IHS Markit®

The Future of Work

The Influence of New Technologies on Employment and Demographic Trends in the Oil, Natural Gas, and Petrochemical Industries

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DISCLAIMER: The employment projections estimated herein are based upon public data and IHS Markit data and models and conform to established methodology consistent with standard industry practices. All results and observations are based upon information available prior to February 2020. Accordingly, all results presented in this report do not take into account the impacts of the COVID-19 pandemic on the oil and gas industry and the US economy, including the resulting drop in oil prices. To the extent that additional information becomes available or the factors upon which our analysis is based change, our results could be subsequently affected. No express guarantee of employment, either direct or indirect, is implied by these forecasts.

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Preface

As the American Petroleum Institute (API) considers the future workforce needs of the oil and natural gas industry and how to attract and retain the best available talent, both the changing demographics of the United States and the changing nature of work shape our efforts in a meaningful way.

According to the US Census Bureau, "By 2030, one in five Americans is projected to be 65 and over; by 2044, more than half of all Americans are projected to belong to a minority group." The Pew Research Center found that 293 US counties were already majority nonwhite in 2018.[1] Most relevant for this study, demographic trends suggest that the white share of prime-age workforce (25- to 45-year olds) will fall below 50% before 2040.[2] In addition, women are continuing to participate in the labor force in large numbers and more women than men are now receiving two- and four-year degrees and certificates.

The aging workforce also plays an important role in looking to the future of work. In a significant increase from previous work, this report finds that more than 80% of the total job opportunities projected for the oil, natural gas, and petrochemical industries will come from replacement needs—primarily individuals who will be retiring. This represents not only an incredible opportunity for millions of future workers, but also a challenge for the industry to successfully and seamlessly fill the leadership positions and the industry and institutional knowledge these seasoned workers will leave with.

In addition to these shifting demographics in the years ahead, transformative technologies are changing the very nature of work. The ways that these technologies impact the number, types, and demographics of the workforce are critical pieces to understand as the oil and natural gas industry aims to attract and retain top talent and continue tackling the world's greatest energy challenges in increasingly safe, sustainable, and efficient ways.

API has been developing strategies, research, and programs to better understand the challenges and opportunities associated with engaging and growing high impact partnerships based on shared interests in job creation and workforce opportunities in the industry. This focus on greater collaboration, outreach and education with African Americans, Asian Americans, Hispanics, Native Americans, Millennials, Veterans, and Women begins with in-depth research and is in support of API's primary objectives and vision.

This report, *The Future of Work: The Influence of New Technologies on Employment and Demographic Trends in the Oil, Natural Gas & Petrochemical Industries*, continues a series of research studies commissioned by API to better understand our future workforce needs and how strategic partners can play an increasing role in our industry. The focus of this report is the impact of digital and automation technologies on future job opportunities for people of color and women in the oil and natural gas industry, considering the long-term US demographic and labor market trends that we will see over the coming decades. We present projections of job opportunities that will be created based on industry growth and investment, jobs arising from pro-development policies, and the need to replace workers retiring from the industry over the next two decades. These projections should not be considered ceilings but are estimates based on current and projected trends in factors such as labor force participation rates and population growth rates.

The more than 1.9 million direct job opportunities projected through 2040 in the oil, natural gas and petrochemical industries speak to the continuing importance of these industries in the US economy as a whole and to individuals and families looking for well-paying career opportunities. As seen in this report and other API research studies, communities of color, women, and other strategic partners represent critically vital and available talent pools to help meet our future workforce demands.

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[1] https://www.pewresearch.org/fact-tank/2019/08/21/u-s-counties-majority-nonwhite/

[2] https://www.brookings.edu/blog/the-avenue/2018/03/14/the-us-will-become-minority-white-in-2045-census-projects/

Executive summary

This report examines the employment outlook of people of color, specifically African Americans, Hispanics, and Asians, and women in the US oil, natural gas, and petrochemical industries through 2040. Job opportunities for people of color and women are projected under a scenario that assumes relatively aggressive adoption of new technologies. This report also provides details on how technologies such as cloud computing, internet of things, artificial intelligence and remote monitoring using robots and drones will affect activity, occupations, and hiring in the industry.

The report presents detail on employment hiring by occupation, race/ethnicity, and gender in the upstream, midstream, downstream, and petrochemical segments of the industry. This analysis considers forecasts of the US population growth, forthcoming changes in the demographics of the national labor force, demographic trends in employment by occupation, and projections of retirement and other types of separations by current workers.

The principal findings for employment conditions and job opportunities are:

- The industry currently employs about 2.1 million people and the projected workforce will grow to over 2.3 million by 2040, adding 258,800 new jobs.

- The majority of job growth will be in the upstream segment. The fastest growing occupational category will be for professional and related jobs, followed by management type jobs and highly skilled craft positions.

- Retirement and other reasons for employment separation will require hiring 1.645 million workers over the next 20 years. Adding new jobs to replacements yields total job opportunities to over 1.9 million over the next 20 years.

- The largest number of job opportunities will be for the upstream activity, as a majority of the employment will remain in this segment, despite new technology incrementally lowering labor needs for upstream activity.

- Hispanic workers are projected to be hired for 600,200 of job opportunities across all segments, which is 31.5% of the total job opportunities. African Americans are projected to account for 7.0%, and Asians are projected to account for 3.4 %. Combined, these three groups are projected to fill 41.9% of total job opportunities over the study period.

- Women are expected to receive 390,600 (20.5%) of the job opportunities. Their share of hiring will grow to almost 25% by 2040 as efforts to attract more women to STEM professions are successful.

The changes from new technology that are adopted by the industry will be significant for oil, natural gas, and petrochemical producers.

- Artificial Intelligence (AI), the Internet of Things (IOT), and 5G will all be truly transformative technologies impacting every major industry—with 5G being the leading technology mover followed by AI and IOT.

Technology will enable an employment transition with job creation for highly skilled and professional jobs being created, allowing the transition from the basic labor and semi-skilled labor classes.

1 Introduction

This project has two main goals: 1) to update a study released in 2016, *Minority and Female Employment in the Oil and Gas and Petrochemical Industries*[3], to reflect fundamental changes in the energy sector in the intervening period since that research was conducted, and 2) to properly understand and model the effect of technology on employment narratives in the sector.

The results of the 2016 study can be summarized as follows:

- Considering all sources of job opportunities and all types of job growth, the 2016 study projected a total of nearly 1.9 million direct job opportunities during 2015–35. This was specified as the baseline plus the pro-development policy.
- Of those job opportunities during the 2015 to 2035 time period, Hispanic workers were expected to account for 576,000 jobs and African American workers 131,000, combining to account for 38% of total job opportunities.
- Women were projected to fill more than 290,000 of the job opportunities through 2035, or 16% of the total.

The 2016 study was conducted under "static market conditions," reflecting demographic changes in the economy, estimated labor force participation rates, and occupational trends in the economy. This study uses a similar set of assumptions for a baseline scenario. Updated estimates of job growth are used for the same subsector definitions in the original study—upstream, midstream, downstream, and the petrochemical industry. Changes to the original estimates of employment from the 2016 study were completed by API and provided to IHS Markit prior to the start of this project.

The current study is designed to analyze job trends in the energy sector that will affect hiring, particularly for people of color and women. Using the updated baseline jobs estimates where no significant effects on employment from technology adoption were assumed to take place, we considered the effect of expected shifts in technology for each of the industry sectors, along with demographic impacts, to estimate future hiring in the energy sector. This study has a base year of 2019, and projects employment opportunities from 2020 to 2040.

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[3] IHS, *Minority and Female Employment in the Oil & Natural Gas and Petrochemical Industries, 2015-2035*, March 2016

2 Methodology

The analysis in this report requires numerous distinct steps to convert current employment and projected hiring for the oil and natural gas industries into demographic breakdowns by race and gender. This chapter provides an overview of the general approach of the study. The sections that immediately follow provide details about (1) the definitions of the relevant segments of the energy industry that are used throughout the report, (2) industry employment projections and technology adoption, (3) job replacements from retirement and permanent separation, and (4) an overview of methodology for estimating future race/ethnicity and gender hiring for the industry. The other chapters in the report build on these sections and present the effects of expected technology adoption by oil and natural gas producers, with an emphasis on the implications for women and people of color.

2.1 Industry definitions

The definition of segments or subsectors within the industry is primarily based on the North American Industry Classification System (NAICS) code definitions as shown below:

Upstream Oil and Gas Industry Operations

- NAICS 2111, Oil and gas extraction
- NAICS 2131, Support activities for mining

Investment in the Upstream Oil and Gas Industry

- NAICS 2131, Support activities for mining
- NAICS 23712, Oil and gas pipeline and related structures construction
- NAICS 54136, Geophysical surveying and mapping services

Midstream Oil and Gas Industry Operations

- NAICS 486, Pipeline transportation
- NAICS 4821, Line haul railroads
- NAICS 49319, Other warehousing and storage

Investment in the Midstream Oil and Gas Industry

- NAICS 23712, Oil and gas pipeline and related structures construction
- NAICS 3312, Iron and steel pipe and tube manufacturing
- NAICS 33242, Metal tank (heavy-gauge) manufacturing
- NAICS 33291, Industrial valve manufacturing, and 332196, Fabricated pipe and pipe fitting manufacturing
- NAICS 333132, Oil and gas field machinery and equipment manufacturing
- NAICS 5413 Architectural, engineering, and related services

Downstream Oil and Gas Industry Operations

- NAICS 32411, Petroleum refineries

Petrochemical Industry

- NAICS 325211, Plastic Material and Resin Manufacturing
- NAICS 32531, Fertilizer Manufacturing
- NAICS 32511, Petrochemical Manufacturing [Alkalies and Chlorine Manufacturing (325181) and Other Basic Chemical Manufacturing (32519)]

Capital Investment in the Petrochemical Industry

- NAICS 23712, Oil and gas pipeline and related structures construction
- NAICS 33242, Metal tank (heavy-gauge) manufacturing
- NAICS 33291, Industrial valve manufacturing, and 332196, Fabricated pipe and pipe fitting manufacturing
- NAICS 333132, Oil and gas field machinery and equipment manufacturing
- NAICS 5413 Architectural, engineering, and related services

Different sections below discuss important issues and trends for subsectors when relevant and insightful. The main conclusions in this report, however, are based on aggregates across all parts of the industry.

2.2 Employment projections and technology adoption

The industry employment projections that are discussed below were developed as a two-step process. The first step used IMPLAN to create a static technology baseline scenario.[4] The second step added the incremental effects of relatively aggressive adoption of technology by the industry to create the findings presented in the report.

Employment growth rates for the operational sectors for the baseline were taken from the Bureau of Labor Statistics' (BLS's) projections to 2026 by industry and occupation. To calculate baseline employment levels for the 2019 base year, growth rates were assumed to be linear between 2016 and 2026. Employment levels from 2027 to 2030 were assumed to be constant at 2030 levels. Employment due to capital spending is assumed to be constant at 2018 levels through 2030, which was modeled based on 2018 capital expenditures. Base-level employment is assumed to be constant from 2030 to 2040.

The resulting baseline employment is a pro-development forecast and includes opening new areas for upstream oil and natural gas development such as the Eastern Gulf of Mexico, the Atlantic, the Pacific, ANWR, and offshore Alaska. The pro-development effects increase total industry employment by roughly 15% by 2040, mainly in the upstream sector.

After establishing the initial baseline employment levels, it was then modified to show the impact of technology on employment, and the resulting scenario is used in the report. The technology effects were derived from four elements: impact assessment, use-case mapping, technology timeline, and an industry use case adoption timeline. These elements served as an overlay to base job estimates by industry sector and reflect the expected impacts of new digitalization and automation technologies. In the final calculations, technology acts both as a substitute and a compliment to the workforce, reducing labor demand in some cases and creating new jobs in other cases.

2.2.1 Impact assessment

The impact assessment rates each technology's ability to disrupt jobs/employment within a sector. This score is based on complete development and adoption of the technology (i.e. its maximum point of impact). Within this assessment, the following factors were considered:

- Percent of jobs/operations that would use this technology,
- Percent of the time that technology would be used,
- Increased efficiency achieved through technology implementation, and
- New support/staff required to use technology.

The impact assessment was done at the level of detail of the sub-technology that makes up the three macro digital and automation trends, as well as by the 31 specific job codes. For the sub-technologies below, a matrix was developed and subsequently examined and scored for distinct impact. The 14 sub-technology domains were scored per 31 specific job codes for completeness. Below are the three macro trends with each of their respective sub-technologies:

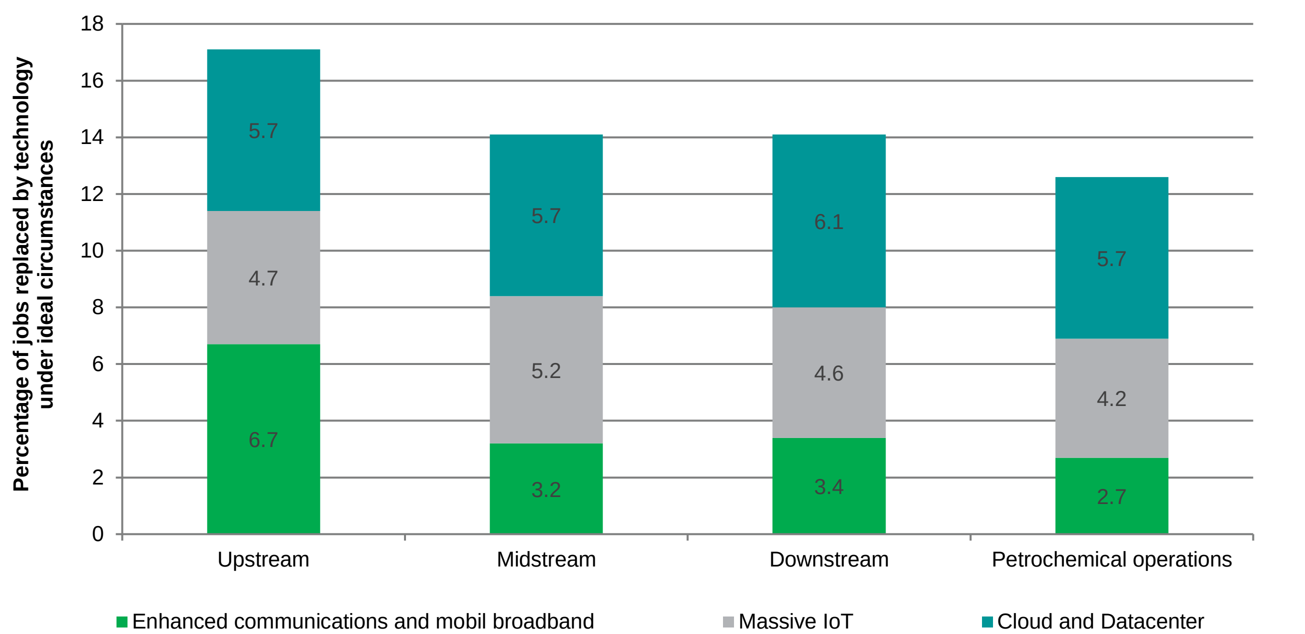
[4] IMPLAN (https://www.implan.com/) is both a database and a methodology to make economic projections that reflect the impact effect from a set of 'scenario' assumptions. This database is based on employment estimates from the US Bureau of Economic Analysis (BEA). Where IMPLAN data was not available for certain NAICS codes, other public sources were used. The US Census was used to estimate employment in the Geophysical sector. The Bureau of Labor Statistics (BLS) was used to estimate oil and gas pipeline and related structures construction and Petroleum Market Wholesalers.

1) ENHANCED COMMUNICATIONS AND MOBILE BROADBAND
   a. Enhanced Indoor Wireless Broadband Coverage
   b. Enhanced Outdoor Wireless Broadband
   c. Mission Critical Communications
   d. Training/Collaboration
   e. Augmented/Virtual Reality
   f. Extending Mobile Computing
2) MASSIVE INTERNET OF THINGS
   a. Remote Monitoring
   b. Physical Infrastructure and Industrial Automation
   c. Video Surveillance and Inspection
   d. Safety/Wearables
   e. Robots and Drones and Autonomous Vehicles
3) CLOUD AND DATACENTER
   a. Digital Twins
   b. Data Analytics, Artificial Intelligence (AI), and Machine Learning (ML)
   c. Edge Computing

The resulting rollup is shown in Figure 2.1 for the major technologies and industry segments.

Figure 2.1

Job replacement by technology type and energy segment



Source: IHS Markit

2.2.2 Use case mapping

Use case mapping was used to evaluate the applicability of the technology to different job functions and rates the extent to which the technology will be fully adopted and embraced. The mapping is an industry-specific impact adjustment that complements the overall impact that a technology can deliver. Once again, the 14 sub-technologies were scored across the 31 job codes. This filter serves to moderate that a given technology can impact the 2019–2040 adoption timeline but can also be limited by other factors such as legacy equipment deployments, installed base of equipment, or relevance of the technology in the specific job class.

2.2.3 Technology timeline

We used a technology timeline to establish when change is likely to occur based on technology readiness; it establishes an independent baseline for innovation that extends beyond oil and natural gas markets to all other markets. The timeline compensates for the readiness of the technology and its evolution over the 2019 to 2040 time period. As an example, while 5G deployments are beginning in 2019, it is not until the 2023–2027 timeframe that additional features, such as ultra-reliable low latency connectivity (URLLC) or network slicing, become fully deployed.

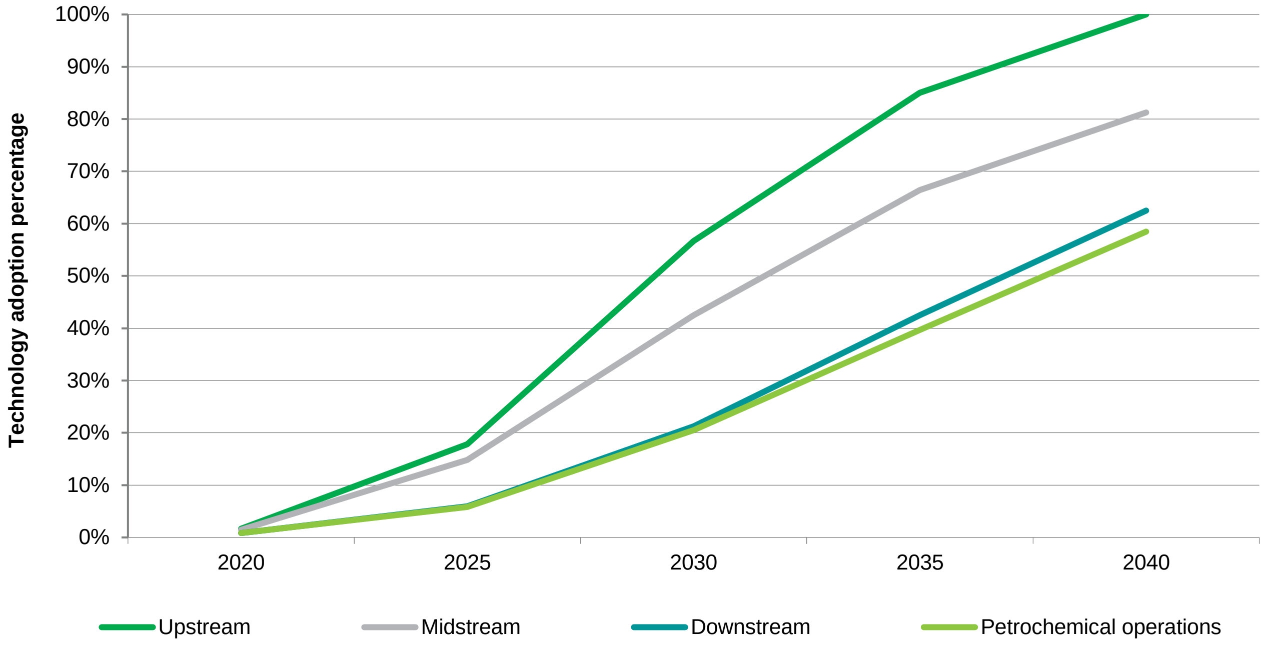
2.2.4 Use case timeline

A use case timeline was used to account for the technology maturity and integration of the oil and natural gas industry. The use case timeline is independent of the technology timeline and reflects the industry-specific adoption and deployment curve.

By combining the technology and use case timelines, we created an adoption curve over time.

Figure 2.2

Technology adoption curves by energy segment



Notes: Upstream normalized to 100% in 2040.
Source: IHS Markit

The results of the adoption curve are shown above. Here, the results have been normalized such that in 2040 an adoption rate of 100% is reached by upstream to visualize the relative adoption within the oil and natural gas industry over time.

Through the adoption curve, new technologies will both increase productivity, thus lowering employment needs, and create new jobs, as individuals will be needed to manage their use (See appendix for further details).

2.3 Job replacements from retirement and permanent separation

Before determining the likely race and gender breakdown of the job additions, we estimated job opportunities in the industry that will arise as workers leave the industry, primarily through retirement (but other reasons for exiting the labor force are not excluded). This category of job opportunities was part of the 2016 study, which used projections of "replacement needs" that the BLS produced in 2014 for different occupations and covered the 2012–22 period to compute 570,000 in replacement needs between 2015 and 2025. We use the same general methodology to estimate replacement needs, but now employ the BLS's "separation" concept that is not the same as the older "replacement" concept. We estimate 1.645 million as the industry's replacement hiring needs between 2020 and 2040, increasing total job opportunities to 1.903 million (with 258,800 coming from industry expansion) over the same time period.[5]

The replacement rate assumptions that we use in this study are much higher than the replacement rate assumptions of the prior study. In the 2016 study, replacement rates were estimated to be in the 1.5% –2% range per annum (as an average across all occupations), compared with an average of 3.5% in this study. The increase is less from the change in definitions by the BLS and more from a recognition that workers have become more likely to leave the labor force or simply change jobs or occupations (compared with the assumptions in the 2016 study). Higher replacement needs are consistent with a clear long-term decrease in labor force participation rates across the

[5] See Appendix C for a discussion of the separation versus replacement issues and for details about the estimates.

nation's working-age population. Almost all recent studies of labor force participation show that workers are now more apt to either temporarily or permanently leave the labor force, with many accepting early retirement.[6]

2.4 General approach for estimating race and gender hiring shares

From a high-level view, the calculations for estimating the race and gender hiring for any industry is straightforward. We start with estimates of projected hiring or job opportunities by occupation (for 2020 through 2040 in this study) and then apply estimates of expected shares by race/ethnicity: (a) White, (b) African American, (c) Hispanic, (d) Asian, and (e) Other.[7] We then apply expected male and female shares to each race estimate to compute hiring for each race-gender breakdown, such as White male and Hispanic female. Finally, female estimates for all groups are aggregated to provide an estimate of total female hiring as an additional demographic group. In all cases, the calculations are made for projections of occupations within the industry segments listed above, which allows us to consider how technology will affect the demographics of industry hiring through occupations and subsectors.

Taking projected job opportunities by subsector-occupation as given, there are two significant complications or limitations that affect the precision of the demographic breakdowns. First, the BLS provides details about the current race and gender makeup of the national workforce, but the industry and occupation details from the BLS fall short of what is needed for this study. Hence, we combine demographic statistics from the BLS with other data sources to compute race and gender shares that are specifically relevant for the industry-occupation groups that are used in this study.

Second, government statistics treat Hispanic as an ethnic origin and not as a distinct race. In the BLS employment statistics, an individual can be Hispanic and a race such as White or African American. We use detailed age-based population data from the US Census Bureau surveys to derive Non-Hispanic shares for the White, African American, Asian, and Other races. Thus, all numbers for White, African American, Asian, and Other as a 'race' in this report exclude those with Hispanic origin as they are captured separately as their own 'race.'

[6] For analysis of overall US labor force participation trends that support the higher separation rate assumptions that are used in this study, see the articles: Harley Frazis, "Employed workers leaving the labor force: an analysis of recent trends," Monthly Labor Review, US Bureau of Labor Statistics, May 2017, US Bureau of Labor Statistics, May 2017, https://doi.org/10.21916/mlr.2017.16. Daly, Mary C., Joseph H. Pedtke, Nicolas Petrosky-Nadeau, and Annemarie Schweinert. 2018. "Why Aren't U.S. Workers Working?" FRBSF Economic Letter 2018-24 (November 13). https://www.frbsf.org/economicresearch/publications/economic-letter/2018/november/why-are-us-workers- not-participating/ Montes, Joshua. 2018. "CBO's Projection of Labor Force Participation Rates." Congressional Budget Office Working Paper 2018-04, March 16. https://www.cbo.gov/publication/53616. Abraham, Katharine G., and Melissa S. Kearney. 2018. Explaining the Decline in the U.S. Employment to-Population Ratio: A Review of the Evidence. No. w24333. National Bureau of Economic Research.

[7] "Other" includes all other race categories not specified here.

3 Technology and the oil and natural gas industry

This chapter gives an overview of the major technologies used in this analysis and provides guidance on how the energy sector compares to other economic sectors in terms of technology adoption. We examine the adoption and impact of three specific and transformative technologies—Enhanced Communications and Mobile Broadband (which is synonymous with 5G), Massive Internet of Things (IoT), and Cloud and Datacenter Technologies (specifically Artificial Intelligence [AI]). This chapter then looks at the impact of these technologies in the oil and natural gas industry.

3.1 Technology narratives and industry readiness

Each of these technologies will alter the status quo; AI is likely to be the most transformative. The implications of each technology were important in deriving the path of the oil and natural gas industry employment in this report. We look at these technologies with a specific focus on the following:

- **Readiness:** The anticipated development timeline for this technology. When is it expected that this technology will be viable and widely implemented?
- **Impetus:** The motivation behind adoption of this technology. What are the key reasons that will drive implementation of each technology?
- **Impact**: The influence this technology is expected to have once fully implemented. How will it change or disrupt industries in the coming years?

The analysis recognizes that each technology is at a different point of its development cycle and will progress at its own pace. In addition, there is great disparity in how these technologies will affect individual industries. We conclude that 5G, IoT, and AI will have significant impacts in the oil and natural gas industries, but the immediateness of the impacts will vary.

3.1.1 Enhanced Communications and Mobile Broadband

3.1.1.1 5G

Fifth generation of mobile network technology, i.e. 5G, is the successor to current 4G LTE standards. This technology offers the latest innovation in mobile connectivity, and like previous cellular generations, builds upon existing cellular systems and infrastructure to provide numerous enhancements. Once fully developed, 5G will bring three primary benefits: faster data speeds, lower latency, and increased connectivity.

3.1.1.1.1 5G readiness

5G networks have now been launched in most regions of the world. As of early July 2019, IHS Markit noted launches of 5G networks in 11 countries by 20 different operators.

Figure 3.1

Global map of existing 5G networks and associated operators

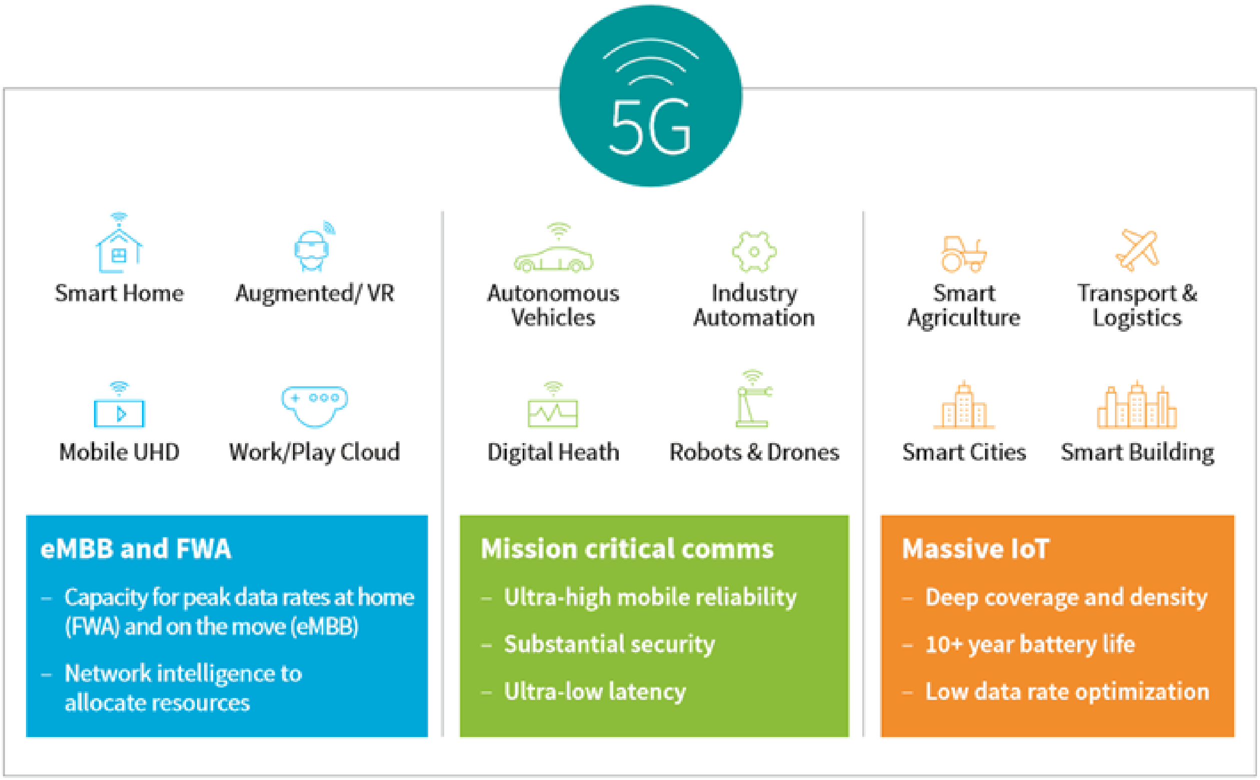
Along with these network launches, the first wave of 5G capable devices, mostly smartphones, were released in the first half of 2019. An IHS Markit survey of consumers found that demand for these 5G devices is strong and indicates they will have a very strong adoption. As a result, IHS Markit estimates shipments of 5G handsets will reach 9 million in 2019 and grow to 609 million by 2025.

These network launches and device releases represent an important milestone for 5G technology. However, the full range of planned 5G capabilities will not be available during the initial 5G launches and will instead be implemented in a phased approach over the next few years.

To better understand this, it is important to note there are three distinct use cases for 5G: enhanced Mobile Broadband (eMBB) and fixed wireless access (FWA), Mission Critical Communications (MCC), and Massive IoT (MIoT). These three use cases present contradictory technical requirements at times, but excitement for 5G is high because it aims to support these divergent needs within a single network architecture. Creating that type of umbrella architecture is a critical step toward achieving the economies of scale and technical coordination needed to make the use cases envisioned for 5G not only possible, but also technically and commercially viable.

Figure 3.2

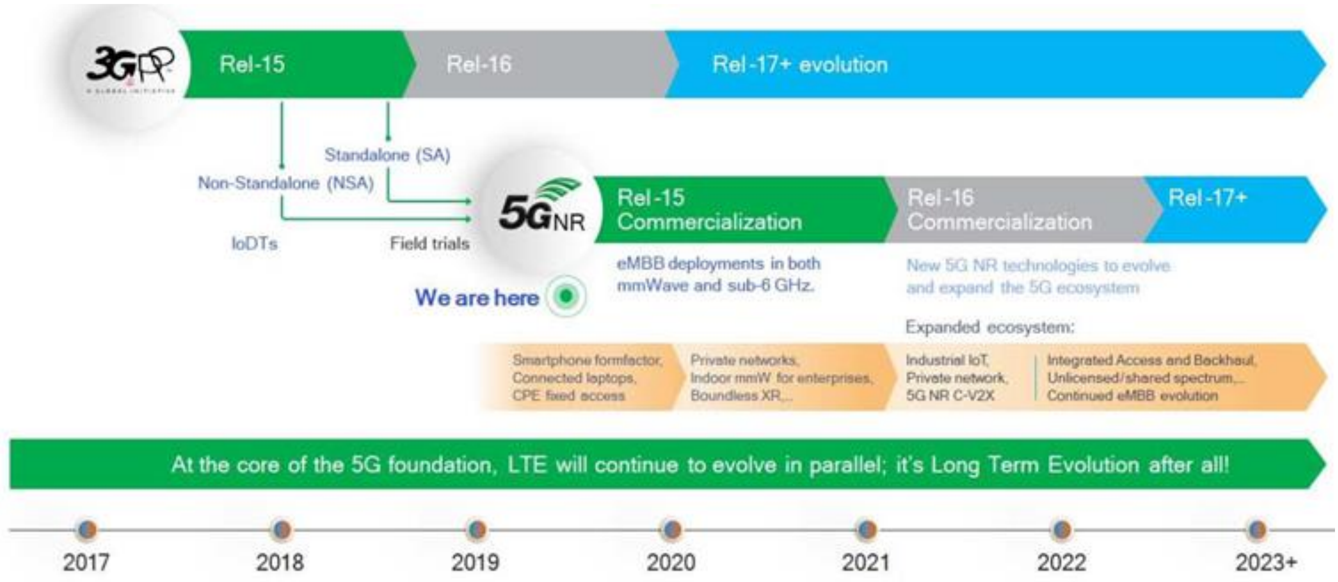
5G technologies and vertical alignment



However, as with most new technologies, not all the capabilities of 5G will be available immediately and, in fact, many are still in the process of being standardized. The 3rd Generation Partnership Project (3GPP) completed Release 15, the first full set of 5G standards, in 2018. This release primarily enables eMBB use cases. Future 5G standards based on Release 16 and 17 will be developed in upcoming years to address the MIoT and Modulation Coding Scheme (MCS) requirements, as shown in Figure 3.3.

Figure 3.3

3GPP standard roadmap



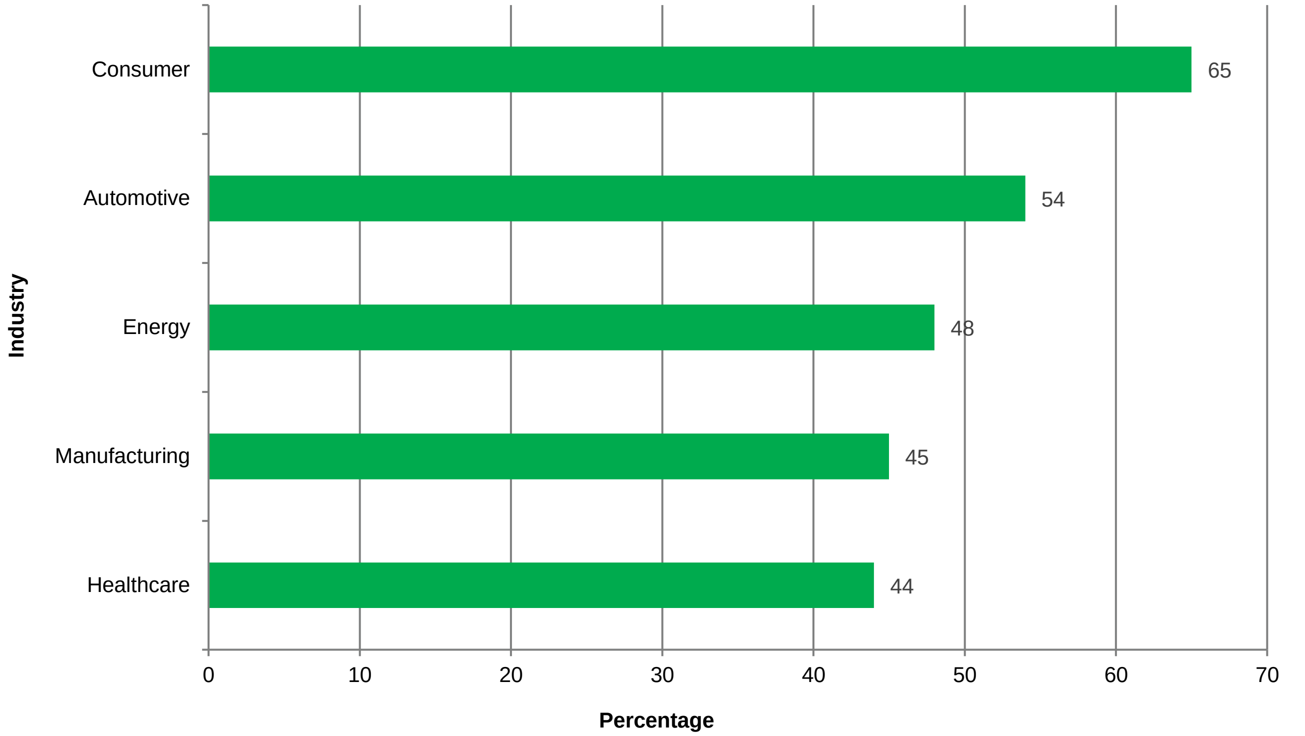
What does this mean? The 5G networks deployed in 2019 are focused solely on the features necessary to support eMBB. Today's 5G networks do not include the capabilities that are required to specifically support Mission Critical and Massive IoT applications. Due to the extended (though not unusual) rollout of the technology, the actual readiness of 5G technology varies widely depending on the use case or application. For instance, 5G in its current form can address the needs of many consumer market applications, like improving viewing of video on smartphones, as these are largely dependent on eMBB.

Conversely, the capability (or readiness) of 5G to address Massive IoT and Mission Critical applications is much further out (e.g. factory automation, asset tracking, autonomous driving, and remote monitoring). At a minimum, this will require 3GPP Release 16 and 17. In addition to these releases, there are also coverage issues that will also need to be resolved. Initial 5G networks are largely concentrated in high-density urban areas. This network coverage will have to be far more ubiquitous for 5G to be deemed "ready" for immense, wide-scale implementation in industries such as automotive and energy.

The divergence of 5G readiness is reflected in Figure 3.4 from the *IHS Markit Digital Orbit Executive Briefing*. With the initial network launches focusing on eMBB, which is tightly aligned with the needs of the consumer market, the 5G readiness scores for the consumer segment are much higher than other industries. It is the future versions of 5G, especially those that offer ultra-reliable, low latency (URLLC), that will make the technology truly "ready" for most of the applications associated with industries like healthcare, manufacturing, and energy. While readiness is a qualitative measure, the relative rank order below serves a useful function for comparisons. Energy represents a midpoint compared to other industries: it scores higher than healthcare, which can be limited by regulatory bodies, and manufacturing, which has extreme diversity of equipment as well as a large installed base to overcome. Energy is a mid-moving market in terms of both readiness and willingness to adopt this new technology.

Figure 3.4

5G readiness by industry, 2019



Source: IHS Markit

3.1.1.1.2 Impetus of 5G adoption

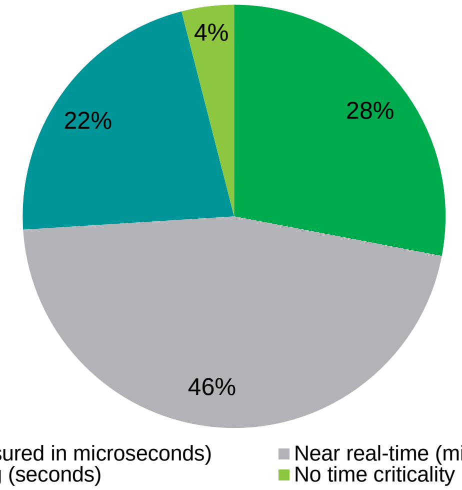
The motivation of implementing 5G will vary depending on the use case. Existing technologies, both wired and wireless, can adequately handle many of the applications envisioned for 5G. However, 5G will typically be able to perform these functions with greater speed and increased reliability.

For consumer-oriented applications, the primary motivation to move to 5G will be increased speed, which will result in a better user experience. For instance, with today's 4G LTE service, downloading a high-definition movie might take 10 minutes, but with 5G technology this could take a matter of seconds. 5G will also extend cellular coverage into a broader range of structures, including office buildings, industrial parks, shopping malls, and large venues. The net result is that consumer end-users that move to 5G technology will have an improved and more consistent experience using mobile broadband applications regardless of location.

For most other applications, especially those on the enterprise or industrial side, IHS Markit believes the availability of ultra-reliable, low latency connections will be the key impetus for implementation of 5G. These applications—which include everything from autonomous automobiles to oil and natural gas equipment monitoring—require extremely low latency, allowing for millisecond response/reaction time. This latency ensures that a required action (i.e. shutting down a pipeline because an anomaly is detected or steering around an obstacle in the road) can be taken. As seen in the below survey results, nearly half of respondents from a survey of the manufacturing sector stated millisecond latency (achievable with 5G) is required in their factory floor applications.

Figure 3.5

Latency requirements in factory floor applications (percent of respondents)



Source: IHS Markit, Digital Orbit Survey

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Many industrial applications currently rely on wired technologies to achieve low latency communication, and adoption of 5G in these markets is likely to be slow until it has proven its reliability. However, 5G can provide a tremendous advantage over existing wired solutions in that it can combine extreme low latency with unparalleled mobility. For instance, on a factory floor, machines connected with 5G could be quickly reconfigured to allow for new production capabilities. Similarly, drilling equipment connected via 5G could be rapidly moved from one exploration site to another without the timely process typically associated with wired connectivity.

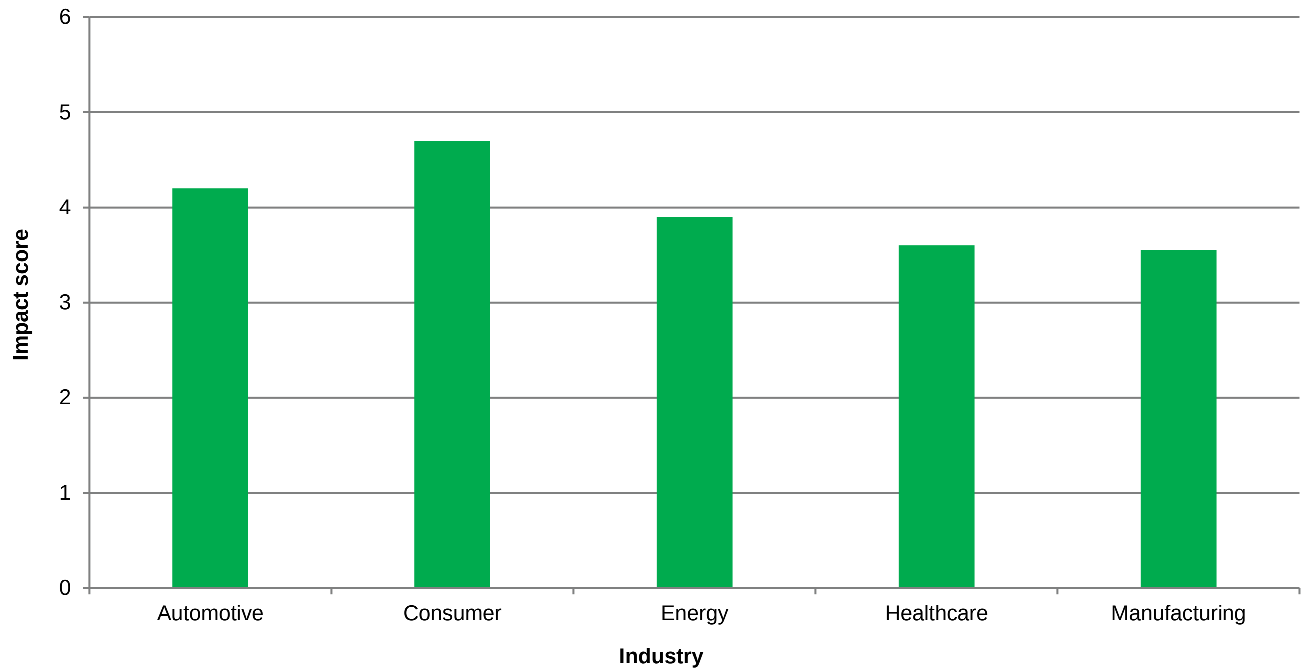
3.1.1.1.3 Impact of 5G

In terms of economic impact, IHS Markit forecasts that in 2035 5G will enable $13.2 trillion of global economic output. That is nearly equivalent to US consumer spending in current dollars ($13.9 trillion) or the combined spending by consumers in China, Japan, Germany, the United Kingdom, and France ($13.4 trillion) in 2018.

As noted earlier, initial 5G deployments center on eMBB applications that address consumer-centric demand for access to multi-media content, services, and data. This is where the most immediate impact of 5G will be seen. The below graph from the *Digital Orbit Executive Briefing* shows expected impact over the next three years as measured and quantified by industry surveys, analyst insights, and research. The relative economic impact is an indication of where the global economic output dollars will be distributed by industry.

Figure 3.6

5G impact score by industry (next three years)



Source: IHS Markit, Digital Orbit Q2 2019 survey

However, while 5G will have an immediate impact and provide a better user experience on devices like smartphones, because these are largely enhancements to existing services, the net impact of 5G in this market will be less transformative. In time, the far greater impact brought by 5G is likely to be in mission critical applications. No other wireless technology can support 5G's characteristics of mobility, deep coverage, high speed, and low latency. This incredible flexibility means that 5G will be able to address an unprecedented number of industrial use cases such as autonomous vehicles and remote operation of complex automation equipment where failure is not an option. Among the leading benefits enabled by 5G (alongside other capabilities and technologies, such as analytics and AI), will be increased operational efficiencies, more flexible production techniques, improved customer experience, and new revenue opportunities.

Many of these more transformative use cases for 5G are still emerging applications/markets (e.g. autonomous vehicles, commercial drones, and remote medical treatment), so growth will be dependent on market innovation and development of appropriate regulation, as well as the deployment of 5G networks. As a result, the impact of 5G in these areas may take longer to accelerate but given the broad implications of some of the use cases, their overall influence on society and business is expected to be tremendous.

3.1.1.1.4 What this means for the oil & natural gas industry

While initial 5G launches have begun, many aspects of the technology that are relevant to the industry are still in development. The oil and natural gas industry could begin investments knowing 5G is a long-term platform but should be cognizant of using a phased approach. Over the next 3 to 5 years, 5G allows investment into expanded outdoor wireless communications which can be used in the following areas:

- Enhanced safety platforms for workers,
- Expanded critical communications infrastructure,
- Remote monitoring of assets that do not require the most critical performance, and

- Initial investments in enhanced indoor broadband.

Eventually 5G will be able to provide an ultra-reliable connection that is indistinguishable from wired technologies, and thus be able to support most applications in the oil and natural gas industry. This includes equipment and devices that require high reliability, ultra-low latency connectivity with strong security, and availability. Examples of applications that 5G could enable include the following:

- Autonomous vehicles (includes automobiles, trucks, and other industrial equipment such as bulldozers and dump trucks);
- Drones used for site exploration, as well as asset monitoring and equipment monitoring, either in remote or safety critical locations;
- Robotics;
- Instantaneous control and management of machines; and
- Enhanced video surveillance.

As noted previously, while wired technologies are frequently relied on in the oil and natural gas industry today, 5G can combine extreme low latency with unparalleled mobility. For instance, drilling equipment connected via 5G could be rapidly moved from one oil exploration site to another without the timely process typically associated with wired connectivity.

3.1.1.2 Internet of Things (IoT)

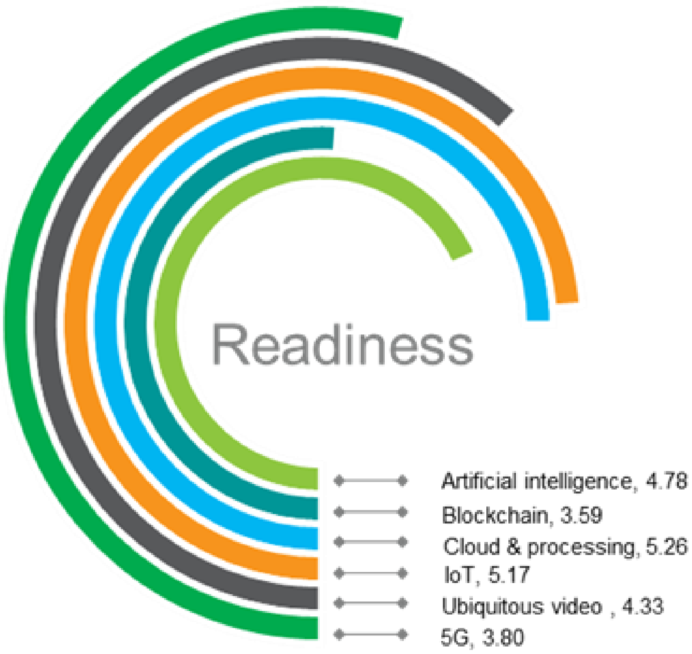
The IoT is not a specific device or technology—it is a conceptual framework, driven by the idea of embedding connectivity and intelligence in a wide range of devices. IHS Markit defines an IoT device as an object that has some form of embedded connectivity that allows the device to be directly connected to the internet (i.e., IP addressable) or allows the device to connect (tether) to an IP-addressable device. This connectivity can be wired or wireless. These devices can include a range of sensors and some type of user interface (UI), but neither sensors nor a UI is required under this definition.

3.1.1.2.1 IoT readiness

According to the 2nd quarter 2019 IHS Markit *Digital Orbit Executive Briefing*, IoT's relative readiness (compared to other transformative technologies) is high and was only surpassed by Cloud & Virtualization.

Figure 3.7

Digital Orbit technology readiness

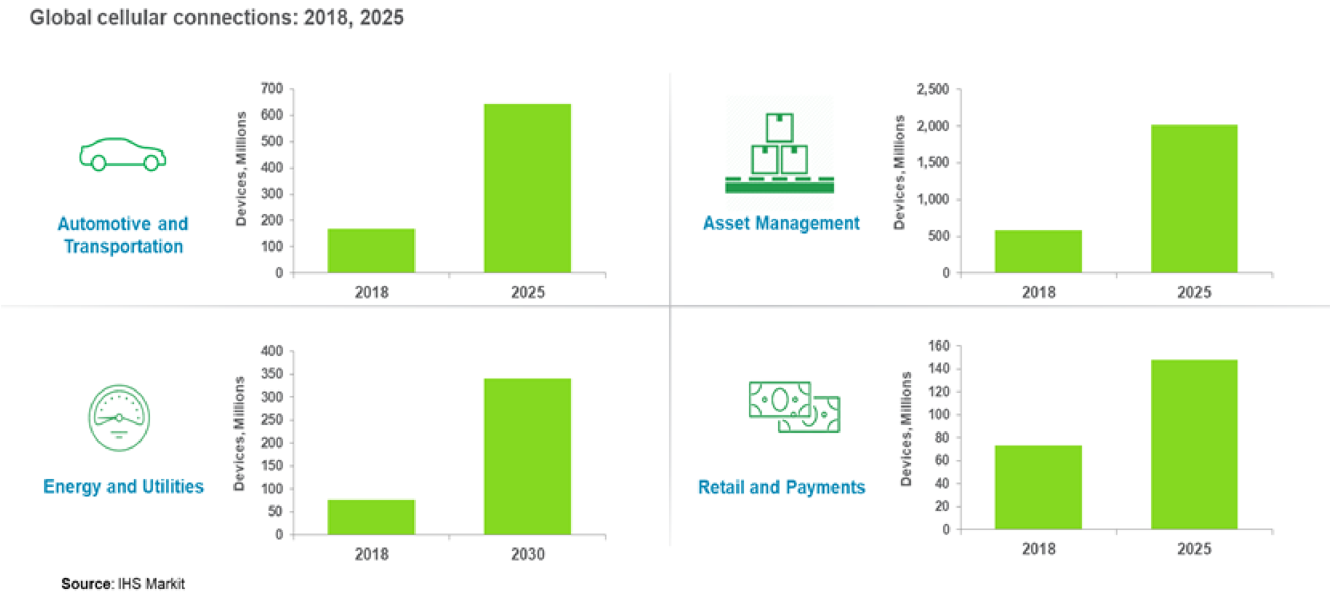


Given its relative technical maturity, proven usability, and wide range of established use cases, the high scores for IoT are anticipated. Many IoT applications have been around for well over a decade, and companies have had time to grow comfortable in adopting them to reap cost savings and offer new products or services. Additionally, a plethora of recent advances, including the development of low power connectivity technologies and increased computing power down to the node, have made it easier to connect a streetlight, sensor, electricity meter, home appliance, or any of the other “things” which make up the IoT.

IoT has proven applicability across a range of industries, including many with both sizable and addressable markets. As a result, IHS Markit estimates the worldwide installed base of IoT devices exceeded 23 billion at the end of 2018 and forecasts this number to surpass 55 billion in 2025. Figure 3.8 shows the distribution of the connectivity and associated growth with energy and utility management being a key investment area for smart cities and homes.

Figure 3.8

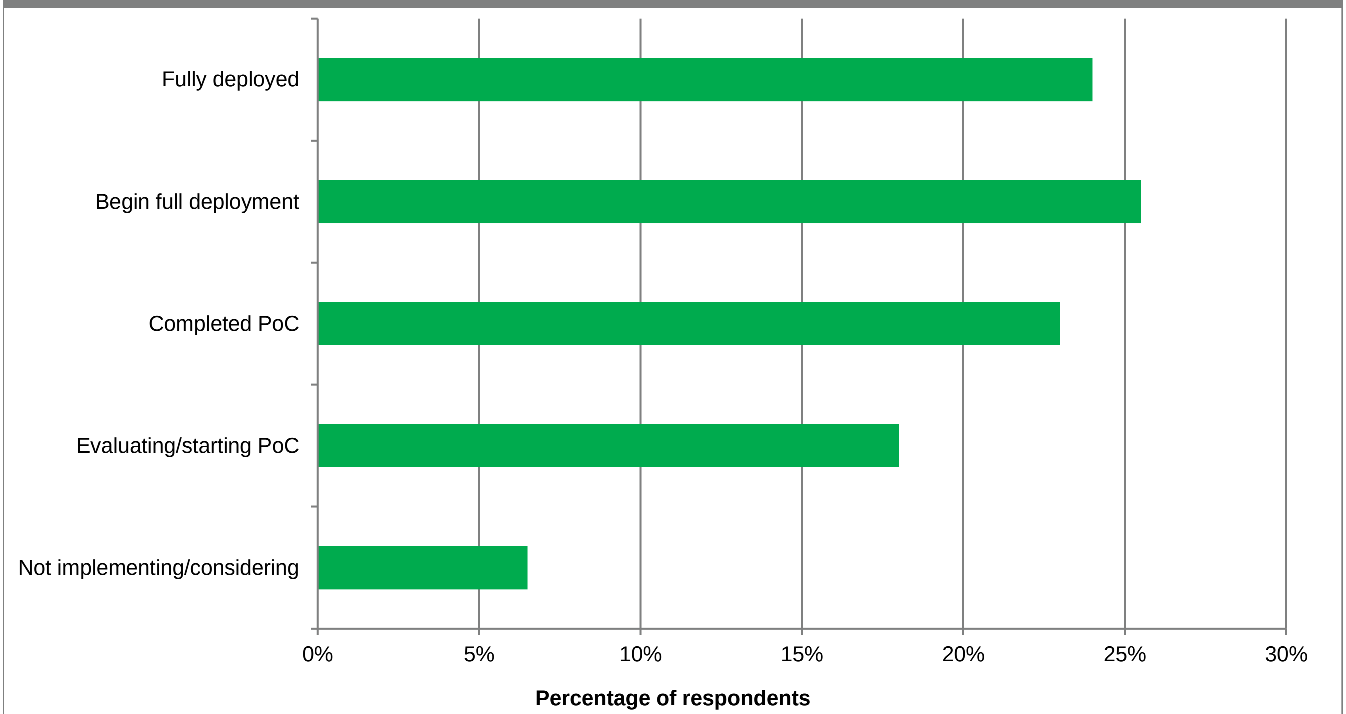
IoT cellular connectivity by industry



Among transformative technologies, IoT has one of the highest percentages of projects moving beyond proof of concept (POC) and into full deployments whether it is fully deployed or beginning full deployment (49%), as seen in the results from the a recent IHS Markit technology survey of key organizational influencers who have IoT projects under management (see Fig. 3.9).

Figure 3.9

Key Influencer Survey: What stage is your organization at in terms of IoT adoption?



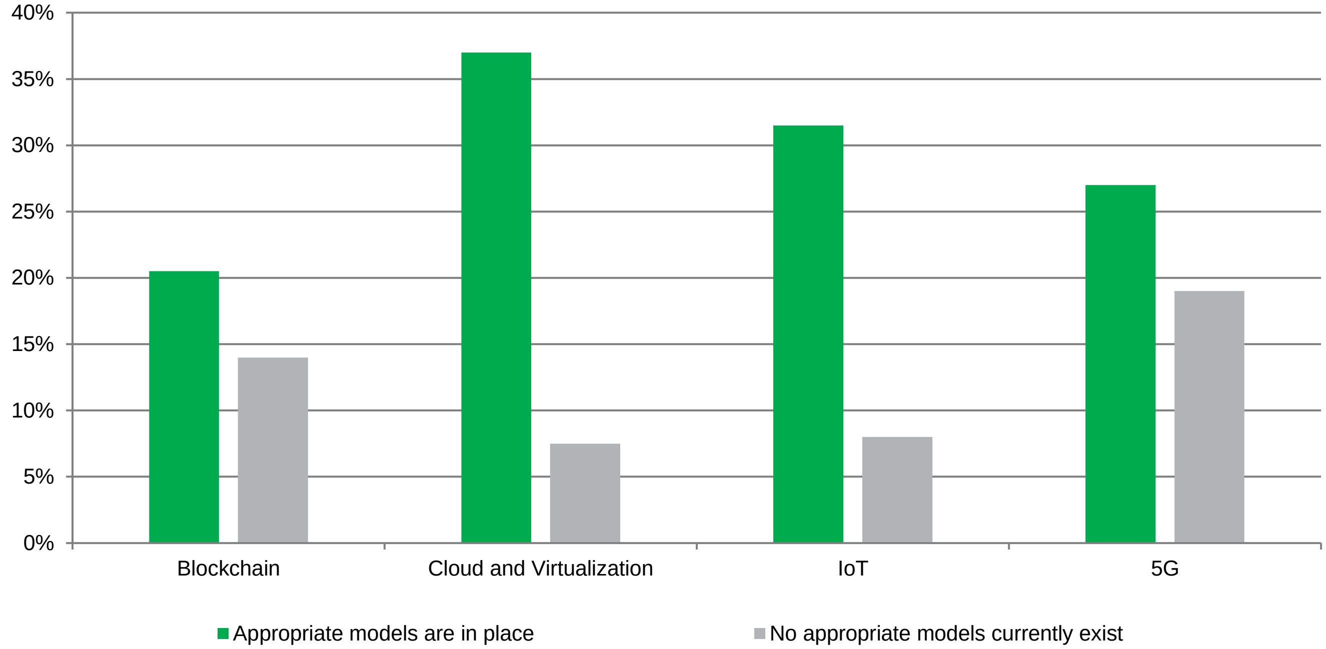
Source: IHS Markit

The total cost associated with the core elements of an IoT solution continues to drop. Looking at the cost of connection, compute and platforms—three key aspects of an IoT solution—IHS Markit estimates the costs to integrate and maintain an IoT solution has declined by nearly 37% since 2016. This trend is critical to the growth of IoT, as it removes a key barrier to entry.

Respondents to a Digital Orbit survey also indicate a higher portion of respondents believe appropriate business models are in place for IoT. Just 8% of respondents believe that no appropriate business models are in place to capitalize from IoT (see Fig. 3.10).

Figure 3.10

Key Influencer Survey: Are appropriate business models in place to capture value from this technology?



Source: IHS Markit

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3.1.1.2.2 Impetus for IoT adoption

The primary motivation behind the implementation of a vast majority of IoT applications is simply to improve operational efficiencies and reduce costs. There are a range of case studies in multiple verticals demonstrating the ability of IoT to provide a quick and strong return on investment. Examples of such established applications include fleet management (which can ensure efficient use of vehicles and reduce fuel costs), remote asset tracking (which helps eliminate misplacement or complete loss of equipment and machinery), and automated meter reading (which removes the need for manual collection of data from electric, gas, water, and heat meters).

In some instances, the introduction of IoT applications is intended to open new revenue streams or create product differentiation. A key example of this is in the automotive market, where IoT solutions have allowed for the introduction of features (infotainment, mobile WIFI hotspots, concierge services, etc.) that can be monetized by the automotive manufacturers.

Over 58% of respondents indicated that reducing costs/improving operational efficiency was their organization's primary driver for implementing their largest IoT solution.

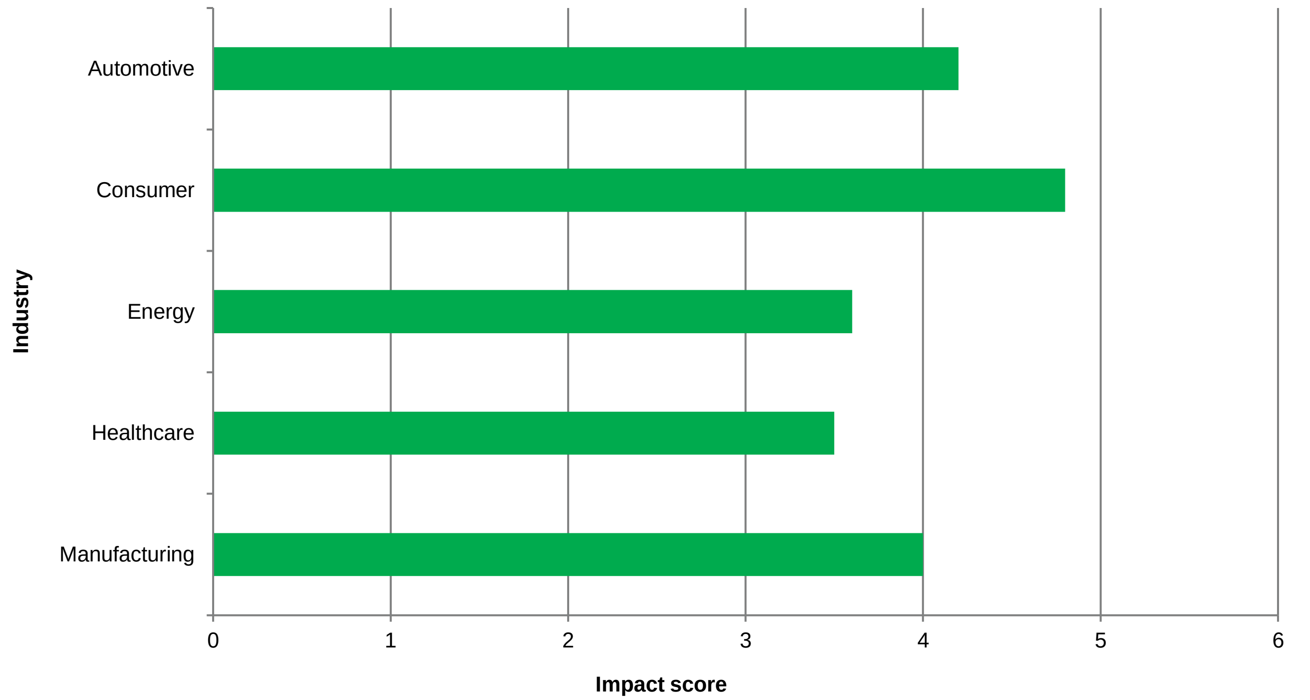
Another driver for implementation of IoT solutions is to conform to government regulations. One example would be a mandate which requires all vehicles be connected via cellular technology so they can alert emergency services when in an accident. Government regulations are also driving implementation of IoT in the utilities sector, with government mandates placing increased pressure on utilities to ensure efficient use of finite energy resources.

3.1.1.2.3 Impact of IoT

According to another IHS Markit technology report, IoT offers a potential economic benefit of up to $11.1 trillion a year by 2025.[8] As seen below in Figure 3.11, IHS Markit expects that much of this impact, especially over the next three years, will be in the consumer segment, driven by smart home applications and wearable devices.

Figure 3.11

IoT impact score by industry (next three years)



Source: IHS Markit, Digital Orbit Q2 2019 survey © 2019 IHS Markit

However, the greatest influence of IoT in coming decades is likely to be in sectors such as manufacturing, oil and natural gas, mining, and power generation. This increased impact will come in part from increased willingness from industry participants to use IoT solutions in their operations. The impact of IoT in these areas will be accelerated by continued improvements to the solution stack to include increased processing speeds, decreased physical size of radio components, and lowered costs (and better performance) of connectivity technologies. These advancements will allow IoT to address applications that previously were not viable—either technically or financially.

3.1.1.2.4 What this means for the oil and natural gas industry

- Readiness is not a barrier to adoption of IoT in the oil and natural gas industry. IoT solutions, with demonstrated ROIs, are increasingly affordable and now commonplace in a wide range of industries. Immediate IoT cases for

[8] *Artificial-Intelligence-Status-of-the-Market-Report,* IHS Markit, *2019*.

the oil and natural gas industry could include fleet tracking, remote asset monitoring and tracking, and lone worker tracking.

- Industrial automation for the physical infrastructure is a mature yet evolving capability and should be considered as an entry requirement for all new projects. As the technology is currently viable, it should become ubiquitous in new equipment and even for large scale upgrades to existing equipment.

- Continued enhancements in areas like processing power, as well as connectivity technologies, will allow IoT to address applications within the oil and natural gas industry that previously were not viable—either technically or financially. Greater availability of 5G and AI will also play a role, allowing for transformative IoT solutions.

- Improved productivity and improved efficiency are the primary benefits of IoT adoption.

- Oil and natural gas companies operate in dynamic and complex environments. Adopting IoT and other transformative technologies can increase the recovery of fossil resources, improve production processes, reduce costs, and improve safety.

3.1.1.3 Cloud and Datacenter

This section focuses mostly on Artificial Intelligence (AI), which is a part of the Cloud and Datacenter technology group. AI generically refers to the body of science that studies how to enable machines to perform independent problem solving, inference, learning, knowledge representation, and decision making. An intelligence machine does not need to necessarily show all the above-mentioned skills, but it must comply with one or some combination. More specifically, AI can fulfill four major skills: perception, learning, abstraction, and reasoning. Machine Learning (ML) refers to a subset of AI when machines are required to show specific self-learning skills.

3.1.1.3.1 AI readiness

AI scored strongly on readiness in the IHS Markit *Digital Orbit Executive Briefing*. The high score was driven by feedback from the *Key Influencer Survey*, with most respondents believing AI will be adopted quickly in their industries.

IHS Markit believes the high readiness score of AI requires closer examination. It is possible that the current rapid adoption of AI in initial applications, combined with the considerable media hype showered on the technology, might be giving rise to misconceptions—or even downright erroneous notions—about AI's readiness for wider-scale implementation. Given that many industries are still learning how to best utilize/deploy this powerful but relatively new technology, the high readiness score of AI strikes as even more of a surprise.

From this standpoint, the readiness of AI is likely lower than many would expect. In fact, AI adoption will vary greatly depending on the industry and use case. While the future of AI is bright, its implementation—especially in complex human-level AI applications—will take time.

IHS Markit does not believe that the rapid implementation of AI in devices such as smart speakers is indicative of the ease or speed at which AI will be adopted in other or more advanced applications. Instead, IHS Markit believes AI implementation will depend on the complexity of the application and what level of AI performance will be required to service it. This complexity can vary widely by industry, and even by applications, within a specific industry.

Consider, for instance, the adoption of AI by the automotive industry, where different AI applications exist, and where each application possesses distinct requirements. While infotainment HMI for speech has more relaxed requirements and has seen rapid adoption in the automobile, far-higher barriers and much more complex challenges must be resolved before AI achieves wider-scale implementation throughout the vehicle and can make needed real-time driving decisions. For example, the hardware to embed deep learning in safety-critical and high-performance automotive applications is not available at a reasonable cost for volume production. It is also not yet clear how to validate and certify to ISO26262 (Road vehicles – functional safety) for deep-learning-based systems. The sequence of events and actions executed by the algorithms are, as of today, not deterministic or traceable. Simulation, validation, and testing is a must for deep learning as well as for all the technologies in the car. The automotive industry will need to set a clear standardization procedure for validating and testing deep learning systems before they can become commercialized.

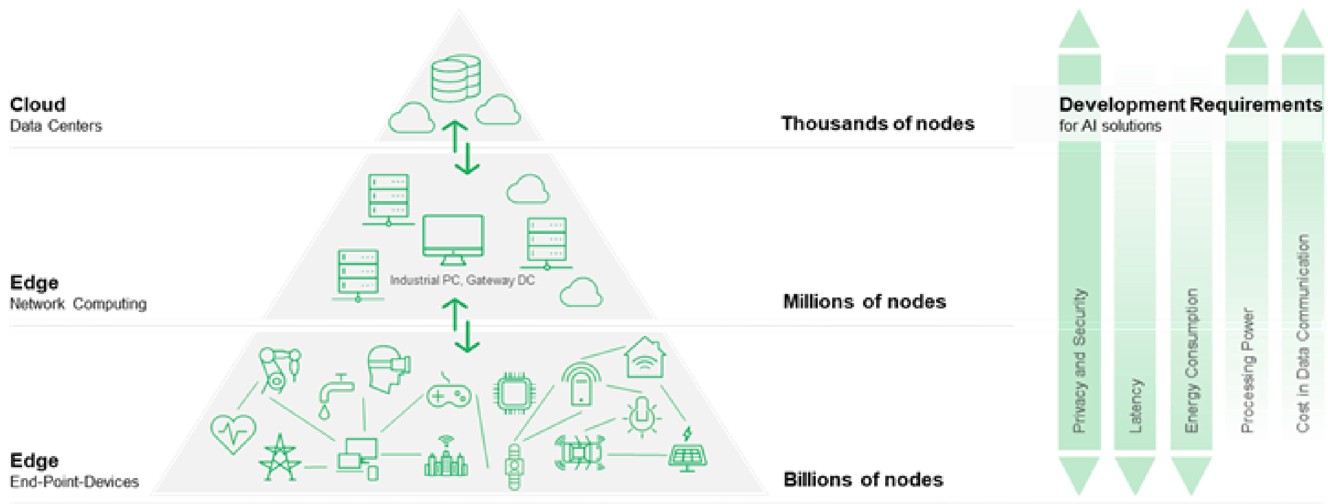
Similar challenges are present in other industries, like healthcare and manufacturing, as they look to implement AI in complex, mission-critical applications. Testing and verifying AI robustness in such applications in the real world—not in demos—will take time.

3.1.1.3.2 Impetus for AI adoption

The motivation behind the implementation of AI technologies in the oil and natural gas industry has multiple sources: being able to address functions and applications that were not possible in the past; improving performance in existing applications; and passing through enhancements in operational efficiencies while reducing costs. There are a myriad of use cases that demonstrate the ability of AI to solve new problems and add value in every industry vertical and horizontal domain, from the Cloud down to the Edge (see Figure 3.12).

Figure 3.12

Graphical representation of AI use cases by location and development requirements



Moreover, although AI is just in its infancy, it has strategic importance for the global community. With an extremely broad spectrum in skills and functions already available today, we are still in the exploratory phase of the potential of AI.

AI will develop much further once some of the following aspects are addressed and available for adoption:

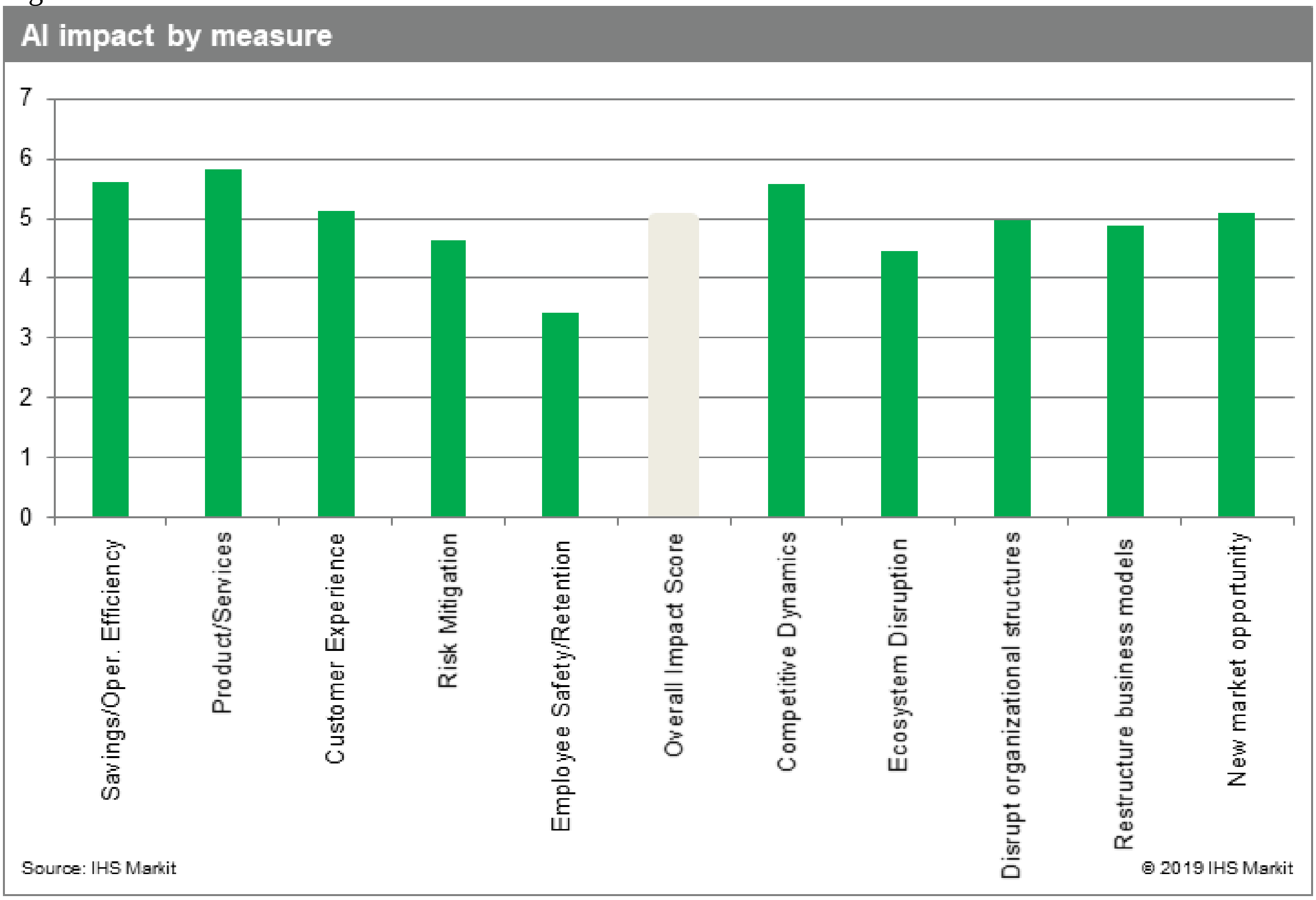
- **Scale:** Instant access to thousands of machines and sensors to perform complex and granular data analytics.
- **Performance:** Fast handling of differentiated AI workloads with adequate power consumption.
- **Quality:** Structured data and system training via accurate and reliable models and certified input data.
- **Custom:** Flexible and adjustable solutions to different use cases—scalable platforms to ensure profitable business cases.

However, the potential of machine learning technologies and their implementation into unmanned devices and robotics pose ethical considerations that, while of beyond the scope of this project, will need to be fully considered in conjunction with the technological developments. IHS acknowledges that it would be prudent to consider proper governance and ethics principles for the advancement of AI in the future.

3.1.1.3.3 Impact of AI

The impact of AI will be disruptive to many industries (probably all), as well as educational systems. AI and data scientist resources and experts are very limited today, which is why professionals with AI competencies around the world can expect significant compensation. The huge potential of AI indicates that its impacts will be not just in industry, but on society broadly.

Figure 3.13



The impact of AI in industry varies greatly across potential use cases because of the variance in AI applications and possible business models. However, the same survey results as depicted in Figure 3.13 also indicate scientists and industry leaders agree that AI is a new and fundamental technology that in time will be broadly adopted.

In terms of market expectations, the overall revenue from AI hardware and software spend is expected to grow from $214 billion in 2019 to almost $1 trillion in 2025, with an average compound annual growth rate (CAGR) of 28% from 2019 to 2025 across multiple industry domains. The major growth in adoption of AI systems is expected to occur in industries like automotive, manufacturing, healthcare, and defense.

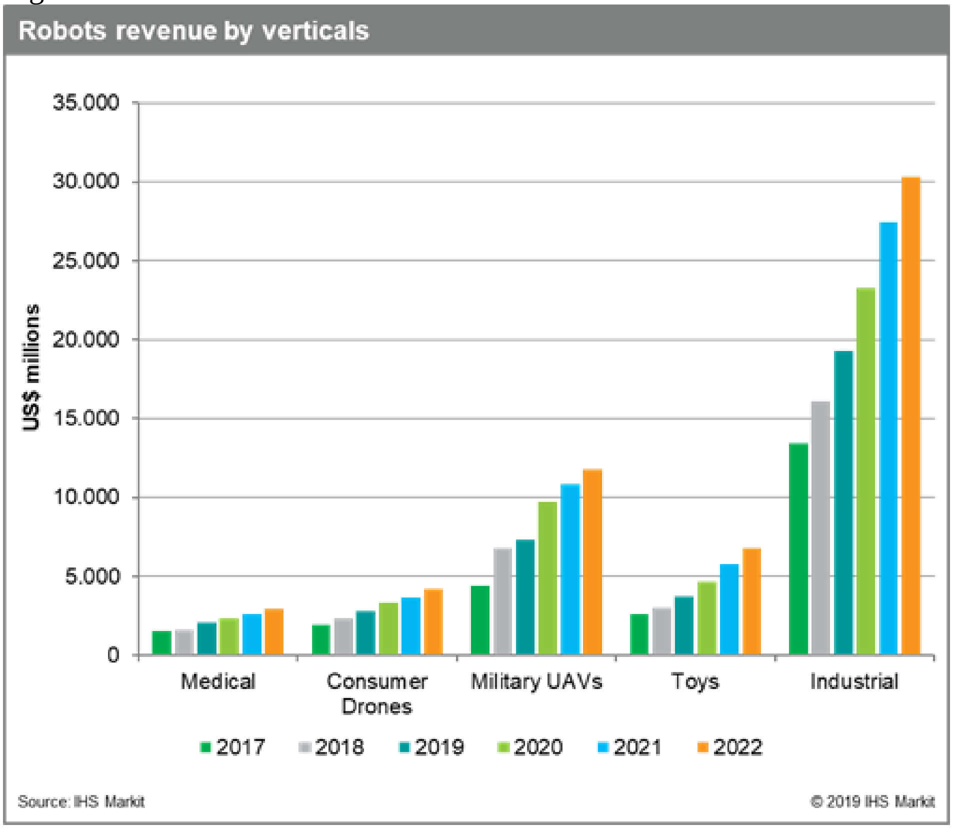
More broadly, Cloud and Datacenter computing will form the main infrastructure for training, whereas inference will be carried out along different layers of the edge devices, including local and on-premises servers where latency (the time it takes information to travel from the source to the compute processing node) will play a major role. Revenue from edge datacenters—with a round trip tip (RTT) of less than 20 milliseconds—is expected to top $20 billion by 2025 with a CAGR of 20% from 2019 to 2025.

Machine learning technologies together with advanced electro-mechanical and sensory science, such as machine vision, are enabling the fast development and deployment of different autonomous entities. These are able to accomplish several tasks with different levels of complexity that were previously done by people.

In IHS Markit nomenclature, autonomous machines refer to the following major categories:

- Automotive (light vehicles, buses, and trucks);
- Agriculture (harvesting and crop);
- Co-robots (industrial robots and healthcare);
- Consumer robots (toys, drones, service robots);
- Marine and military; and
- Mining and Construction.

Figure 3.14



As shown above in Figure 3.14, the industrial robotics market is the fastest growing vertical within the autonomous machine’s category in terms of revenue. Additionally, the industrial robotics market shows about 0.53 million units shipped in 2018, but that is expected to rise to 3.32 million units by 2025. Industrial robots have the largest share in terms of revenue because of the high selling price of average industrial equipment. Total revenue for the industrial segment in 2018 was $16 billion and is expected to be $41 billion by 2025.

From the power of AI to the potential of 5G, the growth of these transformative technologies is shaping our connected lives. Powerful on their own, they are now converging to fundamentally change how we interact with the world, how we do business, and even how we communicate with each other. As this convergence continues, formerly separate industries are intersecting in new ways, with new emerging opportunities (and challenges). The synergies between technology trends drive exponential, rather than linear, change.

3.1.1.3.4 What this means for the oil and natural gas industry

- Digital twins are currently seen in areas such as the utilities industry, which has sophisticated grid models for storm preparedness simulations. Digital twins can require substantial engineering investment to accurately model a complex system which will slow usage in some areas. In the next 5 years, more off-the-shelf industry tools are expected to become available to make this investment quicker and broaden the technology reach, which will benefit the oil and natural gas industry adoption.

- Data Analytics and Machine Learning depend on good, detailed data, and should correlate within the oil and natural gas industry to the investment in IoT technology.

- Data Analytics will be at the forefront of adoption within the oil and natural gas industry and will be a proxy for technology adoption.

- AI will be a lagging technology; more immediate benefits will be in robots and drones and autonomous vehicles used as force multipliers within the oil and natural gas industry, but as AI matures, it will show significant and reaching impact to all areas.

3.2 Industry use case analysis of technology

We can enhance our understanding of the expected impact of technology on the industry through use case analysis. This section focuses on digital and automation technologies that are attracting great attention and are anticipated to play a significant role in the future of the industry. In addition, unlike advances in core oil and natural gas technologies (e.g., seismic acquisition, drill bits, water treatment, enhanced oil recovery), digital and automation technologies are changing how work is done in the industry, with resulting shifts in workforce demands. While the material in this section is mainly qualitative in nature and thus does not lead directly to the assumptions behind the employment and hiring paths in Chapter 4, the use case analysis lays a foundation for quantifying the impacts of new technology on the oil and natural gas industry and provides valuable context.

3.2.1 The shifting focus of oil and natural gas technology organizations toward digitalization

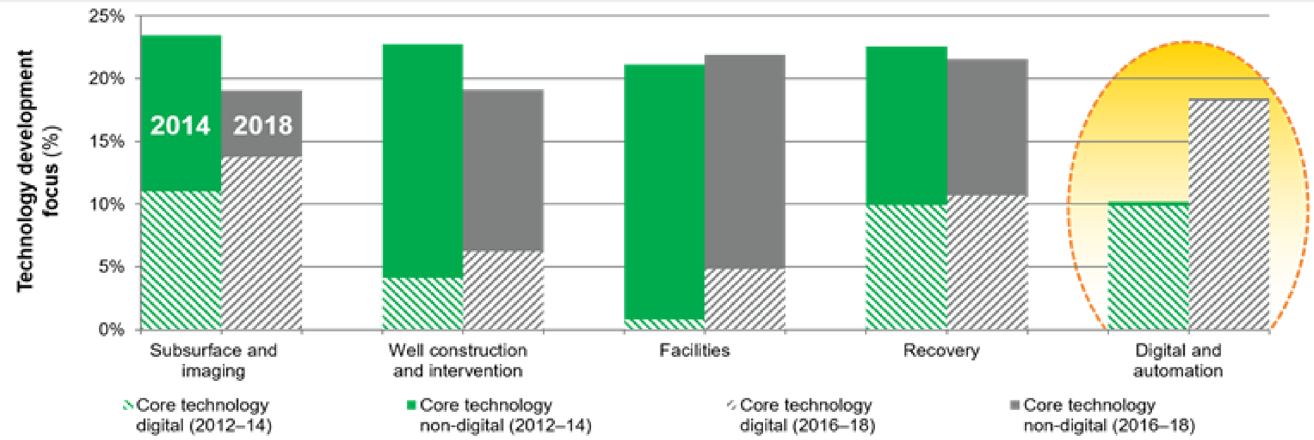
Major energy companies have long maintained organizations dedicated to the development and deployment of core oil and natural gas technologies. These programs include research and development (R&D) organizations (e.g., ExxonMobil's Upstream Research Company), offices of the chief technology officer (e.g., ConocoPhillips), and broader technical organizations (e.g., Chevron's Energy Technology Company).

The recent (re-)emergence of digitalization and automation as a major technology theme in the oil and natural gas industry has prompted major companies to carve out separate organizations dedicated to developing and effectively deploying such technologies, and for independent exploration and production (E&P) firms to stand up formal technology groups where none existed previously within their organizations. The objectives of these newly-formed groups are to develop and/or source technologies most appropriate for the company's operating circumstances, and then to work with the business to ensure rapid, organization-wide uptake and value capture from them—a relatively significant achievement given recent industry experiences.

Figure 3.15 confirms the upstream sector's recent shift toward the development of digital and automation technologies over those in more traditional E&P technology domains (e.g., subsurface and imaging, well construction and intervention). The figure illustrates the results of a survey that IHS Markit conducts every two years to assess the upstream industry's technology development focus areas. It shows the sector's relative focus between the four core technology areas (subsurface and imaging, well construction and intervention, facilities, and recovery) and the digital and automation technology area, as well as the significant increase in digital and automation focus that occurred between IHS Markit's initial survey in 2014 and our last one in 2018. The figure also shows the increased digitalization of core technology areas (the hatched shading) as those elements make their way into traditional E&P technologies (e.g., the increased automation of drilling rigs).

Figure 3.15

Upstream technology development focus areas, with digital component*



Notes: *806 records of 29 E&P and supplier companies for 2012–14, and 2355 records of 51 companies for 2016–18
Source: IHS Markit
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3.2.2 Investments and early outcomes

The oil and natural gas industry's growing embrace of digital and automation technologies is driven primarily by these technologies' strong alignment with overall industry objectives—reduce costs and raise efficiencies in a low-to-moderate price environment, shorten project cycle times, and accelerate time-to-value of technology investments. At the same time, a big part of digitalization's attractiveness is its modest development costs as compared to core oil and natural gas technologies (e.g., enhanced oil recovery, liquids processing) that often require extensive laboratory work, field trials, and capital investments.

It is often difficult to break out investments in digital and automation projects in the same way that companies break out the dollars spent on core technologies that they record as R&D and related field trial expenses. Digitalization investments often include a combination of asset instrumentation (e.g., sensors, automation systems), communication infrastructure (e.g., field wireless networks, subsea fiber-optic cables), software licenses and other information technology (IT)-related elements, and staff. These expenses are sometimes ones that would be borne regardless of whether a company is making a major digitalization push (e.g., control and automation systems), and in other cases, they are embedded in capital and IT budgets.

Additionally, with the industry's strong capital discipline remaining in effect since the oil price downturn, a common directive from senior management has been that digitalization projects should incur no additional capital spending, but they should instead take advantage of technical infrastructure investments made over the previous decades. Expenditure will likely rise over the coming years as companies make investments in advanced communication networks, higher levels of asset automation together with robots and autonomous vehicles, and software development and support. However, digitalization and automation project costs are still likely to remain modest compared to core oil and natural gas technology development costs.

IHS Markit has had greater effectiveness estimating the digitalization and automation-related expenditures of mid-sized and large independent E&P firms than for the major firms, as the mid-sized and independent firm efforts are often centralized in a single corporate entity, rather than distributed across multiple technical functions and operating units as they are for the major oil and natural gas companies. The digitalization and automated-related efforts of these smaller companies are primarily in the data science domain (i.e., artificial intelligence, advanced analytics, machine learning), with some lesser activities related to drones and robots, extended mobile computing, and buildout of 5G wireless communication networks. These data science groups are typically composed of 10 to 20 members, incurring roughly $8 to $15 million annually in staffing and software license fees. The major oil and natural gas companies have larger groups and are incurring expenses on the order of $50 to $200 million annually.

3.2.3 Technology deployment strategies

As energy companies move forward with their digitalization and automation strategies that aim to position them to compete effectively on a cost-of-supply basis, they bring with them legacy organizational structures and past experiences related to their attempts to deploy such technologies across their broader organizations. These factors influence the deployment strategies that companies are pursuing today.

Figure 3.2 lays out four distinct models that seem to be emerging within the industry for oil and natural gas companies to develop and institute digitalization capabilities across their organizations:

- "**Big bet**" companies make significant investments (up to $100s of millions annually) in centrally positioned groups that aim to develop advanced and integrated solutions spanning functional groups (e.g., well construction, production) and the entire E&P lifecycle from exploration through to production.
- "**Functions take the lead**" and "**Business take the lead**" approaches are more modest in scope, focusing on the challenges and opportunities associated with specific technical functions (e.g., drilling), operating units, or resource types (e.g., deepwater oil).
- "**Existential crisis**" models exhibited by unconventional operators reflect the urgency with which these companies pursued digitalization to significantly reduce costs and raise productivities following the most recent oil price downturn.

It should be noted that nearly all oil and natural gas companies are pursuing a hybrid of these four approaches, with IHS Markit pointing out what we believe is the dominant model for most major companies in order to provide real world context. In addition, there is no strong evidence to support that one model is better than another. Companies are simply selecting an approach(es) that best matches organizational capabilities and aspirations.

Figure 3.16

Oil & gas digitalization models

Comparative characteristic	"Big bet"	"Functions take the lead"	"Business takes the lead"	"Existential crisis"
Key aspects	• **$100MM+**, corporate-wide investments • **Holistic vision**, while targeting "quick wins" • More **apt to partner** (e.g., BP-BHGE, Equinor-Accenture)	• **Discrete functions** drive advances (e.g., Drilling, Reservoir Management) • **Light integration** underway (e.g., formation of corporate *Digital Transformation* and *Industrial Revolution 4.0* groups)	• **Operating units** drive advances (e.g., Gulf of Mexico, Deepwater, Australia LNG) • Focus on 1) **specific "pain points"** and opportunities, and 2) integration across standalone assets	• Extreme cost pressure drive focus on **immediate benefits in discrete areas** (e.g., artificial lift, drilling) • **Forgo partnerships** in competitive-differentiating areas • Evolve into **broader innovation programs** ("the new R&D org")
Example E&P firms*	Anadarko, BP, Eni, Equinor, Petrobras, Petronas, Total, Woodside	Chevron, ExxonMobil, Saudi Aramco	ConocoPhillips, PDO, Shell	**Independents** (BPX, Devon, EOG, Hess, Oxy, Pioneer, Santos)
Organizational positioning	**CEO** (Corporation, or Upstream division)	**Functional Lead** (e.g., EVP Wells, President Production Company)	**Business Unit Leadership**	**Regional President**, **COO**, **CTO**, **CIO**
Organizational value realized, to date	**Low-to-moderate**	**Moderate**	**Low-to-moderate**	**Moderate-to-high**

Notes: * Oil companies are often hybrids and do not fall exclusively into a single Digitalization model; E&P firm classifications represent each company's dominant or most effective trait
Source: IHS Markit
© 2019 IHS Markit

Companies have also come to appreciate the significant hurdles associated with realizing the full potential of their digitalization and automation technology investments. Unlike some core technologies, these require fundamental changes in how staff work and how companies organize themselves to achieve maximum benefit, and thus introduce more significant challenges related to deploying the technologies at scale across organizations, capturing the value associated with them, sustaining them over time, and beginning to pursue more integrated (versus discrete) approaches. IHS Markit lays out such challenges in Figure 3.17 and describes the technical and organizational solutions industry players are pursuing to overcome them.

Figure 3.17

Oil and Gas Digitization Scenarios

	Rapid Deployment @ Scale	Value Capture	Sustainability	Integration (functional / value chain / lifecycle)
Challenge	• Technical issues sometimes **stymie widespread deployment** of developed & trialed digital solutions • Result = a set of one-off projects having only **modest impact on overall corporate performance**	• Organizational issues often **hinder effective workflow incorporation** of digital solutions • Result = under-utilized digital solutions deliver only **modest corporate performance improvements**	• Workforce **does not maintain high initial level of digitalization uptake** owing to management turnover, degradation of solutions and other factors • Result = successfully deployed digitalization solutions show **steady erosion of realized value**	• Ongoing digitalization initiatives **largely focus on discrete functional activities** (e.g., ESP reliability, stuck pipe avoidance) • Result = solid results in discrete areas, while **missing higher-potential opportunities**
Approach	• **Leverage next wave of digital infrastructure** (e.g., Cloud hosting, Platforms) to facilitate deployment • **Leverage x-asset operational support centers** with global reach (e.g., drilling, equipment surveillance, thermal ops) to rapidly test, deploy, and refine developed solutions	• **Engage technical workforce** throughout tech development cycle to help ensure acceptance • Establish **expectations of higher asset performance** based on capabilities that digitalization can deliver	• Develop effective technical & organizational **methods to maintain & continue to advance** developed solutions • Establish **expectation of digitalization capability** at all levels of the organization	• Overcome data, architecture & organizational issues to enable **transparency across boundaries** • **Target high-value integration opportunities** crossing value chain, functional, and lifecycle borders

3.2.4 Overview of key technologies and use cases

IHS Markit identified a set of emerging technologies that are likely to have the most significant impact on oil and natural gas industry employment and demographic trends over the coming two decades. As stated previously, these technologies fall largely within the broad category of digitalization and automation. The industry's primary emphasis on cost reductions and on efficiency gains aligns well with the benefits that this class of technologies offers and are thus likely to be a significant area of focus for years to come. This class of technologies will also have a significant impact on industry employment and demographic trends—in fundamentally changing how work is done, these technologies will reduce employment in some areas (e.g., field operators, drilling rig crews), increase it in others (e.g., data scientists, surveillance and optimization technicians), and shift where work is done (e.g., fewer field-based staff and more office-based personnel).

While the focus of this report is on technology's impact on the oil and natural gas industry employment and demographic trends, it should be noted that these same technologies will help and in some cases are helping to improve workforce safety and environmental performance in significant ways. Remote monitoring, industrial automation, video surveillance and inspection, and many other digitalization solutions contribute to reducing workforce site exposure and travel (one of the major contributors to industry safety incidents) by allowing operators to remotely perform tasks that previously required an onsite presence, and to be more efficient once in the field. In addition to identifying sub-optimal performance, these solutions can also help to identify and mitigate unintended greenhouse gas releases (e.g., aerial drones with a payload of laser and optical sensors to detect methane) and to optimize asset performance in a way that reduces emissions (e.g., optimizing equipment performance to reduce energy consumption). These outcomes are not surprising—digitalization-enabled asset development and operating models represent a more efficient way to manage resources, which extends to nearly all aspects of industry performance.

IHS Markit provides an overview of each of these key technologies, a high-level view of the influence that each is likely to have on industry employment and demographics trends, and (when available) accompanying industry-leading case studies that IHS Markit has had an opportunity to develop in conjunction with the executing energy company.

3.2.4.1 Massive IoT

3.2.4.1.1 Remote Monitoring

Remote Monitoring is a critical enabler of the new, technology-enabled operating model that oil and natural gas companies are pursuing. By remotely monitoring all (data) aspects of asset performance, operations staff can quickly identify and respond to assets that are shutdown, trending toward failure, performing sub-optimally, or are in some other way in need of attention. This allows companies to shift from a "visit-by-route" to a "visit-by-exception" operating model, significantly reducing field workforce requirements (up to 60 to 80% in some cases) while creating additional needs for office-based surveillance and support staff. Remote Monitoring is executed in conjunction with Enhanced Outdoor Wireless Broadband and Training/Collaboration technologies and shares the potential benefits with them.

<u>Use case:</u> A major oil and natural gas company operating eight production platforms in a deepwater basin has shifted to a new operating model dependent on remote monitoring. Rather than relying on asset engineers to perform basic surveillance tasks, the deepwater business unit has centralized such tasks in a single center supporting all eight platforms. With the support of automated systems, surveillance analysts and engineers continuously monitor all key offshore equipment and infrastructure (e.g., electrical submersible pumps, compressors, subsea flowlines) to identify either performance falling outside of tolerance and/or equipment in need of optimization. Since deployment nearly ten years ago, the business unit is raising overall business unit production rates by nearly 1% annually, reducing time spent offshore commissioning new assets, and increasing the effectiveness of a declining engineering staff.

3.2.4.1.2 Industrial Automation

Industrial Automation is asset instrumentation that enables either remote actuation or onsite, closed loop actuation of a device (for the latter, in conjunction with Edge Computing). Such technologies further advance a company's remote operating model by reducing the need to travel to a site to manually manipulate a device, and likewise further reducing demands on the field workforce. IHS Markit includes drilling rig automation in this technology category (versus in the Robots and Drones and Autonomous Vehicles category), an area that is likely to see significant advances over the coming decades to further reduce rig crew requirements.

3.2.4.1.3 Video Surveillance and Inspection

Video Surveillance and Inspection augments the data capabilities offered by Remote Monitoring by providing real-time video and related feeds (e.g., infrared, hyperspectral imaging). Such video streams further reduce the need to visit site locations (e.g., for physical security purposes), improve the efficiency of maintenance crews by allowing them to better prepare for upcoming tasks, and negate the need for some inspections (e.g., hand held methane detectors) that are more effectively performed by fixed or mobile cameras. Video Surveillance and Inspection is sometimes executed in conjunction with Enhanced Outdoor Wireless Broadband and Robots and Drones and Autonomous Vehicles and shares the potential benefits with them.

3.2.4.1.4 Safety/Wearables

Safety/Wearables are devices worn by workers to track their location, their status (e.g., heart rate, alertness), and environmental conditions. While these devices will certainly improve industry safety performance, they will have only minimal impact on workforce productivity and operating practices, and thus little influence on industry employment and demographic trends. Discrete areas in which they may have an impact include 1) improving maintenance and turnaround efficiency by ensuring appropriately trained and qualified staff are assigned to tasks, and 2) identifying and eliminating system waste (e.g., inefficient routes and work practices).

3.2.4.1.5 Robots and Drones and Autonomous Vehicles

Robots and Drones and Autonomous Vehicles is an area of significant industry interest and technology development, and one that is benefiting from advances coming from outside of the oil and natural gas sector (e.g., defense, aerospace). While there is a wide range of solutions both under development and under trial, the capabilities offered by this class of technologies boils down to either automating the execution of tasks otherwise performed by humans or enabling the more effective collection of data, video and audio streams (or both). Several applications are becoming standard (e.g., flare tip inspection by drone, confined space inspection by drone, subsea inspection by autonomous underwater vehicle), and others are just emerging (e.g., offshore platform instrumentation manipulation by robot, seismic data acquisition by marine drone). While operational and commercial aspects are still being worked out (e.g., several industry drone programs have recently been terminated owing to cost concerns), IHS Markit expects that this class of technologies will have a modest-to-significant impact over the coming decades.

Use case: An Australasia independent E&P firm worked with its country's aviation authority to secure an exemption to operate a military-grade drone (i.e., not a quadcopter) beyond visual line of sight. Operating over 4,000 wells distributed across nearly 100,000 square miles, the company is now able to inspect each well site both visually and via infrared camera every three weeks to identify any security breaches and unsafe conditions, measure tank levels and solids buildup, read equipment gauges disconnected from the local automation and control systems, and perform tasks normally performed by personnel on site. As a result, field operators have reduced kilometers-driven per well managed by 25–30% and allowed the company to add wells without adding new staff.

3.2.4.2 Cloud and Data Center

3.2.4.2.1 Digital Twins

Digital Twins is emerging as a broad concept for integrating multiple static and dynamic data sources to create a complete virtual representation of an asset (e.g., a production system, a refinery or processing plant, a well construction operation). Once developed, Digital Twins has a range of potential applications—work planning, surveillance, optimization, and training. Impacts on industry employment and demographic trends are related to improvements in workforce efficiency (and thus reduced demand) through better training and better task preparedness.

Use case: A North American independent E&P firm has developed a digital twin of its large heavy oil extraction and processing unit. Building on static data sets (e.g., engineering, asset integrity, management of change processes, maintenance management records), the operating unit developed a virtual representation of the plant that is used for maintenance planning and turnaround activities and is also used by 1,500 engineers and technicians to help guide their work daily. It has since expanded to include real-time process data that is used to perform surveillance of the system. Leveraging the solution, the company has reduced plant operating costs by 45%, and shortened plant turnaround times by 25 – 30%.

3.2.4.2.2 Data Analytics, Artificial Intelligence, and Machine Learning

The technologies falling under the broad category of Data Science (that represent the industry taking a more data-driven approach to asset development and operations) are likely to have amongst the most significant impacts on industry employment and demographic trends over the coming decades. Unlike many of the technologies falling within Enhanced Communication and Mobile Broadband and Massive Internet of Things, data science will impact both field- and office-based workers and will be felt across nearly all areas of the business. Data science will help to automate tasks (e.g., seismic survey processing and interpretation), improve asset performance predictability and thus efficiency, and drive autonomous operations (e.g., un-manned drilling rigs). While one net effect will be a reduction in the need for certain job classes (e.g., field operators, maintenance staff, seismic processing support), it will create new ones as industry activity flows into these areas and new groups are formed and expanded.

While significant attention has been paid to data science, it should be noted that it has delivered only modest results to date. IHS Markit expects that to change over the coming decades as data access and data management improves and as solutions are expanded and refined.

Use case: A North American independent E&P firm formed an advanced analytics team in 2015 to support its tight oil operations—improving well construction efficiency, reducing artificial lift failures, and beginning to optimize completion designs to improve productivity. Leveraging the capabilities of its central team to develop algorithms fed by the company's ongoing tight oil activities, the company has been able to raise well productivities by 170%, progress from a last quartile to a top quartile performer (a standout accomplishment) and improve drilling efficiency improvements four times over its peers, significantly lowering well construction times.

3.2.4.2.3 Edge Computing

Edge computing represents "intelligence" at the asset (e.g., sensor, pump, turbine), enabling it to operate in a semi-autonomous manner. The two primary applications of this technology are 1) continuous asset optimization at the local level (e.g. advanced process control), and 2) determining under what conditions to transmit data back to a central location for surveillance and optimization purposes (e.g., a process upset). The former application will have the most significant impact on industry employment and demographic trends, as it will reduce the need for site visits and maintenance activities.

4 Employment projections and demographic profile

4.1 Employment projections by subsector

Table 4.1 shows current and projected employment by subsector. From 2019 to 2040, employers in the industry are expected to add 258,800 jobs, driven largely by additions in the upstream sector (adding 222,400 jobs, an 18.9% increase over current levels).

These projections show approximately 0.9% growth per annum in total industry employment through 2030, falling to 0.2% from 2030 to 2040. The projected growth in both periods is much lower than the expected job growth from 2015 to 2035 used in the prior study, as approximately 500,000 jobs were added in recent years. In other words, much of the job growth that was part of the prior study has already been realized. But as discussed later in this chapter, a much larger number of new hires will be 'replacements' for retiring workers and others that become permanently separated from the industry.[9]

Table 4.1

Employment by subsector
(thous)

Subsector	2019	2030	2040	Added
Upstream	1178.8	1340.6	1401.2	222.4
Midstream	367.6	448.4	441.4	73.8
Downstream	285.6	266.7	259.8	-25.9
Petrochemical	220.9	212.3	209.4	-11.5
Total	**2052.9**	**2268.1**	**2311.7**	**258.8**

Source: API © 2019 IHS Markit

4.2 Employment projections by occupation

Results in this report are based on an analysis that looks at both specific jobs and the major occupational categories in each subsector of the oil and natural gas industry. We used descriptions of detailed occupations for the industry and the skills that are required to place each relevant job into one of the following eight broad categories:

- Management, business and financial;
- Professional and related;
- Service;
- Sales and related;
- Office & administrative support;
- Highly skilled craft;
- Skilled craft; and
- Laborers, workers, helpers.

Table 4.2 presents the breakdown of employment aggregated across all sectors for these eight broad occupation categories, both currently and projected through 2040.[10]

[9] See Appendix C for details on how replacement type need from retirement and labor force exit were computed and applied in this study.

[10] Appendix B has information about the occupational categories for the industry subsectors, as well as details from historical minority shares for different occupations that provided guidance for this study.

Table 4.2

Industry employment by occupation
(thous)

Employment	2019	2020	2030	2040	Change
Management, business, and financial	332.9	337.6	378.8	393.9	61.0
Professional and related	275.9	282.0	341.5	361.0	85.1
Service	7.9	8.0	9.2	9.6	1.7
Sales and related	59.5	59.7	61.6	63.5	4.0
Office and administrative support	233.1	236.0	262.5	274.7	41.6
Highly skilled craft	692.9	701.4	740.3	742.9	50.0
Skilled craft	341.4	345.7	360.7	357.5	16.1
Laborers, workers, and helpers	109.3	110.4	113.5	108.5	-0.8
Total	**2052.9**	**2080.6**	**2268.1**	**2311.7**	**258.8**

Shares	2019	2020	2030	2040	Change
Management, business, and financial	0.162	0.162	0.167	0.170	0.236
Professional and related	0.134	0.136	0.151	0.156	0.329
Service	0.004	0.004	0.004	0.004	0.006
Sales and related	0.029	0.029	0.027	0.027	0.016
Office and administrative support	0.114	0.113	0.116	0.119	0.161
Highly skilled craft	0.338	0.337	0.326	0.321	0.193
Skilled craft	0.166	0.166	0.159	0.155	0.062
Laborers, workers, and helpers	0.053	0.053	0.050	0.047	-0.003

Source: IHS Markit

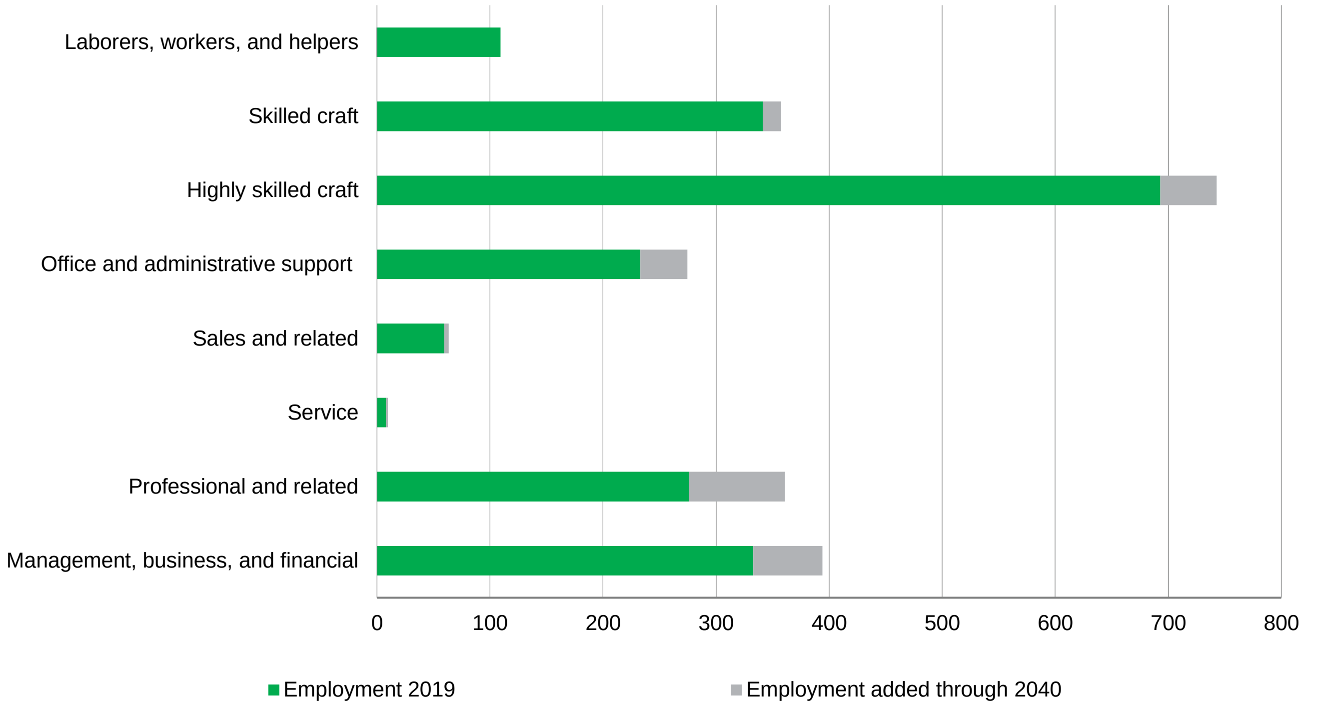
As shown in Table 4.2, highly skilled and skilled craft positions are currently the two largest categories, combining to account for just over 50% the industry jobs in 2019. The shares for additional jobs in these two occupation categories, however, will fall short of current shares over the forecast period, and shares for management, business, and financial and professional and related categories will rise. In fact, additions to the management, business, and financial and professional and related occupations are expected to total 146,100, compared to the combined addition of 66,100 for the highly skilled craft and skilled craft occupations.

Figure 4.1 highlights the importance of highly skilled craft; skilled craft; management, business, and financial; and professional and related categories for current job levels and projected additions. In contrast, positions as laborers, workers, and helpers will remain flat. This chart makes it clear that the industry requires a well-trained workforce (with degrees from either universities, community colleges, or some other post-secondary training program) and can produce well-paid, “good” jobs.[11]

[11] See for example Phillips, *The Quality of Jobs in Construction and Oil-and-Gas for High School Graduates*, January 2020.

Figure 4.1

Industry employment and additions by occupation



Source: IHS Markit

4.3 Overview of US and industry labor force demographics

The BLS estimates that the male/female split of total US employment is approximately 53/47%. Furthermore, the White male share is 33% for the total US workforce and is the largest race-gender group for most industries and occupations. Historically, the male and White male shares have been high in the oil and natural gas industry, such that shares for people of color and women (all races combined) have been lower than national averages (all industries combined).

However, future industry hiring shares for different races are not likely to match current employment shares. While we take guidance from historical and current estimates, race and gender shares are adjusted to reflect expected changes in the US work force. Most important for this study, the Hispanic share of available workers for both sexes are expected to rise and the White male share is expected to fall. Table 4.3 shows 2019 industry employment by occupation, gender, and race.

Table 4.3

Industry employment by occupation, gender, and race, 2019

(thous)

Occupational category	Female total	Female: African American (AA)	Asian (AS)	Hispanic (HISP)	Other	White
Management, business, and financial	102.5	5.1	13.1	12.2	2.8	69.4
Professional and related	57.8	3.7	5.4	6.8	0.9	41.0
Services	1.8	0.2	0.0	0.7	0.0	1.0
Sales and related	16.0	3.8	0.2	4.7	0.2	7.1
Office and administrative support	157.4	8.6	2.4	26.9	4.7	114.8
Highly skilled craft	38.3	9.9	1.2	6.8	2.1	18.3
Skilled craft	30.4	6.4	1.6	6.9	0.9	14.6
Laborers, workers, and helpers	14.8	1.8	0.2	4.6	2.1	6.1
Total	**419.0**	**39.3**	**24.1**	**69.5**	**13.8**	**272.4**

Occupational category	Male total	Male: African American (AA)	Asian (AS)	Hispanic (HISP)	Other	White
Management, business, and financial	230.5	7.6	8.6	31.5	3.9	178.9
Professional and related	218.1	9.7	22.4	19.5	6.4	160.1
Services	6.0	0.4	0.1	1.7	0.1	3.7
Sales and related	43.4	1.2	0.7	4.1	0.9	36.5
Office and administrative support	75.7	7.9	2.1	10.9	1.7	53.1
Highly skilled craft	654.5	37.5	5.6	149.2	17.4	444.8
Skilled craft	311.0	31.2	3.0	86.1	8.9	181.8
Laborers, workers, and helpers	94.5	10.7	1.5	38.9	2.2	41.4
Total	**1633.8**	**106.2**	**44.1**	**341.8**	**41.5**	**1100.3**

Occupational category	Overall total	Total: African American (AA)	Asian (AS)	Hispanic (HISP)	Other	White
Management, business, and financial	332.9	12.6	21.7	43.6	6.7	248.3
Professional and related	275.9	13.4	27.8	26.3	7.3	201.1
Services	7.9	0.5	0.1	2.4	0.2	4.7
Sales and related	59.5	5.0	0.9	8.8	1.1	43.6
Office and administrative support	233.1	16.6	4.5	37.7	6.4	167.9
Highly skilled craft	692.9	47.4	6.8	156.0	19.5	463.2
Skilled craft	341.4	37.6	4.6	93.0	9.8	196.4
Laborers, workers, and helpers	109.3	12.5	1.7	43.4	4.3	47.5
Total	**2052.9**	**145.5**	**68.1**	**411.3**	**55.3**	**1372.7**

Source: IHS Markit

Important inputs in projecting shares of hiring for women and people of color are the IHS Markit forecasts of growth of the US population by age, race, and gender. These forecasts are based on a cohort-based population model that incorporates current demographic breakdowns of the US population and standard assumptions for birth rates by race, and survival rates by age, race, and gender.

Relative to the previous study, there are several critical demographic trends and assumptions that have changed. Most important, there have been downward revisions to Census population estimates, and related to this, changes in assumed immigration. The results in this report anticipate reductions in immigration from levels that had been seen through 2016 and were previously expected to continue, reflecting the current national immigration policy stance. The effects of this change on the results are relatively minor, however, because the domestic-born population is much larger than past, current, and projected immigration levels. In sum, we use updated data and analysis of labor force participation rates and occupational employment trends in this report. Additionally, our underlying forecasts about labor force availability and qualification for people of color and women are relatively conservative.[12] Most important, we are careful to not allow levels of employment for a demographic group in an occupation to become unrealistic (given historical levels for the group). The next section provides a demographic breakdown of hiring in the eight occupational categories.

4.4 Demographic profiles

This section presents results from applying demographic modeling to the path for industry employment. As discussed earlier in the methodology chapter, the analysis requires numerous distinct steps to convert projected hiring for the oil and natural gas industries (both job additions and job replacements from retirement and permanent separation) into demographic breakdowns by race and gender. Importantly, the demographic projections in this report are not to be interpreted as a cap or ceiling on the number of job opportunities that will be available to or offered to women or people of color. These are simply projections of the number of jobs expected to be filled by these groups given current and projected demographic trends. As interest and training are directed to people of color and women, it will help them to be aware of and qualified for all 1.9 million available opportunities.

Table 4.4

Job opportunities by subsector and race groups, 2019–2040
(thous)

		AA and AS and HISP					
Subsector	**Overall total**	**African American (AA)**	**Asian (AS)**	**Hispanic (HISP)**	**Sum of AA+AS+HISP**	**Other**	**White**
Upstream	1179.1	80.3	42.0	353.4	475.7	78.1	625.3
Midstream	398.8	28.6	13.2	131.5	173.4	27.9	197.5
Downstream	177.9	13.0	5.2	62.1	80.2	13.0	84.7
Petrochemical	148.1	11.0	4.4	53.3	68.7	11.3	68.1
Total	**1903.8**	**132.9**	**64.9**	**600.2**	**798.0**	**130.3**	**975.5**
Shares							
Upstream		0.068	0.036	0.300	0.403	0.066	0.530
Midstream		0.072	0.033	0.330	0.435	0.070	0.495
Downstream		0.073	0.029	0.349	0.451	0.073	0.476
Petrochemical		0.074	0.030	0.360	0.464	0.076	0.460
Total		**0.070**	**0.034**	**0.315**	**0.419**	**0.068**	**0.512**

Source: IHS Markit © 2019 IHS Markit

Table 4.4 shows total hiring as well as breakouts by race for the projected job opportunities (through 2040) for the entire industry and in each of the four major subsectors. Job opportunities from 2019 to 2040 are expected to total over 1.9 million. This total combines the additions to employment levels of 258,800 that are discussed in the prior chapters, plus 1.645 million hirings for the replacements of workers that separate from the industry for retirement and other reasons.

[12] For discussion of the changes, see the research articles on the topic of declining labor force participation that are referenced in Appendix C.

The results from applying demographic modeling to industry job opportunities shows that Hispanics are expected to dominate the hiring shares for these groups, and account for 31.5% of the hiring for the entire industry. The Hispanic share is expected to be the highest in the petrochemical sector at 36.0%. Adding together African American, Hispanic, and Asian hiring yields 798,000 jobs, or 41.9% of total projected opportunities.

Table 4.5

Job opportunities by occupation and race groups, 2019–2040

(thous)

		AA and AS and HISP					
Occupational category	**Overall total**	**African American (AA)**	**Asian (AS)**	**Hispanic (HISP)**	**Sum of AA+AS+HISP**	**Other**	**White**
Management, business, and financial	272.1	15.8	16.0	49.0	80.8	9.2	182.0
Professional and related	258.9	16.6	22.8	52.6	91.9	8.3	158.7
Services	10.5	2.1	0.7	3.2	6.0	0.6	3.9
Sales and related	35.1	1.0	2.6	7.6	11.2	1.2	22.7
Office and administrative support	324.3	23.1	4.5	80.1	107.7	20.1	196.6
Highly skilled craft	589.1	37.7	11.2	195.6	244.4	48.9	295.8
Skilled craft	309.0	26.0	5.2	150.2	181.4	32.1	95.5
Laborers, workers, and helpers	104.8	10.7	1.9	62.0	74.6	9.8	20.4
Total	**1903.8**	**132.9**	**64.9**	**600.2**	**798.0**	**130.3**	**975.5**
Shares							
Management, business, and financial		0.058	0.059	0.180	0.297	0.034	0.669
Professional and related		0.064	0.088	0.203	0.355	0.032	0.613
Services		0.202	0.069	0.299	0.571	0.059	0.370
Sales and related		0.028	0.073	0.217	0.318	0.035	0.647
Office and administrative support		0.071	0.014	0.247	0.332	0.062	0.606
Highly skilled craft		0.064	0.019	0.332	0.415	0.083	0.502
Skilled craft		0.084	0.017	0.486	0.587	0.104	0.309
Laborers, workers, and helpers		0.102	0.018	0.592	0.712	0.094	0.194
Total		**0.070**	**0.034**	**0.315**	**0.419**	**0.068**	**0.512**

Source: IHS Markit © 2019 IHS Markit

Table 4.5 shows the aggregates for the eight major occupation categories. The occupation category with the largest number of job opportunities is expected to be highly skilled craft at 589,100. We expect 195,600 Hispanics, 37,700 African Americans, and 11,200 Asians to fill these highly skilled positions, yielding a 41.9% total share to people of color. The same race groups are also expected to fill 181,400 of the 309,000 job opportunities in the skilled craft category. While positions in both the services category and the laborers, workers, and helpers category will have higher shares filled by people of color, the job opportunities in these low-skill occupations will be much lower than the job opportunities for highly skilled and skilled craft workers.

Table 4.6 shows the projected hiring for women and the implicitly assumed shares by major sector. Women are expected to total 390,600 or 20.5% of new hires. The implied male share of job opportunities is projected to be 79.5%, which is about 5% below the current male share in the industry workforce.

Table 4.6

Job opportunities by subsector for women, all races, 2019–2040

Subsector	**Women, all races (thous)**	**Women, all races (share)**
Upstream	251.2	0.213
Midstream	78.8	0.198
Downstream	34.8	0.196
Petrochemical	25.7	0.173
Total	**390.6**	**0.205**

Source: IHS Markit © 2019 IHS Markit

Table 4.7 presents hiring for women for the eight broad occupation categories and their shares of total job opportunities and Table 4.8 presents expected hiring for women across the eight broad occupation categories by race. Office and administrative support is expected to have the largest number of opportunities filled by women at 185,200. The lowest shares of women are projected to be the highly skilled craft, skilled craft, and laborers positions. As a result, these positions have the highest upside potential for women as a group. We project women to fill 5% to 7%, on average, of the job opportunities in these occupations over the next 20 years.

For most other positions, we project the share of women filling those opportunities will increase steadily to at least 25% by 2040. This will be done through industry and national efforts and policies to increase STEM education among young women. Currently, representation of women in the industry workforce is estimated to be 17%, and the 20% overall share reflects an assumption of steady growth in their representation. The appendix discusses the trends that suggest that 20% in hiring of women is a reasonable estimate. For example, the World Petroleum Council recently produced a report about efforts to both monitor and improve gender balance in the oil and natural gas industry. Besides industry efforts, there are many government and private educational institutions that are focused on attracting more women to earn STEM degrees and/or receive skills training. As these efforts bear fruit, more women are expected to be trained in the types of skills needed to fill the many opportunities in the oil and natural gas industry.

Table 4.7

Job opportunities by occupation for women, all races, 2019–2040

Occupational category	Women, all races (thous)	Women, all races (share)
Management, business, and financial	78.3	0.288
Professional and related	53.1	0.205
Services	2.2	0.206
Sales and related	6.5	0.185
Office and administrative support	185.2	0.571
Highly skilled craft	42.0	0.071
Skilled craft	16.7	0.054
Laborers, workers, and helpers	6.6	0.063
Total	**390.6**	**0.205**

Source: IHS Markit © 2019 IHS Markit

Table 4.8

Female job opportunities by occupation and race, 2019–2040

(thous)

		AA and AS and HISP					
Occupational category	Female total	African American (AA)	Asian (AS)	Hispanic (HISP)	Sum of AA+AS+HISP	Other	White
Management, business, and financial	78.3	7.0	4.5	13.2	24.6	2.6	51.0
Professional and related	53.1	4.4	4.6	10.1	19.1	1.7	32.3
Services	2.2	0.5	0.1	0.8	1.4	0.1	0.7
Sales and related	6.5	0.3	0.5	1.3	2.1	0.2	4.2
Office and administrative support	185.2	11.1	2.7	41.8	55.6	12.0	117.5
Highly skilled craft	42.0	7.3	0.7	11.4	19.4	3.2	19.4
Skilled craft	16.7	2.4	0.2	10.0	12.6	1.0	3.1
Laborers, workers, and helpers	6.6	1.5	0.1	4.1	5.6	0.3	0.7
Total	**390.6**	**34.4**	**13.4**	**92.6**	**140.5**	**21.2**	**228.9**

Source: IHS Markit © 2019 IHS Markit

5 Conclusion

The US workforce is experiencing four significant changes: (1) technology is playing an increasing role in numerous occupations across many industries, (2) the share of people of color is rising, (3) retirement rates for almost all occupations and industries has increased significantly along with an aging workforce, and (4) women are being recruited to science and technology occupations at an increasing rate. Recognizing these trends, this study quantifies the number of job opportunities in the oil, natural gas, and petrochemical industries that will arise over the next 20 years for women and people of color. The analysis specifically recognizes how technologies such as cloud computing, internet of things, artificial intelligence, and remote monitoring using robots and drones will affect activity, occupations, and hiring in the industry.

Based on this analysis, the combined oil, natural gas and petrochemical industries workforce will grow to over 2.3 million by 2040, adding 258,800 new jobs, despite the expected adoption of new labor-saving technologies. More significant, the industry will need to hire almost 1.645 million workers over the next 20 years due to retirement and other reasons for employment separation, yielding total job opportunities of over 1.9 million over the next 20 years. The largest number of job opportunities will be for upstream activity. In terms of demographics, Hispanic workers are projected to be hired for 600,200 jobs, which is 31.5% of the total job opportunities. The combined share for African Americans, Hispanics, and Asians will be 41.9%. In addition, women of all races are expected to fill 390,600 jobs or 20.5% of the job opportunities over the next 20 years. These numbers will surely produce a more diverse work force, as the share of white males to the overall US and industry workforces is poised to decline.

6 Appendix A: Baseline employment projections

6.1 Baseline employment projections

The baseline employment projections were created by API in 2019 for the upstream, midstream, downstream, and petrochemical sectors, with a split between operations and investment activities.

The methodology and assumptions can be summarized as:

- Started with 2016 BEA employment counts that are part of the IMPLAN software for major sectors, or US Census or BLS counts for some of the smaller sectors,
- Added industry-specific growth based on BLS employment projection from 2016-2026. The 2019 values are intermediaries that are consistent with the 2016 to 2026 path.
- Except for the upstream sector, baseline employment levels were held at 2026 levels for 2027-2040 (i.e., zero growth was assumed). The implicit assumption is labor productivity and output growth increase at the same rate during this period in the 'frozen employment' sectors.
- Upstream employment from 2026-2030 was increased using the EIA's 2018 Annual Energy Outlook increase in production, using a small increase of about 1.6% over 2026. No growth for 2030-2040 was assumed, matching the assumption of the other sectors.
- Pro-development jobs were added to the baseline in the 2019 to 2030 period (+189K jobs) and the 2030 to 2040 period (+152K jobs) for upstream and midstream sectors only.

The net results:

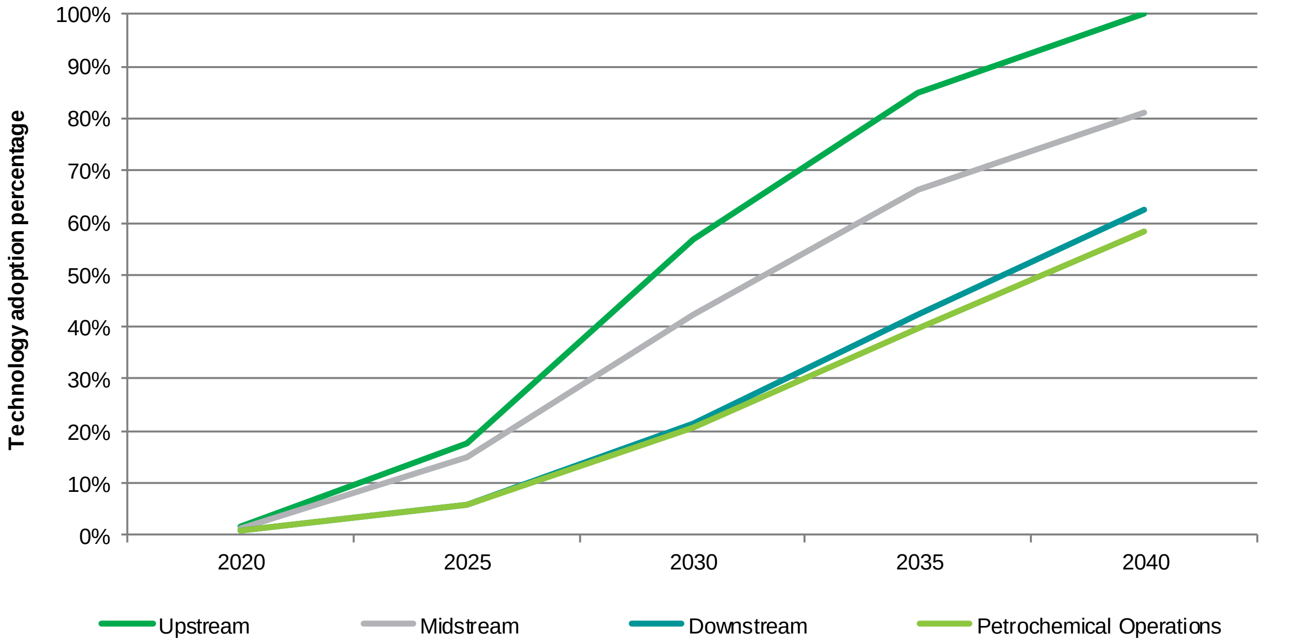
- From 2019 to 2030, 1.3% average annual growth in employment across all sectors, slowing to 0.6% for 2030-2040.
- Fastest growing sector from 2019 to 2030 is midstream investment followed by upstream investment. Midstream, downstream and petrochemical operations all lose jobs in the 2019-2030 period, which implies that labor productivity grows faster than output in all the operations sectors, save for upstream operations.

6.1.1 Technology adoption curve

The final employment projections that are used in the report are based on combining technology and use case timelines into an adoption curve that adjusts the baseline case. The results of the adoption curve are shown in Figure A.1. These effects are normalized such that in 2040 an adoption rate of 100% is reached by the upstream sector, which allows a visual of the relative adoption rates across the different sectors over time.

Figure A.1

Technology adoption curves by energy segment



Notes: Upstream normalized to 100% in 2040.
Source: IHS Markit

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6.1.2 Effects on employment by subsector

A final job influence score was used to represents the results of the analysis and is the matrix product of the previous four inputs. The multiplication of all the scoring components provides granularity as to how oil and natural gas industry employment will be impacted by the adoption of these technologies.

The new technologies will both increase productivity (thus lowering employment needs) and create new jobs (as individuals will be needed to manage their use). By bringing these two estimates together, it is possible to provide a detailed job outlook over the forecast period.

Next, we quantify the number of jobs that will be created to support the new technologies. These effects add to the industry job base in each sector and partially counter any job reductions. The largest increase in new technology-intensive jobs are in upstream operations.

The full analysis shows an increase of 258,800 industry jobs from 2019 to 2040 across all sectors of the industry (yielding an average annual growth rate of 0.6%). It is also worth noting that technology adoption within the industry is very much predicated on scale. Larger companies can invest more in all three technology areas, and many have had investments in these areas for years. Small companies can be nimble in one area but often lack the resources to be comprehensive. To this end, company size and technology scale are proportional.

6.1.3 Changes in the distribution of occupations

To calculate the effects of technology on the distribution of jobs, we considered 31 job classifications with job codes that are specific to the oil and natural gas industry. Each of these jobs was then placed into one of the eight broad occupation categories.

Each job type was matched to specific job codes that are relevant for the industry and then compared with those technologies that were likely to impact these job codes. The same methodology was used to determine where the new jobs created for technology adoption and support would reside.

One note about the analysis is that the technology replacement and job creation could go into more than one category as a computer occupations job type. We deemed professional and related, petroleum, mining and geological engineers, and highly skilled craft occupations as the most relevant broad occupation groups. There was some discretion on the exact placement category for new technology jobs. This study elected to default, where possible, to the highly skilled craft class, but retained healthy growth in the more generic professional and related class.

The results show a shift relative to the previous study from the semi-skilled and laborer categories to more highly skilled workers as technology is introduced. Professional and related jobs also grow as more computer engineers are projected to be deployed within the industry.

7 Appendix B: Industry employment by occupational classes

This appendix explains how industry employment is split into the eight broad occupational classes, and how the corresponding minority and female employment shares for each occupation were derived and used.

7.1 Employment by occupational classes

The BLS produces a report of Occupational Employment Statistics (OES) that provides estimates of employment and wages for over 800 occupations.[13] Each occupation that in the OES is classified according to the Standard Occupational Classification (SOC).[14] In this report, we used a grouping scheme that puts each specific occupation into eight broad occupational classes:

- Management, business and financial
- Professional and related
- Service
- Sales and related
- Office and administrative support
- Highly skilled crafts
- Skilled crafts
- Laborers, workers, and helpers

This grouping recognizes how the OES uses the SOC to systematically assign workers and jobs to specific occupations. In the SOC, workers are classified into occupations that are based on their job duties, rather than on their job titles.

The OES classifications have 23 major groups that are indicated by the first two digits of the SOC code:

11-0000	Management Occupations
13-0000	Business and Financial Operations Occupations
15-0000	Computer and Mathematical Occupations
17-0000	Architecture and Engineering Occupations
19-0000	Life, Physical, and Social Science Occupations
21-0000	Community and Social Service Occupations
23-0000	Legal Occupations
25-0000	Educational Instruction and Library Occupations
27-0000	Arts, Design, Entertainment, Sports, and Media Occupations
29-0000	Healthcare Practitioners and Technical Occupations
31-0000	Healthcare Support Occupations
33-0000	Protective Service Occupations
35-0000	Food Preparation and Serving Related Occupations

[13] The OES is based on a semi-annual survey of non-farm establishments. Part-time and full-time workers who are paid a wage or salary excluding self-employed, owners, unpaid family workers etc. are recorded. OES estimates are available at various regional and sectoral granularities. Refer to https://www.bls.gov/oes/home.htm for more information on this data.

[14] SOC is a statistical standard used by federal agencies to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data. All workers are classified into one of 867 detailed occupations. Detailed occupations in the SOC with similar job duties, and in some cases skills, education, and/or training, are grouped together. To facilitate classification, detailed occupations are combined to form 459 broad occupations, 98 minor groups, and 23 major groups (https://www.bls.gov/soc/).

37-0000	Building and Grounds Cleaning and Maintenance Occupations
39-0000	Personal Care and Service Occupations
41-0000	Sales and Related Occupations
43-0000	Office and Administrative Support Occupations
45-0000	Farming, Fishing, and Forestry Occupations
47-0000	Construction and Extraction Occupations
49-0000	Installation, Maintenance, and Repair Occupations
51-0000	Production Occupations
53-0000	Transportation and Material Moving Occupations
55-0000	Military Specific Occupations

Adding the next digit gives 98 minor groups. The next two digits reflect broad occupations and the most granular categories are the detailed occupations. The following table gives an example of this system.

47-0000				**Construction and Extraction Occupations**
	47-5000			**Extraction Workers**
		47-5010		Derrick, Rotary Drill, and Service Unit Operators, Oil and Gas
			47-5011	Derrick Operators, Oil and Gas
			47-5012	Rotary Drill Operators, Oil and Gas
			47-5013	Service Unit Operators, Oil and Gas
		47-5020		Surface Mining Operators and Earth Drillers
			47-5022	Excavating and Loading machine and Dragline Operators, Surface Mining
			47-5023	Earth Drillers, Except Oil and Gas

Our approach does not use a variation of the 23 major groups and was designed to be directly relevant for the oil and natural gas industry. The first step selects jobs from the full list of detailed OES and SOC occupations that appear in the oil and natural gas industry. This step relied on how the occupational breakdowns in the OES are for specific sectors that are based on the North American Industry Classification System (NAICS).[15] Focusing on the NAICS for the oil and natural gas industry reduced the list of relevant occupations substantially.[16] The next step mapped each of the selected occupations to one of the eight broad occupational classes. The challenge in this step is that a simple aggregation based on the first two digits of the SOC code was not possible. For example, employees engaged in planning and directing of resources are classified in management occupations (major groups 11-0000), whereas supervisors of workers in major groups 13-0000 to 29-0000 are classified in the same SOC group as the workers they supervise. According to BLS they usually perform activities similar to those of the workers they supervise. Hence, for occupations beyond the 13-0000, the SOC list was manually mapped into the eight occupational classes. In this step, we referenced the occupation mapping from the 2016 API Minority Report to ensure comparability and consistency of the approach.

[15] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the US business economy.

[16] In case OES data was not available for the granular NAICS sector, the next aggregated NAICS level was used assuming that the aggregated sector has a similar occupational structure.

8 Appendix C: Replacement rates

This appendix describes how replacement rates – estimates of the percentage of a workforce that will need to be replaced each year due to some type of separation, including retirement. The main data source for retirement and separation was produced by the BLS and is provided by occupation categories. Replacement rates are calculated using the latest release of separation projections for the period 2016-2026.[17] Replacement rates were derived for broad occupational classes, as described below. We also explain why the most recent BLS data shows a significant increase in these separation rates for many occupation classes, compared to rates used in the previous report.

The BLS separation data shows information on occupational exits and occupation transfers for over 800 detailed occupational categories that are defined by the Standard Occupational Classification (SOC) scheme. Not all these categories are represented in the oil and natural gas industry. The calculation of replacement rates is based only on those occupations which have been identified as industry occupations. As a first step, we identified 27 cases that were most relevant for the oil and natural gas industry. We then identified 103 more cases that were also deemed relevant and roughly 400 additional cases that were potentially relevant (but are more common in industries outside of the scope of the report).[18] These occupations were split into the 8 broad occupational groups that are used in the report. Once the relevant occupations and groups were identified, we calculated a weighted average exit rate from the detailed data for each of the 8 classes. The weights were based on the relative size of each detailed occupation in a broad class (using national numbers).

The results from using the 130 focused cases produced slightly lower overall labor force exits rates than using either the smaller set of 27 occupations or the larger set of 500+ occupations. To be conservative in our estimates, this set—averaging near 3.5% as an annual replacement rate—was used. Most important, the rates from using any of the three subsets of occupations are substantially below the average rate in the completely excluded occupations, as workers in oil and gas related occupations tend have a higher than average tenure.

The 2016 API Minority study used annual replacement rates between 1.5-2.5% depending on the year and sector. Hence, even with the screening steps, the new labor force exit rates are higher than the old replacement rates, although the former is potentially more limited in its reasons for ‘separation’. The increase is due to the fact that exit rates are rising from a host of forces, such as an aging workforce, workers taking early retirement, increased disability classification, and younger workers becoming more apt to move in and out of the work force.[19] A rising retirement rate had been foreseen by BLS in earlier projections, but they seemed to amplify the trend in their most recent projections (produced in 2018, covering 2016 to 2026). Five years ago, similarly computed projections of national labor force exit rates probably would have been in the 2.5% to 3.0% range.[20]

The full effect of new methods and updated projections is that the updated report shows much higher replace/retirement needs: 1.65 million over 20 years (2020–2040), versus .570 million in the 2016 report (2015-

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[17] Downloaded from: https://www.bls.gov/emp/tables/occupational-separations-and-openings.htm

[18] BLS provides the data as part of their Occupational Employment Statistics (OES) project. See https://www.bls.gov/oes/#data for the Occupational Employment Survey (OES) data items that offer industry-occupational employment detail. While OES does not cover the exact sector granularity that is needed for all occupations, we were able to move up one aggregation level to provide a useful approximation for the occupational structure in each sector.

[19] For analysis of overall US labor force participation trends that support the higher separation rate assumptions that are used in this study, see the articles: Harley Frazis, “Employed workers leaving the labor force: an analysis of recent trends,” Monthly Labor Review, US Bureau of Labor Statistics, May 2017, US Bureau of Labor Statistics, May 2017, https://doi.org/10.21916/mlr.2017.16. Daly, Mary C., Joseph H. Pedtke, Nicolas Petrosky-Nadeau, and Annemarie Schweinert. 2018. “Why Aren’t U.S. Workers Working?” FRBSF Economic Letter 2018-24 (November 13). https://www.frbsf.org/economicresearch/publications/economic-letter/2018/november/why-are-us-workers- not-participating/ Montes, Joshua. 2018. “CBO’s Projection of Labor Force Participation Rates.” Congressional Budget Office Working Paper 2018-04, March 16. https://www.cbo.gov/publication/53616. Abraham, Katharine G., and Melissa S. Kearney. 2018. Explaining the Decline in the U.S. Employment to-Population Ratio: A Review of the Evidence. No. w24333. National Bureau of Economic Research.

[20] This is only a conjecture based on other studies of labor force exit, as the BLS did not publish new method effects that can be compared to older projections.

2035). Part of the increase is due to new BLS methods, part is due to new labor force trends (lower participation and higher exit rates), and part is due to applying the new rates uniformly (every year) to much higher industry employment than in 2015. Modifying the application of BLS separation rates to use only exit rates that apply to oil and gas industry occupations partially reduced the overall effect–as the industry's occupations tend to show lower labor force exits than other occupations on average.

The BLS has endorsed the new methodology for its current release of the 2016–2026 replacement projections. This methodology computes labor force exit rates and occupation-change separation as two separate items. The former is dominated by retirement—both regular and early retirement. Occupational separations are defined as the number of workers permanently leaving an occupation either because they permanently exit the labor force, e.g. due to retirement, or since they transfer to a different occupation.

The previous method, known as the replacement method, only partially captured workforce changes, tending to underestimate permanent labor force exits for reasons other than retirement and transitions to other occupations. It was based on the cohort-component method usually used for population projections. This method compares the size of a cohort of workers at two different times, and the difference can be interpreted as net replacement. This approach is compatible with the traditional, rather linear concept of a career path with workers entering an occupation at a young age and a couple of decades later retire from this occupation. Ignoring other career paths, which are more common today, this method underestimates the actual retirement rate.

9 Appendix D: Demographic hiring shares

9.1 Demographic shares by occupation

The minority and female hiring figures in the report were derived by applying race and gender shares for each of the eight broad occupations. The table below was used for the bulk of the allocations and was built to represent the most-likely shares for future minority hiring of Hispanic, African American, and Asian workers.

Table D.1

Projected hiring shares by race

Occupational category	African American	Asian	Hispanic	Other	White
Management, business and financial	0.058	0.059	0.180	0.034	0.669
Professional and related	0.064	0.088	0.203	0.032	0.613
Service	0.202	0.074	0.303	0.061	0.360
Sales and related	0.029	0.074	0.216	0.036	0.645
Office and administrative support	0.071	0.014	0.247	0.062	0.606
Highly skilled crafts	0.064	0.019	0.332	0.083	0.502
Skilled crafts	0.084	0.017	0.486	0.104	0.309
Laborers, workers, and helpers	0.102	0.018	0.592	0.094	0.194

Source: IHS Markit

The figures in the table above can be thought of as estimates of the race breakdown for applicants over the next 20 years. These shares were derived from IHS Markit-developed demographic projections that have greater detail than any government report on labor force demographics and handle Hispanics as a separate race. We updated assumptions, calculations, and results from the prior Minority Hiring study to yield projected breakdowns of race and gender hiring on a geographic, sector, and occupation basis over the main period of hiring for this study. In the calculations for the report, all race and gender counts were aggregated to a national level for the eight occupation groups (compared to regional breakdowns in the 2016 report) and then used to compute race shares as above (by occupation) that are used as fixed share over all years.

The projected race-gender shares were then compared to (a) recent BLS reports that show race and gender breakdowns for broad industry groups (none are exactly defined as the oil and natural gas sectors that are used, however), (b) the Census Department’s American Community Survey (ACS) that yields greater detail but is not as timely as the CES, and (c) BLS Employment projections by race and gender through 2028. Shares for races were generally adjusted slightly upward (less than 1 percent) for the Asian group to better reflect a projected share of the future national workforce of almost 7%.

In sum, the race shares above reflect a combination of current demographic shares for the oil and natural gas industry workers and projected shares for each race in the future work force. The forward-looking aspect recognizes that future hiring is likely to be more racially diverse than current industry demographics.

The second table for computing demographic shares determines the share of women for each race. These gender shares are based on the same source as the race shares and are used in this form to make the male-female split explicit for each race. Because industry-occupation counts are sparse for the Asian and Other races, we grouped the White, Asian and Other shares for each occupation. We also verified that the implied aggregated female shares (all races) were conservative by being only modestly above current estimates of the share of women for the oil and natural gas industry workers (at roughly 12%), remaining far below the US all industries and occupations share of women of over 47%.

Table D.2

Projected hiring shares for women

Occupation group	African American	Asian	Hispanic	Other	White
Management, business and financial	0.419	0.265	0.254	0.265	0.265
Professional and related	0.248	0.188	0.177	0.188	0.188
Service	0.209	0.176	0.227	0.176	0.176
Sales and related	0.242	0.158	0.151	0.158	0.158
Office and administrative support	0.482	0.598	0.522	0.598	0.598
Highly skilled crafts	0.053	0.018	0.016	0.018	0.018
Skilled crafts	0.074	0.026	0.053	0.026	0.026
Laborers, workers, and helpers	0.124	0.029	0.059	0.029	0.029

Source: IHS Markit

9.2 Demographic modeling calculations

The formulas using the demographic shares are straightforward. First, the race shares are used to split each year's hiring (new jobs and replacements, as described in the prior sections of the appendix and the report) into the 5 race groups (White, African American, Hispanics, Asian, and Other). Next the race counts are split into male and female hires using the second table.

An additional gender adjustment is computed by assuming an incremental hiring of women effect that increases the relatively low female shares in the table above (excluding sales and related) to grow smoothly to produce an overall female hiring share of 25% by 2040. The effect was assumed to be strongest in the highly skilled occupations due to its current low female share, changing job roles from technology, and the likely attractiveness of wages in these occupations. It was assumed this additional female hiring reduces White male hiring on a one-to-one basis, as opposed to reducing any minority male hiring.

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