a variety of other occupations, ranging from providing legal advice to gravel quarrying to steel pipe fabrication."[110] As illustrated in the previous chapters of this study, all of these supplier sectors figure prominently across producing and nonproducing states.

Identifying the industries that comprise the supply chain for unconventional oil and gas development therefore was a necessary first step in determining the core occupations employed in those sectors. The list of industry sectors or NAICS codes that constitute the unconventional supply chain are presented in the first section of this study.

As a first step in identifying core occupations, we divided the individual economic sectors comprising the unconventional energy supply chain into nine functional categories based on similarities in the types of goods and services they provide:

1. Construction contractors;
2. Road building contractors;
3. Other transportation and distribution services;
4. Equipment manufacturers and dealers;

108 The exemption is the FMI study of the construction industry, which identifies occupations, but is broad and international in scope. See FMI Incorporated. *Skill Shortages.*

109 MSETC. *Pennsylvania Statewide Marcellus Shale Workforce*: 28

110 Ibid.

5. Material suppliers (steel, aggregates, sand, chemicals, cement);

6. Professional services;

7. Support services;

8. Transportation—crude oil and gas; and

9. Water and wastewater services.

Applying multiple criteria, IHS identified an initial list of 71 detailed occupations (out of 840 US Bureau of Labor Statistics [BLS] occupational categories) as core occupations in the unconventional energy supply chain.

Some occupations required by supply chain economic sectors are not on the core list, primarily because they have a large supply and did not meet the definition of core occupations. Most of these occupations are in the services-providing sectors such as lawyers, accountants and sales persons; while they are necessary parts of the supply chain, only small shares of them are directly involved in meeting demands from the unconventional energy supply chain at any one time. There are some localized exceptions, such as specialized legal services for obtaining leases or arranging contracts with land owners.

Interview and survey stakeholders

To validate and refine the initial list of core occupations, IHS solicited feedback from a range of stakeholder organizations through a series of interviews and a short survey. The goal was to draw on the experience and expertise of those organizations directly involved in the supply chain sectors, to

- Identify the most in-demand or high-priority occupations, both nationally and especially in the four states selected for focus in the study—Pennsylvania, Texas, Ohio, and Colorado—because of their large unconventional plays;
- Describe the workforce challenges confronting the supply chain sector; and
- Examine the workforce training and development efforts and capacity, especially in the selected states, to address growing workforce needs of the unconventional energy supply chain sectors.

Nearly 50 individuals representing over 40 stakeholder groups in the unconventional energy sector and/or its supply chain provided direct input for this analysis. These included business and trade associations, individual companies (such as construction contractors, equipment manufacturers, and distributors), labor unions, workforce education and training providers, government agencies, and others. Over 30 interviews (several involving multiple individuals) were conducted and 33 surveys were completed. While many respondents represented organizations that were national (if not international) in scope, or their organizations operated in multiple states, a large number were also engaged in unconventional energy activities in the four selected states.

The stakeholder interviews included questions designed to probe more deeply into the occupational needs of supply chain sectors, and the availability and adequacy of workforce development programs, especially in selected states, to meet perceived skill challenges. Specific questions explored included

- Which industry occupations are the most important, and why?
- What are the associated skills and training required to meet industry criteria?

- Which occupations currently present the greatest challenges for meeting the demand for workers with needed skills, and why?
- What is the pipeline for the core occupations in states with unconventional oil and gas plays?
- What are the strengths and weaknesses of current workforce programs in addressing the gaps in unconventional energy skills?

The survey was designed to supplement the interviews and quantitative analysis. Respondents were asked to review the initial list of core occupations and identify, from their own perspective, which occupations are very important, somewhat important, or not important for the unconventional energy supply chain. They were also asked to identify other occupations they considered important, which were not on the original list.

Review of literature and online resources

The IHS team conducted an extensive review of numerous reports, documents, and articles. Of particular value were multiple assessments of occupational needs and employment growth for unconventional oil and gas development in Pennsylvania,[111] Ohio,[112] Texas[113] and Colorado,[114] done either by academic research institutes or state agencies, and some sponsored by oil and gas industry associations.

Determine high-demand occupations (HDOs)

An important objective was to identify which in the list of core occupations are in especially high demand. The team compared the findings from multiple sources, including: 1) the statistical analyses; 2) interview and survey findings; and 3) the relevant literature, particularly studies evaluating workforce needs in Pennsylvania, Texas, and Ohio.

To provide further insight, the team compared several metrics that could indicate demand for a particular occupation and appeared to be growing within a state. The metrics included trends in employment levels – up, down or stationary; annual growth rates; location quotients; trends in annual wages; and comparisons to trends in noncore occupations. Upward trends are potentially indicative of high demand for certain occupations, but demand for them may also be coming from other industries, such as conventional energy production, manufacturing, and construction.

Increases in average yearly wages for an occupation, especially relative to other occupations, might suggest growing demand—or insufficient supply of candidates for that job. In the interviews and in some of the literature, it was frequently noted that the demand for some occupations in the unconventional energy sector had risen to such an extent—perhaps also reflecting difficulties in ramping up the supply for those jobs—that some workers in those positions were seeing dramatic increases in their wages compared to the norm and to other occupations. Again, there could be other factors affecting these trends, which also had to be considered.

A complicating factor in the analysis is the evolving nature of the types of unconventional oil and gas exploration and development and the different unconventional energy activities in different states. An academic expert on shale energy in Ohio found it difficult to respond to the survey because the "state is at a crossroads—moving beyond the initial drilling rush and into the earliest states of the midstream and downstream phases of the play. This requires different types of skills and workers to lay pipeline and operate chemical plants."[115] Another respondent said that Ohio is about two years behind Pennsylvania in the maturity

111 For example, see: MSETC. *Pennsylvania Statewide Marcellus Shale Workforce*; CWIA. *Fast Facts*; PIOGA. "Careers in Oil and Natural Gas"; Kaufman and Fisher. *Workforce Analysis Report*.

112 JFS. *Ohio Shale, Quarterly Economic Trends*; OOGEEP. *Oil and Gas Careers.*

113 RRC. *Eagle Ford Task Force*; CCBR. *Workforce Analysis for the Eagle Ford Shale*.

114 BCS Incorporated. *Colorado's Energy Industry*.

115 Phone interview and survey, Ohio University Voinovich School of Leadership and Public Affairs, June, 4, 2014.

of its unconventional energy sector, which added complications regarding workforce demands and skills in a play that is straddling three levels of development.[116]

Similarly, the ShaleTEC study of the Marcellus Shale identified three phases of development—a predrilling phase, a drilling phase, and a production phase—each having a different set of occupational needs and levels of employment. Likewise, the Eagle Ford Shale study identified similar distinct developmental phases—exploration, production and processing—creating varying levels of labor demand and evolving types of labor for individual industries. This in turn requires that education and training of workers remain flexible enough to accommodate the varying needs of industry.[117]

Employment forecasts for core and high-demand occupations

This section describes, step by step, the methodology used by High Road Strategies and IHS to forecast US employment in the core and high-demand occupations from 2012 to 2025 in the unconventional energy supply chain sectors.

Derive occupational employment shares by supply chain sector

IHS's Business Markets Insight (BMI) database has forecasts of occupational employment by four-digit NAICs sectors for the United States. The historic distributions of detailed occupational employment by economic sector in the BMI are based on the Bureau of Labor Statistics (BLS) matrices of occupational employment by four-digit NAICs code. We used these matrices to determine detailed occupational employment shares for all four-digit NAICs codes, including those in the supply chain.

The BMI database generates occupational employment forecasts by industry sector in several steps:

- Annual employment forecasts are prepared by four-digit sector through 2040 that serve as caps that the detailed occupational employment for that sector must equal.
- Historical BLS occupation by industry employment matrices are used to separate out the historic employment estimates for each four-digit NAIS code by detailed occupational code.
- Growth rates for each occupation, which apply across all the economic sectors, are derived using: 1) historical rates from BLS Occupational Employment Statistics (OES) data, and 2) growth rates in BLS recent 10-year occupational forecasts. The consensus occupational growth rates are then used to forecast annual occupational employment for each four-digit sector throughout the forecast period, producing unadjusted occupational employment estimates.
- The unadjusted annual occupational forecasts are then modified to fit within the annual sector totals determined in step 1.

Employment shares are estimated across all detailed occupations so as to accurately estimate how the future occupational mix within a single supply chain sector will change over time. Since growth rates vary by individual occupations, the relative differences between them determine each occupation's share of the total employment for a single economic sector in a specific year. We then calculated, for each four-digit NAICS sector by year, employment shares for all detailed occupational codes.

Forecast occupational employment by supply chain sector

The economic impact assessment prepared annual employment forecasts for the United States from 2012 through 2025 for the supply chain sectors. Each sector's annual total employment forecast was then multiplied by the occupational employment shares developed in the step above to derive annual estimates of

116 Phone interview, Zane State College, Ohio, June 26, 2014.

117 CCBR. *Workforce Analysis for the Eagle Ford Shale*: 11.

detailed occupational employment by supply chain sector by year. Estimates were extracted for the core and high demand occupations.

Estimate employment in supply chain sectors that supports unconventional energy activity

The economic impact assessment also provided estimates of the shares of US employment in 2012 in each supply chain sector that directly supported unconventional energy activity. The shares were derived using purchasing patterns estimated during the economic impact assessment that traced the share of each supply chain sector's total output that is used by the oil and gas production sector. The primary sources of purchasing patterns included:

- Input/output (I/O) coefficients, especially from the use table;
- State by state commodity flow data from IHS's Transearch database;
- Results from other recent IHS economic impact analyses of the unconventional energy sector that had described types and shares of intermediate inputs used;
- Assessments of IHS industry and energy experts with detailed knowledge of production process used to extract unconventional energy.

Because the IO coefficients were from 2007 (i.e., before the unconventional energy sector really began to grow), and also do not separate the oil and gas extraction production sector into conventional and unconventional components, it was necessary to use the sources listed in bullets two, three and four above to estimate purchasing demands attributable to unconventional energy activity.

The shares ranged from under 1% in many of the service providing sectors (e.g., equipment leasing, scientific and consulting services, and wholesale trade) to 4–8% in durable manufacturing sectors benefiting from capital spending, to over 18% in sectors closely connected to the level drilling activity such as 2131 – Support activities for mining. IHS estimates that total US employment in 2012 in the supply chain sectors, across all occupations, that directly supported unconventional energy activity was 532,491 jobs, of which 226,312 jobs were in the core occupations and 167,134 were in the high-demand occupations.

IHS assumed that the shares of 2012 employment in each supply chain sector that directly supported unconventional energy activity would remain constant through 2025. These shares may change over time as the unconventional energy sector matures and becomes more productive (i.e., fewer inputs such as steel, fracturing fluids, and water are needed per well installed), and as drilling activity plateaus and the required distribution infrastructure is completed. However, estimating how these shares could change is speculative, and in our judgment, the prudent decision is to use the current shares by supply chain sector. The share for each sector was then multiplied by its detailed occupational employment to derive estimates of occupational employment attributable to unconventional energy demands. Finally, the occupational estimates were summed across the supply chain sectors to derive totals by occupation.

For example, the number of jobs in code 11-9021 Construction Managers, one of the 24 high-demand occupations, is forecast to decline from 6,157 jobs in 2012 to 4,324 by 2025 as infrastructure construction to support unconventional energy declines, while employment in code 49-3042 Mobile Heavy Equipment Mechanics is forecast to grow from 3,530 jobs to 5,799 jobs over the same period. Employment in the 24 high-demand occupations is expected to rise from 167,134 jobs in 2012 to 237,026 positions by 2025, a net increase of 69,892 jobs generated by economic growth in the supply chain sectors that use them.

Forecast total demand for employment by occupation considering replacement need

While there will be substantial net increases in employment in 22 of the 24 high-demand occupations between 2012 and 2025, additional positions will also have to be filled due to replacement needs (e.g., retirements, workers switching to other occupations or dropping out of labor force, etc.). The replacement issue is important because workforce development programs will have train enough workers to meet the gross increase in employment, which is defined as the net change due to economic growth plus replacement needs. The project team estimated replacement needs, and then gross employment changes, for the core and high-demand occupations using occupation-specific replacements rates produced by the BLS. Their replacement rates between 2012 and 2022 were adjusted to show the percentage of each occupation's total 2012 employment that would have to be replaced each year; the annualized rates were then used to forecast replacement needs between 2012 and 2025. The total net increase in employment in high-demand occupations would be 69,892 jobs over the forecast period; an additional 48,423 positions would also have to be filled due to replacement needs, for a gross employment demand of 118,315 jobs. The five high-demand occupations with largest absolute increases in gross employment are heavy and tractor trailer truck drivers; service unit operators; roustabouts, oil and gas; operating engineers; and machinists (see table in Appendix B).

Appendix B: Employment growth and replacement needs in high-demand occupations

High-demand occupations ranked in terms of 2012 employment: Employment growth and replacement needs

High-Demand Occupations (SOCs*)	Employment: 2012	Employment growth: 2012-25	Percent employment growth: 2012-25	Job demand due to replacement needs: 2012-25	Net job demand due to growth and replacement needs: 2012-25	Percent job demand due to growth & replacement needs: 2012-25
Heavy & Tractor-Trailer Truck Drivers (53-3032)	27,774	19,803	71.3%	5,774	25,577	92.1%
Construction Laborers (47-2061)	26,105	(1402)	-5.4%	7,262	5,860	22.4%
First-Line Supervisors-Construction & Extraction (47-1011)	14,986	1,504	10.0%	2,100	3,604	24.0%
Operating Engineers & Other Equipment Operators (47-2073)	14,131	4,199	29.7%	4,080	8,279	58.6%
Welders, Cutters, Solderers, & Brazers (51-4121)	11,630	1,968	16.9%	3,710	5,678	48.8%
Machinists (51-4041)	8,973	5,341	59.5%	2,671	8,011	89.3%
Service Unit Operators, Oil, Gas, & Mining (47-5013)	8,604	7,766	90.3%	4,527	12,293	142.9%
Roustabouts, Oil & Gas (49-9041)	8,387	8,352	99.6%	2,891	11,242	134.0%
Industrial Machinery Mechanics (47-5071)	6,440	3,826	59.4%	2,417	6,244	97.0%
Construction Managers (11-9021)	6,157	(1833)	-29.8%	1,261	(572)	-9.3%
Mechanical Engineers (17-2141)	6,064	2,541	41.9%	2,691	5,232	86.3%
Plumbers, Pipefitters, & Steamfitters (47-2152)	4,954	445	9.0%	802	1,247	25.2%
Mobile Heavy Equipment Mechanics, Except Engines (49-3042)	3,530	2,269	64.3%	1,323	3,592	101.8%
Rotary Drill Operators, Oil & Gas (47-5012)	3,528	3,778	107.1%	1,852	5,630	159.6%
Derrick Operators, Oil & Gas (47-5011)	3,425	3,691	107.8%	1,797	5,488	160.2%
Excavating & Loading Machine & Dragline Operators (53-7032)	3,421	2,190	64.0%	360	2,550	74.5%
Bus & Truck Mechanics & Diesel Engine Specialists (49-3031)	2,411	1,691	70.1%	667	2,359	97.8%
Electrical & Electronics Engineering Technicians (17-3023)	1,681	831	49.4%	454	1,284	76.4%
Welding, Soldering, & Brazing Machine Setters, etc. (51-4122)	1,483	176	11.9%	472	649	43.7%
Petroleum Engineers (17-2171)	1,081	1,036	95.9%	354	1,391	128.6%
Wellhead Pumpers (53-7073)	963	1,200	124.6%	433	1,633	169.5%
CNC Machine Tool Programmers, Metal & Plastic (51-4012)	807	453	56.2%	294	747	92.6%
Health & Safety Engineers (17-2111)	516	20	4.0%	198	218	42.3%
Gas Compressor & Gas Pumping Station Operators (53-7071)	82	42	51.2%	40	82	100.0%
All sectors total	**167,134**	**69,891**	**41.8%**	**48,428**	**118,320**	**70.8%**

* SOC: Standard Occupational Classification

Source: Bureau of Labor Statistics and IHS

Appendix C: High-demand occupation profiles

- To provide further insight into HDOs and their role in the unconventional supply chain, selected high-demand occupations in the unconventional supply chain are briefly profiled below, with discussion of a few related core occupations that are not necessarily high-demand according to the current analysis.[118] These include both national projections and forecast demand for jobs in the unconventional energy supply chain sectors produced by the IHS-High Road Strategies project team.

Professional occupations

The upstream, midstream, and downstream sectors and many of its suppliers employ a large number of workers from a wide range of different professional occupations, including engineers, scientists, technicians, surveyors, lawyers, accountants and other professional services, most during upstream predrilling and drilling phases of energy production, transportation and refining. The equipment manufacturing and materials production sectors also employ many types of scientists, engineers, and technicians.

Petroleum Engineering is one of the most specialized, highly paid, high-demand occupations in the conventional and unconventional oil and gas supply chain. Petroleum engineers analyze oil and gas fields, determine drilling methods, monitor drilling and production of oil and gas, design equipment and processes, and oversee other tasks. Over two-thirds of petroleum engineers are directly engaged in oil and gas extraction, though many may work in architectural, engineering, and related services, petroleum and coal products manufacturing, other manufacturing, pipeline transportation, and other professional and business services.

According to the BLS's *Occupational Outlook*, petroleum engineers are required to have a minimum of a bachelor's degree, and received a median annual income of $130,280 in 2012, well above the national average of $46,400 for all occupations. Total US employment in this field was 34,910 in 2013. The total number of petroleum engineers employed in in the supply chain that directly supports unconventional energy activity was forecast by the IHS team to grow from 1,081 jobs in 2012, to 2,118 in 2025, a 96% increase—with replacement needs of 354 jobs. This is substantially greater than the BLS's projected growth of 26% of US jobs in this occupation between 2012 and 2022 that support all economic sectors, and even greater than the national average increase in jobs, of 11%.

Experts suggest, however, that attracting sufficient people to the field is not its biggest challenge. A report of the Society of Professional Engineers (SPE) notes that, "there may be a talent gap rather than a people shortage in the industry."[119] The number of students enrolled in petroleum engineering educational programs, from undergraduate to doctoral programs, has grown dramatically over the past decade, especially since 2008 when unconventional oil and gas development began to accelerate. Total enrollment in petroleum undergraduate programs in the United States grew fivefold between 2004 and 2014. A total of 300 bachelor's degrees in petroleum engineering were awarded in the United States in 2004; in 2014 it is expected to be a near record of 1,527 degrees.[120]

Over 20 schools offer undergraduate degrees in petroleum engineering. The top 10 account for three-quarters of all undergraduates.[121] The primary workforce concern is attracting and filling the number of faculty positions

118 BLS's Occupational Outlook Handbook website was the source of most of the information in occupational profiles, including the BLS's employment projections, 2012–22. See http://www.bls.gov/ooh/.

119 R. Chase and C. Reece. "2013 SPE Forum Series: 2020 Foresight—Ensuring Educational Excellence for Upstream Engineering Resources." Robert Chase is professor of petroleum engineering at Marietta College, Marietta, Ohio; C. Reece is SPE Management and Information Technical Director, ExxonMobil, retired. Chase and Reese were the SPE Forum Series chairpersons.

120 Chase and Reece. "2013 SPE Forum Series."

121 Ranked in order of total enrollment, they are Texas Tech, Oklahoma, Louisiana State, Colorado College of Mines, Texas A&M, Pennsylvania State, University of Texas, University of Houston, University of Louisiana Lafayette, and University of Tulsa.

that will be needed to train the growing student population in the field. The SPE study reports that the "feeder pool" of people with petroleum engineering doctorates attracted to academia is currently inadequate, with faculty vacancies likely to grow, as nearly two-thirds of the US petroleum engineering faculty will qualify for retirement in the next 10 years.[122]

Mechanical Engineers (MEs) are in one of the broadest engineering disciplines. MEs design, develop, build and test mechanical and thermal devices, including tools, engines and machines. They can develop and build mechanical devices for use in industrial processes and power producing and power-using machines, and work mostly in engineering services, research and development, manufacturing industries and the federal government. MEs need a minimum of a bachelor's degree, though a graduate degree typically is necessary for career advancement. MEs earned a median annual wage of $80,580 in 2012. ME employment in the United States was 258,630 in 2013. In supply chain sectors that directly supported unconventional energy activity in 2012, it was 6,604, and is projected to grow by 2,541, or 42%, by 2025. However, an additional 5,200 of job openings due to replacement needs will increase overall demand for new MEs by 86%. This occupation is especially important to the manufacturing companies that supply equipment and materials to the unconventional oil and gas operators.[123]

Electrical and Electronic Technicians help engineers design and develop computers, communications equipment, medical monitoring devices, navigational equipment, and other electrical and electronic equipment. They are primarily employed by manufacturing firms. This occupation earned a median annual wage of $57,850 in 2012, and typically requires a minimum of an associate's degree. Total US employment in this profession was 146,500 in 2012. Only 1,681 workers in this field were supporting unconventional energy activity in 2012, a figure is expected to grow by 831 by 2025, plus a replacement need of 454 jobs. Some in the unconventional energy sector observe that technological advances are likely to increase the need for workers with greater technology skills, which could drive up the need for mechanical engineers, for example, as well as for electrical and electronic technicians.

For example, the head of a community college program in Ohio identified electrical repair and maintenance workers as being in short supply along with information technology workers who can manage IT control systems and instrumentation.[124] Similarly, an executive from an oil and gas construction equipment manufacturer from Texas said the industry needs people who can "provide automation around mechanical processes, such as putting in sensors, automated controls, feedback mechanisms, and condition monitoring equipment. For example, for sensing pressures in fracking or drilling in harsh environments."[125] These technologies also are important to monitoring of drilling and environmental concerns important for the industry.

122 Chase and Reece. "2013 SPE Forum Series." See also Shelley DuBois. "Petroleum engineers: Big Oil wants you." *CNNMoney* (July 20, 2011)

123 In the IHS-High Road Strategies survey, 26 out of 31 respondents, for example, indicated that mechanical engineers were either "very important" or "somewhat important" occupations.

124 Phone interview, Zane State College, June 28, 2014.

125 Phone interview, Weir Oil and Gas Co., June 15, 2014.

Health and Safety Engineers develop procedures and design systems to prevent people from getting sick or injured and to keep property from being damaged. They combine knowledge of systems engineering and of health and safety to make sure that chemicals, machinery, software, furniture, and other consumer products will not cause harm to people or buildings. Health and safety engineers must have a bachelor's degree, typically in an engineering discipline such as electrical, chemical, mechanical, industrial, or systems engineering. The occupation's median annual wage was $76,830 in 2012, and it employed 23,850 workers in 2013. The supply chain employment that supports unconventional energy activity is projected to grow by only 20 jobs between 2012 and 2025, with additional replacement needs of about 200 jobs. Industries that employ health and safety engineers include professional, scientific, and technical services, building construction, and heavy and civil engineering construction.[126]

Other Scientific, Engineering and Technician Occupations have been identified as important in the unconventional supply chain, if not qualifying as high-demand:

- Scientific fields, including geoscientists, environmental scientists, and hydrologists;
- Engineering fields important to the supply chain, including chemical engineers, mining and geological engineers;
- Technician-level positions, including mechanical engineering technicians, chemical technicians, geological and petroleum technicians, and mechanical drafters.

Construction and extraction occupations

Construction services employ a large number of workers in a wide range of high-demand occupations, especially in the upstream and midstream part of the energy value chain. This includes constructing and maintaining natural gas pipelines; building well pads at gas extraction sites; building access roads, retention ponds, and other infrastructure; and laying temporary pipelines to move water and excavating materials, such as silica sands, used in hydraulic fracturing. Depending on the occupations, many workers in the sector (excluding managers and supervisors) require a high school diploma or equivalent, with little to significant on-the-job training (OJT), including apprenticeship. Many occupations however do not require completing high school, but do require short-term to medium-term OJT.

Construction Laborers and Helpers perform many basic tasks that require physical labor on construction sites. They may prepare construction sites by removing debris and possible hazards, digging trenches, backfilling holes, or compacting earth; help craft workers with their duties; and operate or tend equipment and machines used in construction. A representative of the Laborers International Union of North America local in Western Pennsylvania (LIUNA; which represents many workers in this occupation) noted that his members are engaged

126 This occupation was added to the list of high-demand occupations, in part because a large number of individuals from industry and academic workforce programs in the IHS-HRS interviews and survey identified health and safety engineers as being "very important" and "somewhat important."

in most of these operations. These include residual work, such as carrying pipes to and from, putting pipes in the ground, sandbagging to protect the coating of the pipes; clearing the right of way; and building roads, which involves shoveling the asphalt or concrete, checking the grade; and cleaning up after the pipe is laid.[127] Most laborers work full time. Their work is physically demanding, and they have had relatively higher rates of injuries on the job and illness.

The median annual wage for laborers was $29,160 in 2012. Construction laborer is the largest of the occupational categories in terms of employment. There were 1,284,600 workers employed as laborers in 2012. The supply chain employed 26,105 laborers in 2012 in the unconventional energy sector, but this number is expected to decline by 1,400 by 2025, a loss of about 5%. However, replacement needs of 7,300 push the total net new jobs that would need to be filled to 5,800. Most laborers' positions do not have any specific educational requirements, but usually require some OJT. Construction laborers are mostly generalists in their work, though some, especially those who operate machines and equipment, are more likely to specialize. Laying and protecting pipes in the construction of pipelines also requires a higher degree of skill and training.

Operating Engineers (OEs) drive, maneuver, or control heavy machinery used to construct roads, bridges, buildings or other structures. OEs operate one or several types of power construction equipment, such as motor graders, bulldozers, scrapers, compressors, pumps, derricks, shovels, tractors, or front-end loaders to excavate, move and grade earth, erect structures, or pour concrete or other hard surface pavement. They also may repair and maintain loading machines that dig sand, gravel, earth or similar materials, and operate trench excavators, road graders, or similar equipment.

There were 340,950 workers employed as OEs in the United States in 2013; OEs had a median annual wage of $41,870 in 2012. Supply chain employment supporting unconventional energy activity was 14,131 jobs in 2012. The IHS team has projected an employment growth of 4,200 which, combined with replacement needs of 4,080, results in an increased demand for 8,300 new OE jobs. Becoming an OE requires a high school diploma or equivalent, plus moderate-term OJT or three-four-year apprenticeships. After completion of this training they can then go on to become journeymen workers, which offers them greater flexibility and responsibility on the job. Like laborers, a high percentage of OEs belong to a union, the largest being the International Union of Operating Engineers (IUOE).

Construction equipment operators often need a commercial driver's license (CDL) to haul their equipment to various job sites. Related operator positions include *paving and surface equipment operators*, who control the machines that spread and level asphalt, and *pile-driver operators*, who use large machines mounted on skids, barges, or cranes to hammer piles into the ground. Both of the latter two occupations are on the core occupation list, but not identified as high demand.

Welders can work in construction sites and in manufacturing facilities. Their work entails welding and joining metal parts, as well as filling holes, indentations, or seams of metal products using hand-held metal joining equipment. Welding is a ubiquitous occupation. A related occupation, also on the core and high-demand occupation lists, is ***Welding, soldering, and brazing machine setters, operators and tenders***, who set up, operate, or tend welding, soldering, or brazing machines or robots.

It is widely agreed that welding is a high-demand occupation for the unconventional supply chain. The domestic oil and gas boom and subsequent build-out of new pipelines has dramatically increased the demand for skilled welders. In addition, a decade of attrition within the trade has left the United States with welders who largely lack the advanced skills needed to meet performance standards required by the oil and gas industry.[128]

Welders' median annual wage was $36,300 in 2012. The occupation had 352,250 US employees in 2013. Supply chain employment in the unconventional energy sector was 11,360 welders in 2012, which is projected to grow by 2,000 jobs by 2025, a 17% increase. An additional 3,700 job openings are expected by then due

127 Phone interview, LIUNA, Western Pennsylvania, June 2, 2014.

128 Philips. "Welders, America Needs You."

to replacement needs, making a total of 5,700 new welder positions to be filled by 2025. Welders need at minimum to acquire a high school diploma and varying degrees of OJT. Training can vary from a few weeks of technical school or OJT to several years of combined technical school and OJT. In 2013, manufacturing employed 61% of total welding jobs and construction accounted for 11%.

Plumbers, Pipefitters and Steamfitters install and repair pipes that carry liquids or gases to and in businesses, homes and factories. Pipefitters in particular install and maintain pipes that carry chemicals, acids and gases, mostly used in manufacturing, commercial, and industrial settings. The median annual pay for this group was $49,140 in 2012. A total of 351,380 workers are employed as plumbers, pipefitters, and steamfitters. Supply chain employment in unconventional energy was nearly 5,000 in 2012. This figure is projected to grow by less than 500 jobs by 2025, however, with replacement needs of an additional 800 workers. The minimum educational requirement is a high school diploma or equivalent plus a four-five-year apprenticeship. This occupation has a higher unionization rate than average, and is mainly represented by the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada.

Equipment manufacturing, maintenance, and repair

This functional group includes a range of occupations engaged in the construction services industry such as diesel mechanics and the service and repair of heavy equipment, and employees of equipment manufacturers and a number of equipment dealerships, and mechanics working for contractors.

Industrial Machinery Mechanics maintain and repair factory equipment and other industrial machinery, such as conveying systems, production machinery and packaging equipment. They also are called industrial machinery repairers or maintenance machinists, and their job is to keep machines in good working order. It numbered 306,860 employees in 2012, with a median annual wage of $46,920. The supply chain's employment in this occupation supporting unconventional energy was 6,440 workers in 2012, and is expected to grow by 59%, to about 9,800 by 2025, with additional replacement needs of nearly 2,400 new positions. Industrial machinery mechanics require a minimum of a high school diploma and long-term OJT—they usually need a year or more of education and training after high school, and some complete two-year associates degree programs in industrial maintenance.

Related occupations are *machinery maintenance workers,* who do basic maintenance and repairs on machines, clean and lubricate them, and perform basic diagnostic tests. Requiring at least a high school diploma or equivalent, employers may offer onsite training or send workers to local technical schools in addition to OJT. *Millwrights*, with total US employment of 38,680 in 2012, dismantle, repair, reassemble and move machinery in factories, power plants, and construction sites. This is a highly skilled occupation, which requires a high school diploma or equivalent and a four-year apprenticeship, usually offered by employers, local unions, contractor associations, and state labor departments.

Computer-Controlled Machine Tool Operators, Metal and Plastic, develop programs to control machining or processing of metal or plastic parts by automatic machine tools, equipment, or systems. Total US employment in this occupation in 2013 was 24,340 workers. Supply chain employment serving the unconventional energy sector was 807 in 2012, with expected growth of 453 by 2025, and replacement needs of 300 workers. This occupation is represented in several manufacturing-related industries, including machine shops, metal working, other fabricated metal product manufacturing, industrial, and aerospace.

Diesel Service Technicians and Mechanics inspect, repair, or overhaul buses or trucks, or maintain and repair any type of diesel engines. This includes mechanics working primarily with automobile or marine diesel engines. Diesel technicians are employed in motor vehicle, motor vehicle parts and supplies merchant wholesalers, and natural gas distribution industries. Several individuals, including from industry trade associations and companies, identified diesel mechanics as a high-demand occupation in the interviews and survey. For example, an off-highway equipment manufacturer and dealer in Colorado serving the oil and gas construction industry, considers mobile equipment mechanics and diesel mechanics the most important occupation. An executive from a large equipment distributors association said his "industry's greatest

need right now is for well-qualified equipment technicians" and noted that all his organization's "member companies recruit in all these classifications."[129]

Employment of diesel mechanics, which had a median annual wage of $42,320 in 2012, was 238,150 in 2013. Supply chain jobs in unconventional energy totaled 2,411 in 2012 and are expected to require another 1,700 due to economic growth by 2025, plus an additional 667 workers due to replacement needs. While many mechanics learn informally on the job, employers increasingly prefer applicants who have completed postsecondary training programs in diesel engine repair. Industry certification, while not required, can be an important requirement for hiring. Graduates usually advance to journeyman worker status, which gives them more control and flexibility in their jobs.

Heavy Vehicle and Mobile Equipment Service Technicians inspect, maintain, and repair vehicles and machinery used in construction, farming, rail transportation, and other industries. Vehicles and mobile equipment are critical to many industrial activities, including construction and railroad transportation. Various types of equipment, such as tractors, cranes, and bulldozers, are used to haul materials, till land, lift beams, and dig earth to pave the way for development and construction. Relevant industries employing these technicians are mining, quarrying, oil and gas extraction, and heavy and civil engineering construction. Compared with workers in all occupations, heavy vehicle and mobile equipment service technicians had a higher share of workers who belonged to a union in 2012.

Mobile Heavy Equipment Mechanics, Except Engines diagnose, adjust, repair or overhaul mobile mechanical, hydraulic, and pneumatic equipment such as cranes, bulldozers, graders, and conveyors, used in construction, logging, and surface mining industry. Principal employers include machinery, equipment, and supplies merchant wholesalers (the largest employer), commercial and industrial and industrial machinery and equipment rental and leasing. There were 116,590 of these mechanics employed in 2013. Supply chain employment in 2012 was 3,530 jobs supporting unconventional energy, with a projected growth of about 2,300 workers by 2025 due to economic growth, and replacement needs of 1,300 workers. The median annual wage for this occupation was $46,050 in 2012.

Machinists use machine tools such as lathes, milling machines, and grinders to produce precision metal parts. There were 391,130 machinists employed in the United States in 2013, who earned a median annual wage of $39,500 in 2012. The supply chain employed nearly 9,000 machinists in 2012 due to unconventional energy demands, which is expected to increase by 60% by 2025, plus an additional 2,700 jobs due to replacement needs. Machinery manufacturing is the largest employer of machinist and related occupations, followed by machine shops and transportation equipment manufacturing. Machinists must have at least a high school diploma or equivalent. More advanced positions, such as those that use computer-controlled machinery, require employees to have basic computer skills. Training is offered through employer-sponsored apprenticeship programs, and some community colleges and technical schools have two-year programs to train machinists.

Management and supervisory occupations

Several management and supervisory positions, especially in the construction sector, are in high demand, and expected to continue to be in demand as the unconventional energy sector continues to grow.

Construction Managers are first-line supervisors in the construction industry, responsible for planning, coordinating, budgeting and supervising construction projects from development to completion. Construction managers require a bachelor's degree in a construction-related field, plus construction experience—or alternatively, they can have a high school diploma and many years of work in construction trades. These workers are often called general contractors or project managers. The occupation commanded a median annual wage of $82,790 in 2012, and had 213,720 jobs in 2013. Supply chain employment was 6,157 workers in 2012 related to unconventional energy, with an expected net loss of 1,833 jobs by 2025 due to contraction

129 Phone interview, Associated Equipment Distributors (AED) Foundation, May 16, 2014.

in downstream construction, a 30 percent decline. After replacement needs are accounted for, there is still projected to be a net loss of 572 workers in this occupation across the supply chain.

Building construction, specialty trade contractors, and heavy and civil engineering construction are the largest employers of construction managers. However, construction managers are likely to be needed in larger numbers as overall construction activities increase due to population and business growth, the growing need for infrastructure improvements (roads, bridges, sewer pipe systems upgraded), and construction activity increases to match growing unconventional energy production.

First-line Supervisors of Construction Trades and Extraction Workers directly supervise and coordinate activities of construction or extraction workers. They generally are employed by nonresidential building constructing, building equipment contractors, and other building contractors involved in highway, street and bridge construction, and other heavy and civil engineering construction industries. In the oil and gas area, petroleum and petroleum merchant wholesalers, oil and gas extraction, and pipeline transportation of crude oil also employ these supervisors—and pay them the highest wages. There were 467,130 of these supervisors employed in 2013. Median pay for this occupation was $63,860 in 2012. Supply chain employment was 14,986 workers in 2012 that supported unconventional energy activity, and is expected to grow by 1,500 workers by 2025, with additional replacement needs of 2,100 field supervisors.

Industrial Production Managers is a core occupation not identified as a HDO. These employees plan and direct the activities used to create a wide range of goods, such as cars, computer equipment, or paper products. They oversee the daily operations of manufacturing and related plants. They are employed in various industries such as fabricated metal manufacturing, chemical transportation equipment, machinery and food manufacturing, and earned a median annual rate of $89,190 in 2012.

Transportation and materials moving occupations

The most important and ubiquitous transportation occupation is heavy and tractor truck-drivers, who are widely considered in high demand. Three important materials moving occupations on the high demand list are excavating and loading machine and dragline operators, wellhead pumpers, and gas compressor and gas pumping station operators. With only one exception, BLS projected these occupations to grow at somewhat higher rates than the US rate for all occupations through 2022.

Heavy and Tractor-trailer Truck Drivers transport goods from one location to another. Most are long-haul drivers and operate trucks with gross vehicle weight capacity exceeding 26,000 pounds, delivering goods over intercity routes, sometimes spanning several states. These truck drivers require a minimum of a post-secondary nondegree award, and must have CDLs. They earned a median annual wage of $38,200 in 2012. This core occupation had by far has the largest number of employees across all sectors, 1,585,300 in 2013. Supply chain employment was 27,773 workers in 2012 supporting unconventional energy activity, with an additional 19,800 new jobs expected by 2025, a jump of 71%, plus replacement needs of about 5,800 workers. According to the BLS job outlook, demand for truck drivers is expected to increase in oil and gas industries as more drivers are needed to transport materials to and from extraction sites.

Excavating and Loading Machine and Dragline Operators operate or tend machinery equipped with scoops, shovels, or buckets to excavate and load loose materials. Industries employing these operators include nonmetallic mineral mining and quarrying, highway street and bridge construction, other specialty trade contractors, natural gas distribution, and pipeline transportation of natural gas. They earned a median annual wage of $42,970 in 2012. Employment was 44,780 in 2013. Supply chain employment in 2012 was 3,411 workers supporting unconventional energy activity. An additional 2,200 jobs would be needed by 2025 due to economic growth, plus replacement needs of 360 workers.

Wellhead Pumpers operate power pumps and auxiliary equipment to produce flow of oil or gas from wells in oil field. Employing industries include oil and gas extraction and pipeline transportation of natural gas. There were 13,410 wellhead pumpers employed in US in 2013. Supply chain employment due to unconventional energy

demand was 963 workers in 2012, which is expected to increase by 1,200 workers by 2025, with replacement needs of a little over 400.

Gas Compressor and Gas pumping Station Operators operate steam, gas, electric motor, or internal combustion engine-driven compressors. They transmit, compress, or recover gases such as butane, nitrogen, hydrogen, and natural gas. They contribute to pipeline transportation of natural gas, oil and gas extraction, support activities for mining, and chemical and allied products merchant wholesalers. This is a small occupational group, with only 4,520 US employees in 2013. Supply chain employment in unconventional energy was also small, at 82 employees in 2012, with only an expected increase of 42 workers by 2025, plus replacement needs of 40 jobs.

Oil and gas service occupations

These are upstream jobs directly associated with oil and gas extraction and related activities. In all cases, the BLS growth rate is substantially higher than the US average for all occupations.

Derrick Operators run rig derrick equipment and operate pumps to circulate mud through drill holes, and extract oil and gas. US employment was 22,400 in 2013. Supply chain employment serving the unconventional energy sector was 3,425 workers in 2012, with an expected growth of 3,700 new positions by 2025 due to economic growth, plus replacement needs of 1,800 new positions

Rotary Drill Operators set up or operate a variety of drills to remove underground oil and gas, or remove core samples for testing during oil and gas exploration. Employers include oil and gas extraction, and petroleum and coal products manufacturing. US employment was 27,130 in 2013. Supply chain employment was 3,528 jobs in 2012 related to unconventional energy, with a projected growth of 2,300 new jobs by 2025, and replacement needs of 1,850.

Service Unit Operators operate equipment to increase oil flow from producing wells or to remove stuck pipe, casing, tools, or other obstructions from drilling wells. They may also perform similar services in mining exploration. Principal employers include oil and gas extraction, machinery, equipment, and supplies merchant wholesalers, commercial and industrial machinery equipment rental and leasing industries. It had 59,260 US employees in 2013. Supply chain employment supporting unconventional energy in this occupation was 8,604 jobs in 2012, with projected growth of 7,800 jobs, a 90% increase, and replacement needs of over 4,500 additional new jobs, by 2025.

Roustabouts repair oil field equipment using hand and power tools, and perform other tasks as needed—oil and gas extraction, support activities for mining, machinery, equipment, and supplies merchant wholesalers. It had 68,230 US employees in 2013. The supply chain employed 8,387 roustabouts in 2012 serving the unconventional energy sector, and is expected to add approximately another 8,400 positions, with replacement needs of 2,900, by 2025. Taken together, total job openings due to economic growth and replacement needs will equal over 11,000 jobs over the forecast period, equal to a 140% increase by 2025.-

Appendix D: Major producing state occupation and workforce readiness summaries

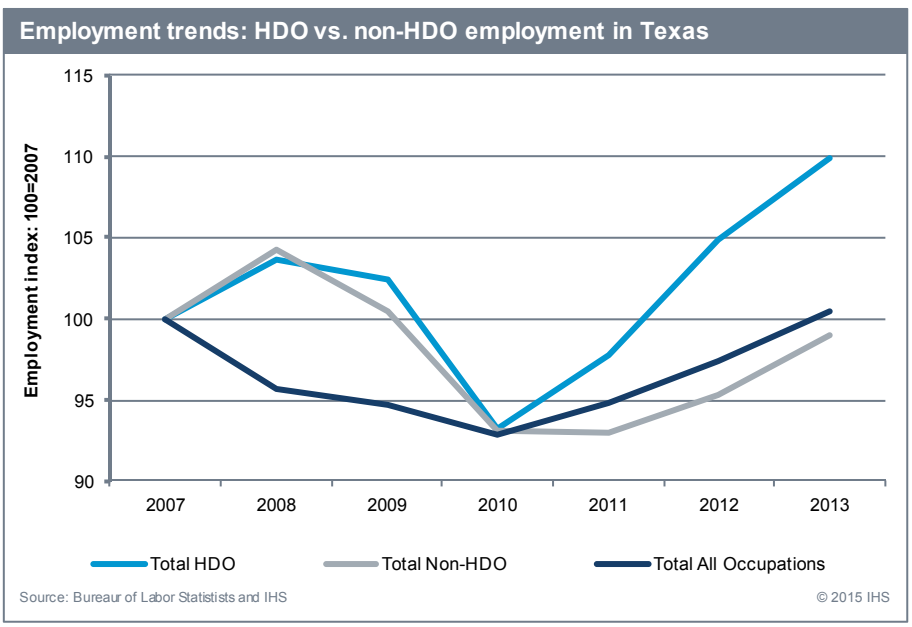
1. Texas summary

Texas has been the leading producer of oil and natural gas in the United States since reserves were first discovered there in the early 1900s. Once hydraulic fracturing technology proved capable of extracting oil and natural gas from tight rock formations in commercial quantities at competitive costs during the 1990s, exploration and drilling grew rapidly in Texas's shale plays, especially the three largest: Haynesville/Bossier, Barnett, and Eagle Ford, and in the Permian Basin in the western part of state. The Barnett was the nation's earliest unconventional play and remains one of the largest producers of natural gas in the country. In recent years, exploration and production has shifted to the Eagle Ford Shale, one of the largest oil and gas developments in the world.

According to the US Department of Energy, in 2013 Texas produced 8.211 trillion cubic feet (Tcf) of natural gas, highest among the states, with 4.017 Tcf (48.9%) coming from shale formations. In 2007 Texas already had a well-established unconventional energy sector, producing 1.265, Tcf of natural gas from shale, yielding an average annual growth rate of 21.2% through 2013. Texas also produced 2.54 million barrels per day (MMb/d) of crude oil in 2013, again highest among the states and 33.9% of total US production.

Core and high-demand occupations

Texas has both a large, mature conventional energy and an unconventional energy sector, so it already has significant employment levels in the core and high-demand occupations (HDOs). As shown in the chart, Texas's employment in all occupations fell slightly from 2007–10, while in the core and HDOs*—71% of core occupation employment—it rose through 2008 before declining somewhat. Employment levels fell less in Texas after 2007 than virtually any other state because its economy was less affected by the Great Recession. Even the construction and manufacturing sectors that were especially hit hard nationally by the recession, and that have highest shares of core and HDO jobs, were less affected in Texas. Occupational employment in all sectors, especially in HDOs, began to recover in 2011 so that by 2013 employment levels were above prerecession values—though employment in the 24 HDOs had grown substantially faster than in the remaining 49 core (non-HDO) occupations.



The top 10 HDOs in Texas in 2013 in terms of employment* were *heavy and tractor-trailer truck drivers* (157,260), *construction laborers* (108,160), *first-line supervisors of construction and extraction workers* (57,050), *welders* (47,040), *operating engineers* (36,850), *machinists* (33,480), *plumbers, pipefitters and steamfitters* (31,740), *industrial machinery mechanics* (30,510), *roustabouts, oil and gas* (30,290), and *construction managers*

(29,380). Together the top 10 HDOs accounted for 78.5% of total HDO employment and 58.4% of total core occupation employment in 2013. The rising demand for goods and services needed by Texas's conventional and unconventional energy sectors contributed to the sharp upward trend in supply chain employment, as shown in the chart.

The employment levels in the core occupations and their distribution by major occupational category vary across the states due to the structure of economies, especially in manufacturing, and the scale and maturity of conventional and unconventional energy activities. Production occupations' share of total core occupation employment in Texas in 2013 was 19.4%, lower than in the other traditional manufacturing states such as Illinois, Ohio, and Pennsylvania, and below the US share. In contrast, employment in construction and extraction occupations was 37.3% of Texas's total core employment, second highest among the six states (Colorado, Illinois, Louisiana, Ohio, Pennsylvania, and Texas) considered in this study. The high share of core occupation employment in the construction and extraction occupations is in part because of the state's large energy sector, and because the level of construction activity in Texas was relatively unaffected during the Great Recession. Figures in the table are for total employment in each individual core occupation in the state across all industries— not all of the workers in the core occupations directly supporting unconventional energy activity.

Core occupation employment by major occupational category: 2013—Texas

Occupational category	Texas		United States	
	Numer of jobs	% total	Numer of jobs	% total
Management	41,050	4.3%	379,060	4.6%
Architecture and Engineering	80,960	8.4%	721,500	8.7%
Life, Physical and Social Science	31,730	3.3%	242,190	2.9%
Construction and Extraction	358,740	37.3%	2,525,470	30.5%
Installation, Maintenance and Repair	86,310	9.0%	830,730	10.0%
Production	187,000	19.4%	1,865,030	22.5%
Transportation and Material Moving	176,110	18.3%	1,708,920	20.7%
Total	**961,900**	**100.0%**	**8,272,900**	**100.0%**

Source: Bureau of Labor Statistics and IHS

Workforce readiness initiatives

Because of the size and maturity of its conventional and unconventional oil and gas sectors, Texas has a wide range programs designed to prepare workers for employment in them and in their accompanying supply chains. Some of the major workforce programs are summarized below.

- ***The Eagle Ford Shale Task Force*** was created to promote economic activity and establish best practices to meet the demands from the Eagle Ford play. It involves a diverse group of stakeholders. The findings of a recent report included a major chapter on workforce development.

- ***The Eagle Ford Consortium*** was created to maximize the regional economic development benefits of the Eagle Ford Shale play. Among other issues, it addresses workforce training and education needs; seeks to increase employment of dislocated and underemployed workers; and helps obtain public and private resources for workforce development efforts.

- ***Workforce Solutions of the Coastal Bend*** is a collaborative statewide network formed to assist both employers and employees during the recruitment and hiring process. Its network of partners and providers offers a wide range of no-cost and low-cost opportunities for employers and job seekers. One of its important efforts has connected employers with skilled workers in the Eagle Ford Shale.

- ***Texas community colleges***, as the backbone of the state's workforce development system (as in many other states), work especially hard to provide training and credentials to skilled technical and trades workers, with many programs geared toward preparing them for careers in energy. A sampling of these programs includes:
    - *Alamo Colleges – San Antonio Area* offers associate degrees, certificates and licenses in programs that prepare students for jobs and four year degrees.
    - *Coastal Bend College* has partnered with several organizations to provide field training to students who take various petroleum industry training courses, from CDL certification and petroleum safety and environmental hazards, to technology/ technician management and oil spill response.
    - *Laredo Community College* offers degrees and certifications in electrical technology, diesel engine mechanics, and an oil and gas industry specialization.
    - *Southwest Texas Junior College* offers associate degrees and technical certifications in diesel technology, and welding.
    - *Del Mar College* offers various associate degrees, certifications, and continuing education, including training in a number of industrials skills.
    - *Victoria College* offers associate degrees and technical certifications in business, welding, and instrumentation technology.
    - Other community colleges involved in energy sector workforce development include Navarro College, a partner in ShaleNET and Panola College, an academic partner in the Gas Compressor Association's national workforce program. Several major universities are also involved in training students for the oil and gas and related sectors, including: Texas A&M International University (TAMIU), the University of Texas at Austin, and the University of Texas at San Antonio (USTA).

2. Pennsylvania summary

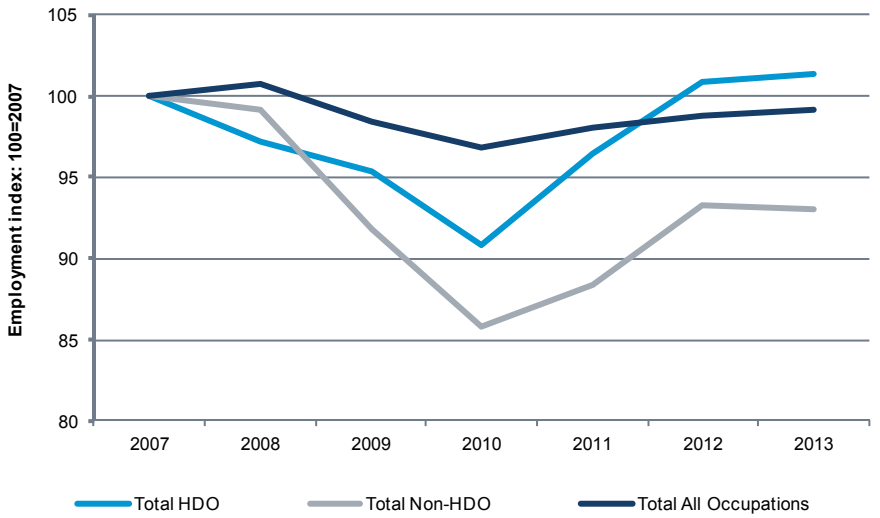
The modern oil industry started in Pennsylvania in 1859 when the first well whose only purpose was to extract oil was successfully drilled near Titusville in Venango County. Pennsylvania produced half of the world's oil until the discovery of oil in East Texas in 1901. It continues to produce low amounts of conventional crude oil annually through 350,000 wells that have been drilled in the state since 1859, about 60,000 of which are still active. Once hydraulic fracturing technology was developed in the 1990s, energy companies began trying to extract natural gas from shale plays around the country, including the Marcellus Shale Formation, which lies under the western two-thirds of Pennsylvania and portions of New York, Ohio, and West Virginia. The ability to successfully extract natural gas from the Marcellus in commercially significant quantities at a competitive cost using hydraulic fracturing was confirmed in 2005, and the first unconventional well drilled into the Marcellus began to produce natural gas in 2008. In 2013 Pennsylvania produced 3.1 Tcf of natural gas from the Marcellus Shale and other unconventional energy resources, making it the second-largest producer of natural gas in the United States, behind only Texas.

Core and high-demand occupations

Pennsylvania's unconventional energy industry is more mature that those in adjacent states of Ohio and West Virginia. As exploration and drilling activity began to accelerate in 2007, the demand also grew for workers in the unconventional energy supply chain. As in most states, Pennsylvania's employment in all occupations fell from 2007–10 during the Great Recession, by 3.2%. Employment* in the core supply chain occupations and in high-demand occupations (HDOs)—about two-thirds of core occupation jobs—fell even more sharply, as shown in the accompanying chart. The construction and manufacturing industries, which account for the largest shares of core and HDO occupation jobs, were especially hit hard by the recession. Employment in Pennsylvania in all sectors, and in core and high-demand occupations, began to recover in 2011. By 2013

employment in the HDO occupations exceeded their prerecession levels due largely to the recovery in US manufacturing, although continued growth in unconventional energy activity in Pennsylvania was likely a contributing factor.

Employment trends: HDO vs. non-HDO employment in Pennsylvania



Source: Bureaur of Labor Statistists and IHS

As the chart shows, Pennsylvania employment in the 24 HDOs grew substantially faster than in the remaining 49 (non-HDO) core occupations—and in all occupations—over the last two years. The top 10 HDOs in terms of 2013 employment levels* were *heavy and tractor-trailer truck drivers* (71,970), *construction laborers* (33.380), *operating engineers* (21,140), *machinists* (19,940), *first-line supervisors of construction and extraction* (17,900), *welders* (16,920), *plumbers, pipefitters and steamfitters* (16,010), *industrial machinery mechanics* (15,540), *bus, truck and diesel mechanics* (11,010), and *mechanical engineers* (9,880), which together accounted for 89% of all HDO employment and 62% of all core occupation jobs in the state. The demand for goods and services driven by upstream and midstream capital investment in the Pennsylvania portion of the Marcellus Shale has contributed to the sharp upward trend in supply chain employment.

The 2013 employment levels in core occupations and corresponding shares of total employment vary across the states, reflecting both their industrial composition, and the development stage and scale of their unconventional energy activities. As the table shows, production jobs accounted for 26.9% of total core occupation employment in Pennsylvania in 2013, third highest among the six states considered in this report, and indicative of Pennsylvania's importance as a supplier of equipment and materials (e.g., compressors, fabricated steel tubes)—compared to 22.5% for the United States. Similarly, construction and extraction occupations represented 28.6% of Pennsylvania's core occupation jobs in 2013, fourth highest among the six states. Finally, Pennsylvania's total 2013 employment in the core occupations was 6.7% of its total occupational employment, well above the US figure of 6.2%. Figures in the following table are for total employment in each individual core occupation in the state across all industry sectors; not all of the workers in core occupations directly supported unconventional energy activity.

Core occupation employment by major occupational category: 2013—Pennsylvania

Occupational category	Pennsylvania		United States	
	Numer of Jobs	% Total	Numer of Jobs	% Total
Management	11,820	3.1%	379,060	4.6%
Architecture and Engineering	29,690	7.9%	721,500	8.7%
Life, Physical and Social Science	10,110	2.7%	242,190	2.9%
Construction and Extraction	107,780	28.6%	2,525,470	30.5%
Installation, Maintenance and Repair	37,370	9.9%	830,730	10.0%
Production	101,290	26.9%	1,865,030	22.5%
Transportation and Material Moving	78,870	20.9%	1,708,920	20.7%
Total	**376,930**	**100.0%**	**8,272,900**	**100.0%**

Source: Bureau of Labor Statistics and IHS

Workforce readiness initiatives

As in other states with major unconventional plays, public and private sector efforts to train workers for the unconventional energy supply chain are well established in Pennsylvania.

ShaleNET is a multistate initiative designed to meet the natural gas industry's workforce needs. Pennsylvania has participated in ShaleNET since its start in 2010, when a $4.96 million Community Based Job Training grant was awarded by the US Department of Labor to Westmoreland County Community College (WCCC). ShaleNET is now centered at the Pennsylvania College of Technology.

- ***Pennsylvania's Labor and Industry Departments' Center for Workforce Information and Analysis (CWIA)*** provides information on the workforce requirements of the Marcellus Shale industry. Its annual update each May on Marcellus Shale key facts provides information used by many PA workforce organizations.
- ***Shale Training and Education Center (ShaleTEC)*** is a joint program of the Pennsylvania College of Technology in Williamsport and Pennsylvania State Extension to serve as a central resource for workforce development and education needs of the community and the oil and natural gas industry.
- ***Pennsylvania College of Technology,*** located in Williamsport in north-central Pennsylvania, has established a national reputation for workforce development. Today, it manages the state's largest worker training program through its Workforce Development and Continuing Education unit. Pennsylvania College is a founder and partner with Pennsylvania State Extension in ShaleTEC, and a member of ShaleNET.
- ***Westmoreland County Community College (WCCC)*** is located in Youngwood in western Pennsylvania and has a current enrollment of about 6,600 full-and part-time students. WCCC led the consortium of educators and industry members to create ShaleNET in 2010, with an initial grant of nearly $5 million, for training programs for entry-level jobs in the Marcellus Shale industry.

3. Ohio summary

Ohio historically is a moderate producer of oil and gas. Its annual natural gas production primarily from conventional wells peaked at nearly 160 Bdf in the 1980s, but declined to the range of 70-80 Bcf today. Current interest in Ohio oil and gas exploration is focused on the Marcellus Shale and the Utica Shale. The Marcellus Formation thins under Ohio, and its impacts are limited to eastern counties. The Utica Shale covers most of the state's eastern half and is expected to have a larger impact across Ohio. Natural gas gross withdrawals from Ohio shale gas wells were initially very small (about 10-17 million cubic feet, 2007-2010), but recently they have taken off, reaching 88 Bcf by 2013 (US Energy Information Administration). While still small, shale gas production over the past few years is already having economic impacts, opening up thousands of new shale-related jobs.

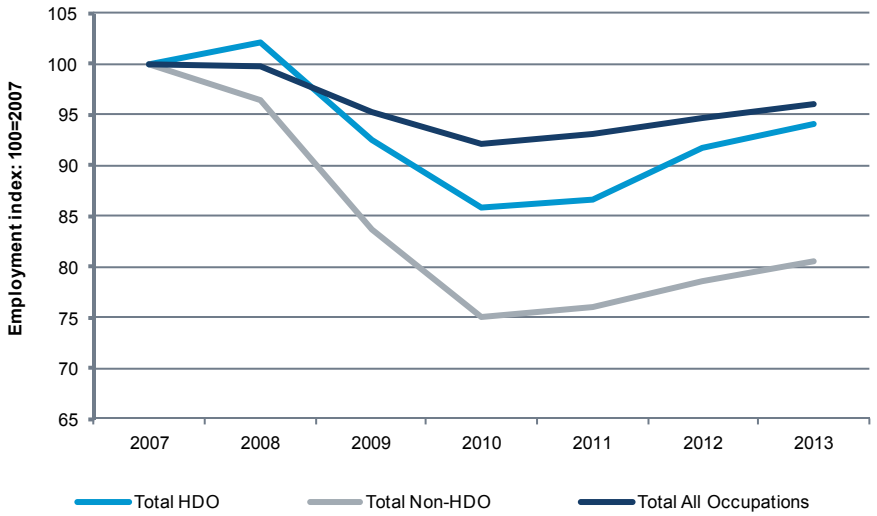
Core and high-demand occupations

While Ohio has gained from the bordering Marcellus Shale development in Pennsylvania, Ohio is at a relatively early stage of development of its Utica play—though it is has been moving beyond the initial drilling rush and into the midstream and downstream phases. As shown in the chart, Ohio's employment in all occupations fell in 2007–10 during the Great Recession. Employment in the core supply chain occupations*—and in high-demand occupations (HDOs), about two-thirds of core occupation jobs—fell even more sharply. The construction and extraction and especially manufacturing sectors, which account for the largest shares of core supply chain jobs, were especially hit hard by the recession. Employment in all sectors, and especially in core and high-demand occupations, began to recover in 2011, although it has not yet returned to prerecession levels.

It is notable that employment in the supply chain's 24 HDOs is growing substantially faster than that of the remaining 49 core occupations. The top 10 HDOs in terms of employment* in Ohio are *heavy and tractor-trailer truck drivers* (65,550 in 2013), *machinists* (28,100), *construction laborers* (25,640), *industrial machinery*

mechanics (15,940), *welders* (14,410), *operating engineers* (13,190), *first-line supervisors of construction and extraction* (12,620), *plumbers, pipefitters and steamfitters* (12,390), *mechanical engineers* (11,660) and *bus, truck and diesel mechanics* (11,260), which together account for 89% of all HDO—and 54% of all core occupation—jobs in the state. In any event, the demand for goods and services driven by upstream and midstream capital investment in the Marcellus and Utica shale plays has helped to fuel the sharp upward trend in supply chain employment as development of Ohio's energy complex expands.

Employment trends: HDO vs. non-HDO employment in Ohio



Source: Bureau of Labor Statistics and IHS

The employment levels of core occupations, and corresponding shares of total employment, vary across the states, reflecting both their industrial composition and scale of unconventional energy activities. For example, production occupations' share of total supply chain sector employment in Ohio—one of the nation's largest manufacturing states—is larger than that of other states, and the nation as a whole. As the table below shows, production jobs accounted for 35% of total core occupation employment in the state—reflecting its importance as a supplier of equipment and materials (e.g., compressors, fabricated steel tubes)—compared to 23% for the nation, in 2013. In contrast, construction and extraction employment represented 21% of Ohio's supply chain jobs in 2013—which is a smaller percentage than for states such as Pennsylvania, Texas, Ohio, Colorado, and Louisiana, which have larger conventional oil and gas sectors and/or more advanced development of unconventional plays. Figures in the following table are for total employment in each individual core occupation in the state across all industries; not all of the workers in the core occupations directly supported unconventional energy activity.

Core occupation employment by major occupational category: 2013—Ohio

Occupational category	Ohio		United States	
	Numer of Jobs	% Total	Numer of Jobs	% Total
Management	20,210	5.6%	379,060	4.6%
Architecture and Engineering	25,300	7.0%	721,500	8.7%
Life, Physical and Social Science	8,340	2.3%	242,190	2.9%
Construction and Extraction	75,980	20.9%	2,525,470	30.5%
Installation, Maintenance and Repair	38,710	10.7%	830,730	10.0%
Production	125,720	34.6%	1,865,030	22.5%
Transportation and Material Moving	69,160	19.0%	1,708,920	20.7%
Total	**363,420**	**100.0%**	**8,272,900**	**100.0%**

Source: Bureau of Labor Statistics and IHS

Workforce readiness initiatives

Compared to other states with major unconventional plays (Pennsylvania, Texas), public and private sector efforts to assess and take advantage of these opportunities are just getting started. The Ohio Department of Jobs and Family Services (JFS) is working with workforce investment areas, community colleges, other post-secondary educational institutions and employers to identify HDOs in the unconventional energy sector and put in place appropriate training programs. Notable workforce readiness initiatives in Ohio include

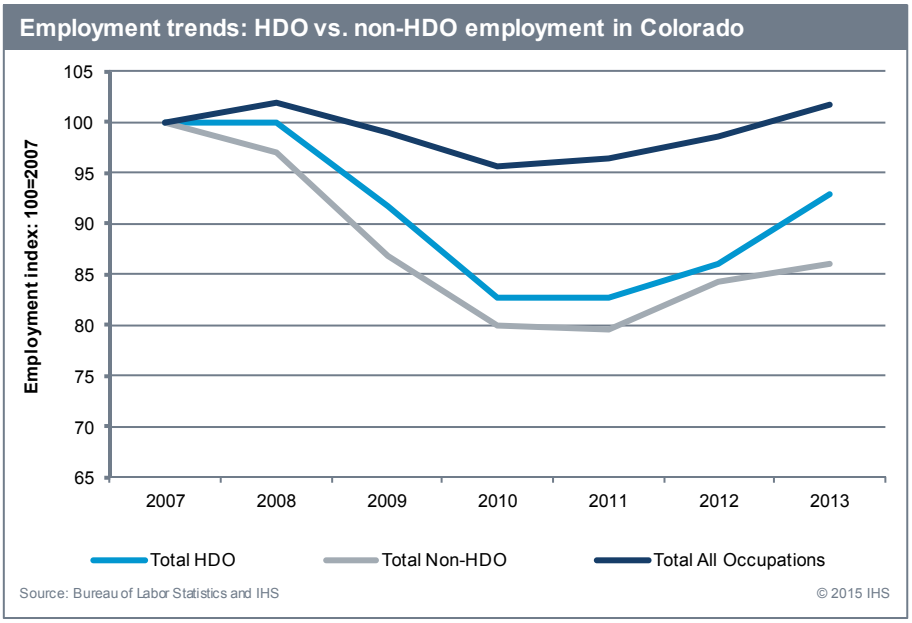
- ***The Ohio Oil and Gas Energy Education Program (OOGEEP)*** is a statewide education and public organization sponsoring a variety of programs to provide factual information about the crude oil and natural gas industry. Programs include teacher workshops, scholarships, student education, firefighting training, industry training, and workforce development, among others.
- ***Zane State***, in Zanesville and Cambridge, offers a variety of two-year associate degree programs, certificate programs, and occupational skills training in the energy field and relevant high-demand occupations. Zane is also an academic partner of the ***Gas Compressor Association***.
- ***Stark State College***, in Canton, offers associate degrees, certificates and professional development in energy high-demand occupations. A member of ***ShaleNET***, a federally supported national workforce training partnership for the oil and natural gas industry, it provides programs in industrial process technology, pipeline technology, petroleum technology and many other related fields.
- ***Career and Technology Education Center (C-TEC)*** **of Licking County**, a state and federally funded one-year career and technical school serving Licking County citizens and industry, offers certificate programs in high-demand conventional and unconventional energy skilled trades.
- ***Central Ohio Technical College,*** **in Newark,** has expanded its training programs, adding 70 people to its welding program and another 50 for machinist training; certificate programs designed by energy supplier companies that contribute to the cost.
- ***Chevron's Appalachia Partnership Initiative*** is a $20 million program to improve education and technical training to meet the workforce needs of the energy industry and related manufacturing industries across southwestern Pennsylvania, northern West Virginia and eastern Ohio.

4. Colorado summary

Colorado has abundant conventional and unconventional oil and gas resources. Oil production, after declining to under 20 million barrels per year by 2000, began to increase again in 2002, and accelerated rapidly in 2008 as hydraulic fracturing and horizontal drilling technologies proved commercially competitive. By 2012 the state's oil output surpassed the earlier peak, reaching 49 million barrels per year—and nearly 65 million barrels per year in 2013—coming mainly from the Wattenberg oil field, and from the Niobrara Shale, which is primarily an oil play. The Niobrara play is in the early stage of development. The Green River Formation in the northwest part of the state has some of the richest oil shale deposits in the world, with estimated reserves of 640 billion barrels of oil in Colorado alone.

Natural gas production has grown steadily since 1990. According to the US Department of Energy, in 2013 Colorado produced 1.604 trillion cubic feet (Tcf) of natural gas, seventh highest among the states, but with only 0.247 Tcf (15.4%) coming from shale formations. Between 2007 and 2013 the amount of natural gas that Colorado obtained from shale formations increased at an average annual growth rate of 10.1%. Colorado also produced 178,000 b/d of crude oil in 2013, eighth highest among the states and 2.4% of total US production. Between 2007 and 2013, crude oil production in Colorado increased by 147.2%; a significant share of this growth is attributed by the US Energy Information Administration (EIA) to the increasing use of hydraulic fracturing and horizontal drilling.

Core and high-demand occupations



The unconventional energy sector has been developing steadily in Colorado since 2007, but it is not yet as mature as in other states such as Pennsylvania and Texas. Demand for workers in the unconventional energy supply chain began to accelerate after 2007 as both unconventional oil and gas activity rose. Colorado's employment across all occupations rose through 2008, then fell slightly until 2010, and has risen gradually since. By contrast, employment* in the core occupations and the high demand occupations (HDOs) fell sharply between 2008 and 2010, leveled off for a year, and then began to rise again in 2011, although by 2013 they were still well below their prerecession levels. However, since 2011, Colorado's employment in the supply chain's 24 HDOs has recovered faster than the remaining 49 core (non-HDO) occupations, as shown in the accompanying chart. By contrast, employment across all occupations in 2013 was above its prerecession level. Colorado's employment in the construction and manufacturing sectors fell between 2007 and 2010 by 27.2% and 14.5%, respectively, due to the Great Recession, contributing to the declines shown in the chart, as these two sectors account for the largest shares of core and HDO jobs.

The top 10 HDOs in Colorado in 2013 in terms of employment were *heavy and tractor-trailer truck drivers* (22,760), *construction laborers* (16,340), *first-line supervisors of construction and extraction workers* (10,610), *plumbers, pipefitters and steamfitters* (7,680), *operating engineers* (7,480), *mechanical engineers* (5,320), *industrial machinery mechanics* (5,160), *welders* (4,650), *machinists* (4,530), and *bus, truck and diesel mechanics* (4,350). Together the top 10 HDOs accounted for 85.7% of total HDO employment in Colorado and 60.4% of total core occupation employment in 2013. Compared to the five other states considered in this study, Colorado has a higher share of its HDO and core occupations in the engineering occupations.

The employment levels in the core occupations, and their distribution by major occupational category vary across the states due to the structure of economies, especially in manufacturing, and the scale and maturity of conventional and unconventional energy activities. Production occupations' share of total core occupation employment in Colorado in 2013 was 13.1%, as shown in the accompanying table, by far the lowest among the six states considered in this study and well below the US share of 22.5%. By contrast, Colorado had the highest shares of its core occupation employment in the Architecture and Engineering; Life, Physical, and Social Science; and Construction and Extraction major occupational categories. The shares in the accompanying table are due to the structure of Colorado's economy, especially its above-average concentrations of employment in the Natural Resources & Mining, Construction, and Professional and Business Service sectors; and the below-average concentration of employment in manufacturing. Figures in the following table are for total employment in each individual core occupation in the state across all industries; not all of the workers in the core occupations directly supported unconventional energy activity.

Core occupation employment by major occupational category: 2013—Colorado				
Occupational category	**Colorado**		**United States**	
	Numer of Jobs	**% Total**	**Numer of Jobs**	**% Total**
Management	5,180	3.5%	379,060	4.6%
Architecture and Engineering	16,400	11.2%	721,500	8.7%
Life, Physical and Social Science	8,160	5.5%	242,190	2.9%
Construction and Extraction	58,850	40.0%	2,525,470	30.5%
Installation, Maintenance and Repair	14,010	9.5%	830,730	10.0%
Production	19,290	13.1%	1,865,030	22.5%
Transportation and Material Moving	25,150	17.1%	1,708,920	20.7%
Total	**147,040**	**100.0%**	**8,272,900**	**100.0%**

Source: Bureau of Labor Statistics and IHS

Workforce readiness initiatives

Because Colorado has long been a major producer of conventional oil and gas, it has some programs already in place to train workers for the oil and gas sector, and its supply chain. The challenge has been to adapt these programs to meet the needs of the unconventional energy industry and its supply chain. Some of the major workforce programs in Colorado are summarized below.

- ***Colorado Online Energy Training Consortium (COETC)*** was founded with a grant for $17.3 million from the TAACCCT program of the US Department of Labor. The consortium focuses on enhancing current energy-related programs with the goal of training highly qualified workers for energy businesses that need a skilled workforce. The Community College of Denver is the lead applicant, along with 14 other colleges across Colorado; major energy companies are also partners in the consortium.

- ***Aims Community College,*** with Department of Labor support, is building a $2 million state-of-the-art training facility to teach students the skills needed to become part of the oil and gas production industry. Certificate and degree areas include oil and gas production; process technology; energy technology; team building; safety and loss prevention. Companies on its advisory committee include Noble, Encana, Halliburton, and Anadarko.

- ***Front Range Community College*** **(FRCC)** offers programs that train students for careers in well-established and emerging industries, including Associate of Applied Science (A.A.S) degrees and certificates in electromechanical and electrical power technology and welding technology. The former involves collaboration with over two-dozen Colorado businesses and organizations. It qualifies students for entry-level positions in manufacturing and maintenance of electrical equipment in energy industries.

- ***The Global Energy Management (GEM) Program at the University of Colorado Denver Business School*** is a hybrid-online Master of Science (MS) degree program exclusively designed to develop future leaders in the energy industry. The impetus for GEM, which is now 5 years old, was that key companies in Denver (Encana, DCP, etc.) saw potential leadership challenges because of market growth, Baby Boomer retirement, and a smaller demographic of people getting into the energy industry.

- ***Colorado School of Mines, Colorado State University, University of Colorado, and University of Denver,*** the state's major research institutions, each have engineering programs that work to meet the Colorado energy industry's workforce needs. Colorado ranks fifth in the nation in terms of the share of its workforce engaged in engineering occupations. In addition to training engineers, these universities are also doing research relevant to the unconventional energy industry, enabling students to gain research experience that enables them to go into research and development (R&D) positions within industry.