TOPIC PAPER #23

HUMAN RESOURCES

On July 18, 2007, The National Petroleum Council (NPC) in approving its report, *Facing the Hard Truths about Energy,* also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the Task Groups and their Subgroups. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached Topic Paper is one of 38 such working document used in the study analyses. Also included is a roster of the Subgroup that developed or submitted this paper. Appendix E of the final NPC report provides a complete list of the 38 Topic Papers and an abstract for each. The printed final report volume contains a CD that includes pdf files of all papers. These papers also can be viewed and downloaded from the report section of the NPC website (www.npc.org).

NATIONAL PETROLEUM COUNCIL

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I. Executive Summary

The exploration and production industry is currently in a boom cycle after an extended bust that lasted about 20 years. The current and projected demographics of personnel in the professional and skilled craft disciplines in the U.S. exploration and production (E&P) industry are disturbing. The large majority of professionals are less than ten years from retirement; many are less than five years away. Not only are those younger than 45 in a minority, there are insufficient numbers of prospective employees in the American academic pipeline. There are fewer academic departments in petrotechnical areas now than before the bust, and significantly fewer students being trained to replace the upcoming retirements. The bust has given the industry a bad reputation for employment, keeping the number of interested students low: there has been a 75% drop in petrotechnical enrollment since 1982.

This is exacerbated by an explosion in the rate of hiring by the industry in the past two years. A survey by Schlumberger Business Solutions in 2005 indicated there was a surplus of petrotechnical graduates in parts of the world, including in Indonesia, Venezuela, and China. However, a recent follow-up survey showed that a rapid increase in hiring has swamped even the ability of those countries to fill the need. Even if the high rate of hiring lasts only a few years, language, culture, and immigration quotas are barriers to rapid flow of graduates from one part of the world to another.

Many E&P industry jobs can and are filled by graduates of other engineering and scientific disciplines. However, the public's image of the industry makes recruiting them difficult. Mid-career hiring is a negative-sum game that doesn't help the industry as a whole; although it helps one company, it does so at the expense of another. It is also an expensive option.

Specific engineering, procurement and construction (EPC) industry data are lacking, but many of the same indicators pertaining to workforce demographics and distribution likely apply to the oil and gas component of the EPC industry. With the exception of exploration and drilling personnel (e.g., petroleum engineers, geologists), EPC contractors are often in direct competition with their oil and gas company clients for many of the same entry and mid-level resources.

In addition, the USA entered a period of craft labor scarcity in 2005, with aggregate demand exceeding supply by 2% in 2005 for labor categories including structural ironworkers, rodmen ironworkers, operating engineers, interior and framing carpenters, drywall carpenters, general carpenters, electricians, glaziers, laborers, masons, painters, pipefitters and plumbers, roofers, and sheetmetal workers. This downward trend is expected to continue, growing to a 15% deficit by 2008.

A. Actions

The following actions are recommended:

- Federal and state governments and industry should work to increase the number of students pursuing paths to an E&P industry profession.
    - Develop outreach plans for high school seniors, their parents and school councilors promoting the industry. In particular, more females and minorities should be brought into the programs.
    - Establish energy and infrastructure as a national strategic priority in a manner similar to other historic federal programs.
    - Increase funding for academic research in E&P topics to attract the most talented students to the programs.
    - Emphasize the high-tech nature of the future challenges and the direction the industry is moving, toward the wired oilfield.
    - Apply similar recruiting actions to potential employees in related disciplines.

    - Adopt a nationally-approved construction education system and increase the awareness of career opportunities in construction.
- Increase immigration quotas for trained petrotechnical professionals and skilled workers, targeting occupations of national importance.
- Support global mobility of both U.S. and non-U.S. workers through policies and tax codes.
- Modify regulations as appropriate to make it easier for retirees to continue working in consultative, training, and teaching capacities. The objective is to keep their knowledge available to the industry and the next generation of petroleum technical professionals.

II. Overview of Methodology

This report is based on publicly available information, primarily reports from a Schlumberger Business Consulting survey, API, Deloitte, The Conference Board, the FMI quarterly, the Department of Petroleum and Geosystems Engineering at the University of Texas at Austin, and reports for the Interstate Oil and Gas Compact Commission (IOGCC).

Three appendices prepared by Fluor are included in this report, detailing supplier capacity considerations.

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III. Background

The U.S. oil and gas industry is cyclical. A peak in activity occurred in the late 1970s and early 1980s in response to an increase in the price of oil. During that time, a large number of professionals and skilled workers entered the workforce. However, this boom was followed by an extended period of low oil and gas prices between 1986 and 1999, which drove trained professionals from the industry and at the same time radically impacted the influx of university students—and therefore newly degreed professionals. Between 1982 and 2004, the number of bachelor of science (BS) programs in petroleum engineering decreased from 34 to 19, BS enrollment in these programs decreased from 9,492 to 1,702, and the number of BS degrees granted decreased from 1,280 to 272.[1] A corresponding number of geoscience degrees also plummeted during this period. Estimates of the combined population of petroleum engineering and geoscience (petrotechnical) degrees indicate a decrease in enrollment of 75% between 1982 and 2006. Currently, the industry is in an up cycle, as activity again has increased in response to higher demand, and upward-biased oil prices put more pressure on supply. Based on our view of global supply and demand fundamentals, the current up-cycle would appear to be a long-term phenomenon, supporting strategic investments in development of the next generation of industry professionals.

With hiring levels down over the past 20 years at most U.S. operators and service companies, a demographic bulge formed, and it is moving though the system. Its peak aged with each passing year; the maximum is currently the 45- to 49-year old group that is nearing retirement. A recent survey of 22 companies by the API indicated the average employee age in key technical positions was in the mid-forties.[2] This included skilled crafts as well as petrotechnical staff. Of the positions listed, only engineering (average age 41) and operations support (39) had average ages less than 44 years. In addition, almost a quarter of the people in those jobs were expected to retire by 2009. The API survey also indicates that by 2009, there will be a 38 percent shortage of engineers and geoscientists and a 28 percent shortage of instrumentation and electrical workers.[3]

Thus, there is a coming "big crew change" as responsibility for the future of the industry transfers from this experienced group to younger workers. However, the number of younger workers is insufficient to replace the retirees, even when allowing for productivity improvements. A growing gap between the supply of and demand for

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[1] Sharma M: "Workforce Initiative." See http://www.pge.utexas.edu/faculty/sharma.cfm.
[2] "Workforce Challenges Survey Results," American Petroleum Institute (May 2005).
[3] Sampath R and Robinson M: *The Talent Crisis in Upstream Oil & Gas: Strategies to Attract and Engage Generation Y*, Deloitte Research (December 2005).

petrotechnical professionals is of great concern for the ability of the industry to deliver the energy resources that will be needed in the future.

E&P has been a high-tech industry for many years, requiring developments for high-pressure, high-temperature equipment, advanced seismic technologies, and massive computer use for reservoir simulations. The coming era will advance this technological position another step into real-time collection, processing, and application of data in a digital oil field. The next generation of professionals has grown up in a wired environment, and the next wave of technological advances in E&P will benefit from that perspective.

Engineering, procurement, and construction (EPC) firms supporting the oil and gas industry also face robust demand for services over the next seven to ten years. However as with the petroleum industry, EPC firms face a myriad of human resource challenges that must be overcome to meet both the short- and long-term demand for services though the year 2030. Engineering has become a global commodity. Workforce and population demographics, declining interest in EPC and the engineering profession, a decline in the number of engineering graduates in the USA versus sharp increases in enrollments internationally all contribute to a rapidly evolving situation where progress must be made in increasing the number, quality and diversity of available employee candidates if the U.S. dominance in the EPC market and support of oil and gas are to be sustained.

The annual need for entrants of craft workers into the construction industry will be 185,000 persons, according to the Construction Labor Research Council, as stated in an FMI study.[4] This need will be almost evenly divided between growth and replacement. The Construction Labor Research Council stated that in 2005 the construction industry had more craft workers in their prime working years (25 to 44) compared to other industries, yet these workers tend to leave construction at an earlier age than do their counterparts in other industries.

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[4] Heimbach A, Hoover S, Schubert N, and Hier N: “Perspectives on Future Construction Labor Shortages,” *FMI Quarterly* Issue 2 (2006): 29–49.

The supplier market for the petroleum industry also has moved to a resource-constrained position. As an example of this shift, when polled at a recent Engineering & Construction Contracting Association (ECC) conference, 93% of owner organizations said they believe we are in a seller's market, compared with 87% of contractors and 78% of suppliers.[5] This includes equipment demand, which is growing rapidly.

In 2001, the Interstate Oil and Gas Compact Commission (IOGCC) published recommendations for regenerating the E&P workforce.[6] Three entities were addressed. The U.S. federal government was encouraged to support E&P research and a national outreach to education associations. State governments were asked to help educate the public and state stakeholders and provide linkages to related associations, such as trucking and utilities, through the IOGCC career center. Industry was expected to work actively through their human resources (HR) professionals, keeping an "on the ground" focus. In a recent review by the IOGCC, the federal government showed little progress, although some DOE programs are progressing. The states have had success in encouraging their universities to recruit actively, and in some cases through recruiting campaigns run by their employment commissions. The IOGCC rated the industry progress as strong in establishing long-term HR plans, providing outreach with universities and others in R&D, and establishing programs for employees to extend their education.

IV. Actions

The following actions are recommended:

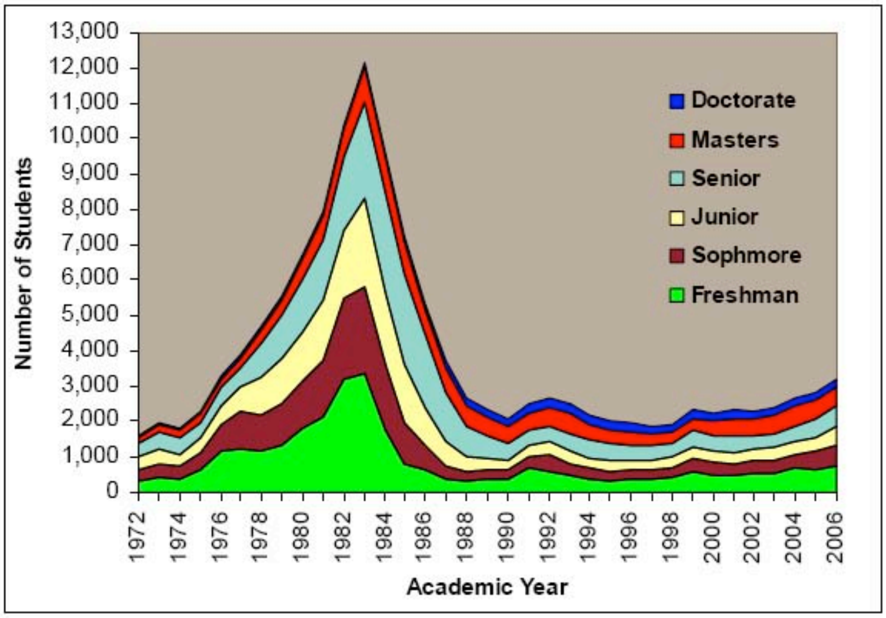
- Federal and state governments and industry should work to increase the number of students pursuing paths to an industry profession.

[5] Cabano S: "Face the Industry," Engineering & Construction Contracting Association. The New Seller's Market. San Antonio. (September 14, 2006). (www.ecc-conference.org/38/index.html)
[6] Fisher WL and Seals SJ.: "Human Resources: the Missing Piece of the Energy Puzzle," Interstate Oil and Gas Compact Commission (IOGCC, 2001).

  - Develop outreach plans for high school seniors, their parents and school councilors promoting the industry. In particular, more females and minorities should be brought into the programs.
  - Establish energy and infrastructure as a national strategic priority in a manner similar to other historic federal programs.
  - Increase funding for academic research in E&P topics to attract the most talented students to the programs.
  - Emphasize the high-tech nature of the future challenges and the direction the industry is moving: toward the wired oilfield.
  - Apply similar recruiting actions to potential employees in related disciplines.
  - Adopt a nationally-approved construction education system and increase the awareness of career opportunities in construction.
- Increase immigration quotas for trained petrotechnical professionals and skilled workers, targeting occupations of national importance.
- Support global mobility of both U.S. and non-U.S. workers through policies and tax codes.
- Modify regulations as appropriate to make it easier for retirees to continue working in consultative, training, and teaching capacities. The objective is to keep their knowledge available to the industry and the next generation of petroleum technical professionals.

A. Work to increase student population

The “big crew change” is recognized as a problem by U.S. companies and professional societies, such as SPE, SEG, and AAPG. These societies, and some companies, are actively pursuing outreach programs to high school and university students to encourage students to major in petrotechnical fields. For example, recently the API Work Force Committee and its member companies partnered with monster.com in a promotional program called “Making It Count.” This program is aimed at high school ninth grade through college freshman classes to promote engineering and science education and related careers like oil and gas.[7]



Source: Texas Tech, SPE, PPHB

Figure IV-A.1. Enrollment in U.S. petrotechnical programs by grade level, including masters and doctoral programs. The decline in enrollment between 1982 and 2006 is about 75%.

As shown in Figure IV-A.1, the number of students enrolled in petrotechnical programs in U.S. universities has recently increased. Several universities, such as the University of Texas and Texas Tech University, have seen rapid rises in enrollment resulting from active recruiting efforts aimed at high school seniors, parents and counselors. These results indicate that aggressive recruiting can have results. We would like to see outreach programs like these expanded by industry and universities.

The same programs for enlightening students can be applied to graduates and mid-career professional in other fields. The remuneration for petroleum engineering graduates today is high, compared with other engineering disciplines. This should be made clear to prospective students.

Similar programs are needed for EPC professions. The E&P cycle affects EPC contractors, and the needs for similar personnel by both E&P companies and EPC

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[7] See www.makingitcount.com (accessed December 5, 2006).

companies increases the scarcity of the human resource. Closer relationships and increased trust between clients and contractors can result is a lesser demand for staff engineers in client companies, reducing costs and dampening the labor rate inflation, as well as impacting total facility cost through lesser demands for space.

Like the petrotechnical experts, EPC professionals are also aging, and insufficient numbers of students are in the pipeline to replace the expected retirement bump over the next decade.

A different set of programs are needed for the trade crafts, but the underlying thrust is the same. Although many of the jobs do not require a college degree, more and more do, and advancement often requires additional education. Vocational training for entry-level positions remains a critical need.

According to an API survey to determine who influences potential students to enter the E&P sector, the primary influencers are parents, high school teachers and college professors. This audience responds to industry reputation, but many are unfamiliar with the industry and the possible careers. High school science teachers and general engineering professors do not currently view petroleum engineering and geoscience as favorable career paths to recommend to their students.[8]

The industry and government should take action to educate the public about the industry, improving its image by explaining the benefits society receives from the energy industry. We need to impress on potential employees the importance that jobs in the E&P industry have for the country's energy security. This will also result in making the E&P industry a more attractive place to consider working. The federal government should treat the coming energy crisis with the emphasis it placed on developing the federal highway system and the early space program—a matter of national importance.

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[8] API: "Choosing Energy: Who Influences Future Engineers and Geoscientists?" American Petroleum Institute (2005).

B. Increase immigration quotas for trained professionals

This report shows that there is a geographical disparity in the supply of new petrotechnical graduates, with the USA having a deficit and other parts of the world a surplus over the next ten years (although in 2006, demand exceeded supply). The number of foreigners allowed to work in the USA is restricted by the number of work permits issued each year. Increasing the quotas on work permits, which requires government action, can help alleviate this imbalance. The alternative for companies is to move jobs outside of the USA.

C. Support global mobility

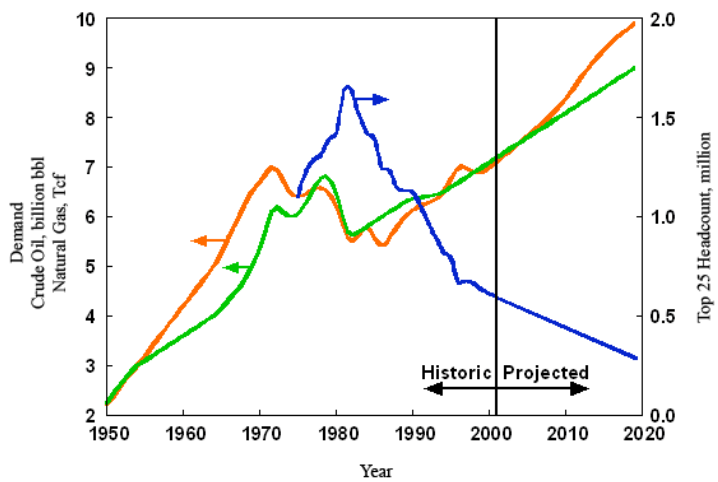
Negative changes to the U.S. tax code pertaining to expatriate income, such as those enacted as part of the Tax Increase Prevention and Reconciliation Act of 2005, hinder the mobility of U.S. employees supporting international oil and gas recovery efforts. This also impedes the competitiveness of U.S. firms, or forces the use of personnel from outside the country. Presently, the USA is one of the few countries that taxes personal income on a worldwide basis regardless of residence and in the manner applied by the IRS tax code. The process totals all worldwide income, then provides to qualifying individuals the opportunity to exclude a portion of income attributed to certain assignment-related income and expenses. The recent tax code revisions reduced the amount filers are able to exclude and deduct.

D. Encourage continued contributions from retirees

A large number of retirees will leave the industry in the next ten years. There is insufficient time to train enough young professionals to fill these positions. The expertise of recent retirees should be harnessed to train the upcoming generation. Retiring craftsmen should be encouraged to join vocational and professional training programs to pass expertise to the next generation of workers.

V. Discussion

In 1980, the price of oil reached a historic maximum, and then dropped to a low price and remained there for about 20 years. Not coincidentally, the top-25 companies employed more than 1.5 million people in 1980. That number has since plunged, driven by dramatic and continuing pressures on cost as well as a continuing stream of productivity improvements (Figure V.1). In 1999 and 2000, mergers among the ten largest oil companies reduced workforces by a combined 38,000 workers—this at the end of a 12-year decline that saw an average 5.2% annual reduction in the industry. However, after an initial fall in reaction to the high prices of the 1970s, demand for both oil and natural gas has risen and is expected to continue to rise.



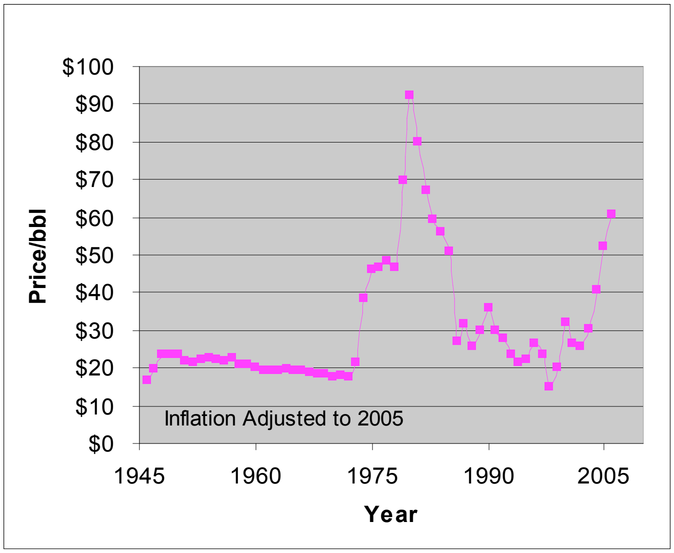


Figure V.1 Demand for oil (orange) and gas (green) vs manpower (blue) [courtesy UT].[9]
Price of crude oil, inflation-adjusted to 2005.[10]

Although some of the former employees of the largest companies went to work for smaller companies, service companies, or became independent consultants, many left the industry. In addition, with headcount declining, companies hired fewer new graduates. This had a chilling effect on students in American universities contemplating entering the petrotechnical fields of petroleum engineering and geoscience (Figures V.2, V.3, and V.4). The student population dropped and many academic programs folded.

[9] Sharma, reference 1.
[10] Data from inflationdata.com/Inflation/Inflation_Rate/Historical_Oil_Prices_Table.asp.

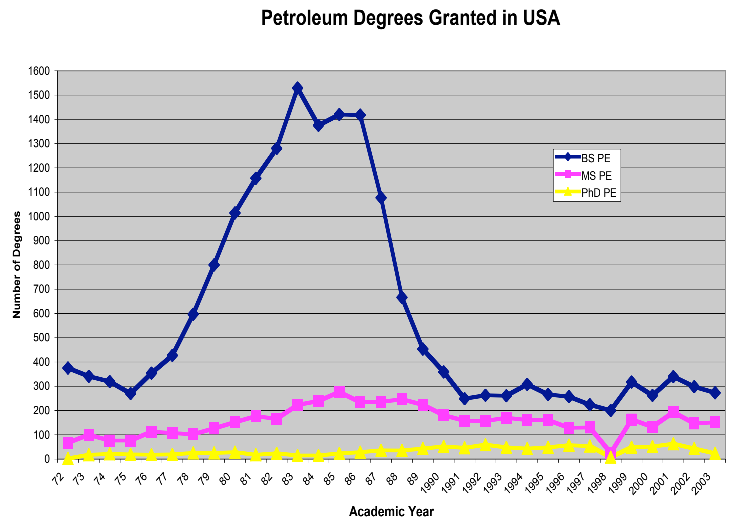


Figure V.2. Degrees granted in the U.S. in petroleum engineering [courtesy University of Texas].

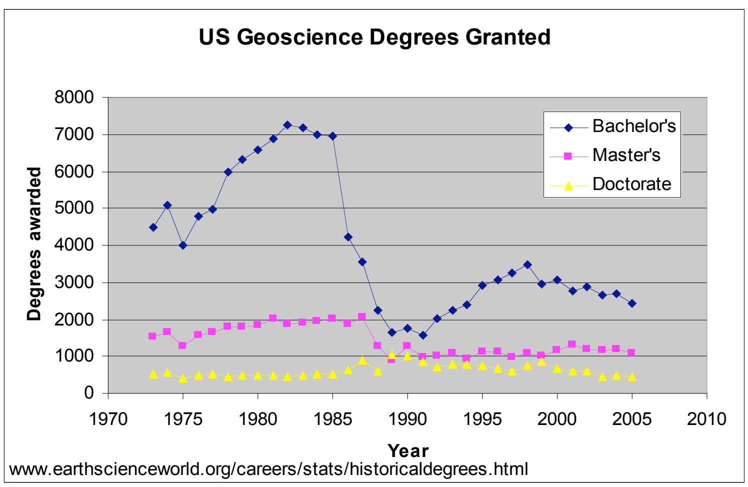


Figure V.3. Degrees granted in the U.S. in geosciences.

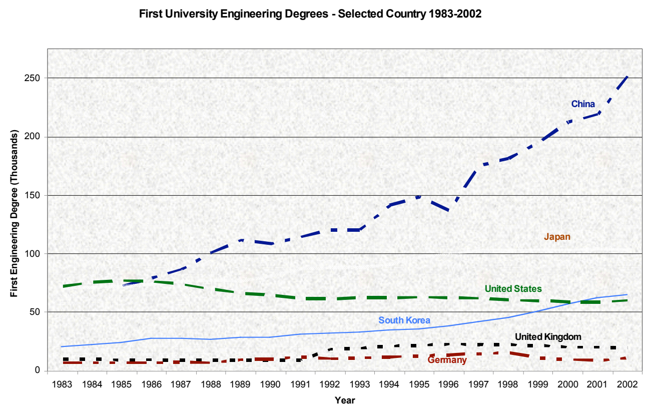


Figure V.4. Degrees granted in the U.S. in engineering.[11]

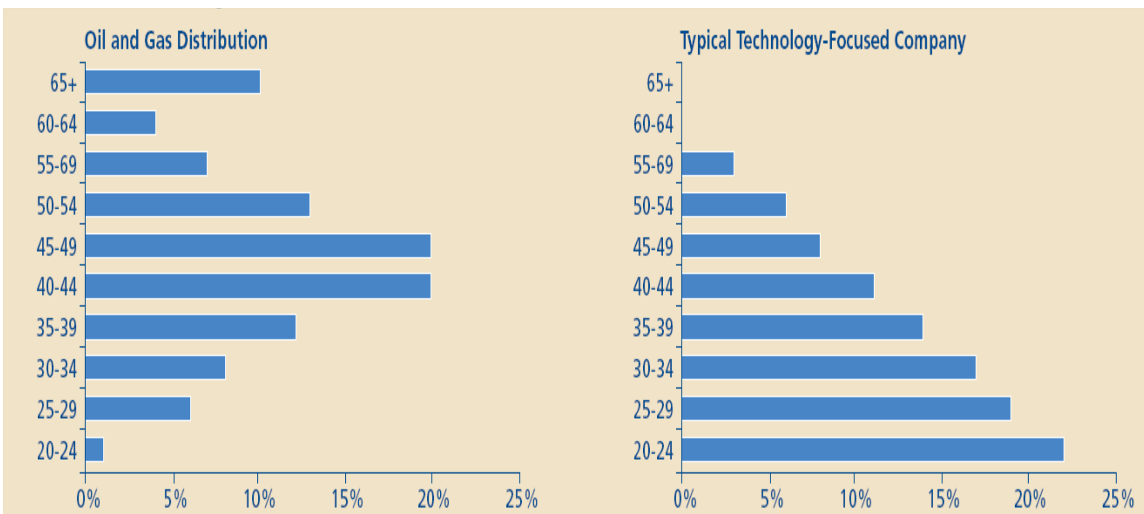


Figure V.5. Demographics of employees in North America.[12]

The extended period of low levels of hiring has had an effect beyond depressing the number of employees in the industry. Since the level of hiring of newly graduated petrotechnical professionals has been low for a long time, the U.S. industry has a demographic bulge in the employment spectrum (Figure V.5). This bulge, which peaks at employees in the age range of 45 to 49, represents the last period of large-scale hiring of college graduates in the late 1970s and early 1980s. The demographic bulge declines on the older side of that age group because of retirement packages provided by companies up to just a couple of years ago. More than half of the

[11] National Science Board (NSB): *Science & Research Indicators 2006*.
[12] Sampath and Robinson, reference 3.

workforce will be eligible to retire within then next five years, which leaves little time to train the younger group.

The demographics are not uniform around the world. Many more petrotechnical professionals in North Asia are in their twenties and thirties than in North America. In 2005, Schlumberger Business Solutions performed a study of institutions granting petrotechnical degrees around the world (Figure V.6). Although there were large annual deficits in new professionals in North America (-420), the Middle East (-350), and Russia (-160), there were large surpluses in Indonesia (+900), Venezuela (+500), China (+410), India (+100), and Mexico (+100). In a followup study in 2006, the rate of hiring by the industry had increased dramatically, and the global supply of graduates was not inadequate to meet the increased demand.

However, graduates are not a fungible commodity. Language, culture and legal impediments prevent substitution of a foreign graduate for a domestic one. Every company wants to hire the best graduates, and not every graduate, or every academic program, is equal to every other one. Thus, culture, geography and preference constrict the pool of graduates available to a given company.

Nonetheless, this imbalance carries with it political implications. Hiring of foreign nationals by U.S. E&P operators and service companies has been restricted by limits on the number of work permits available each year. If U.S. companies cannot hire foreign nationals to fill their petrotechnical needs, they will have to shift the jobs to overseas locations.

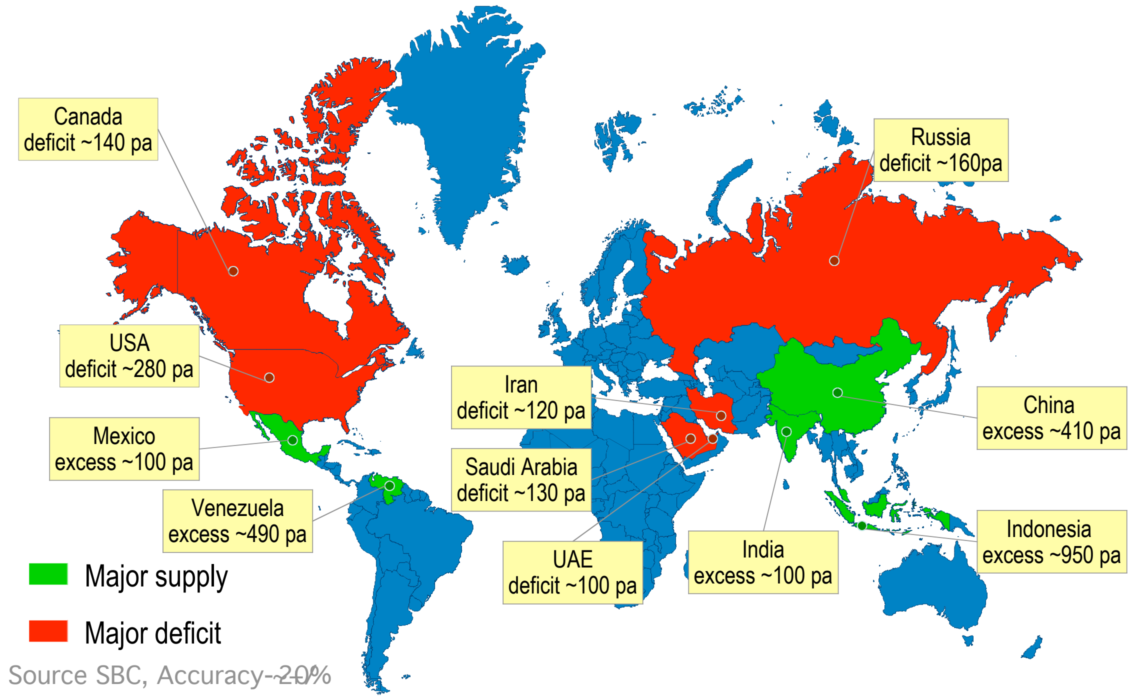


Figure V.6. Annual regional imbalance of young talent.

[courtesy Schlumberger].

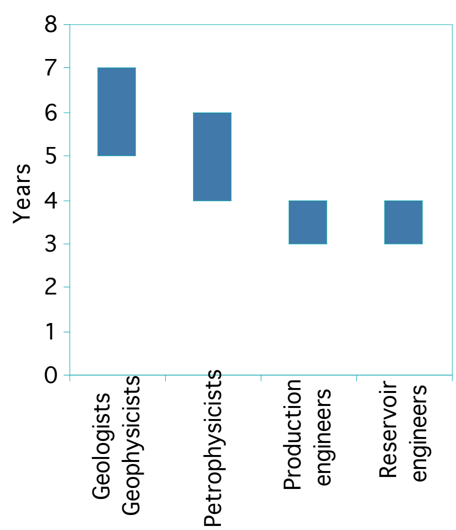


Figure V.7. Training time to create autonomous petrotechnical professionals.

< Source: 2005 O&G Survey>

New hires require time to become autonomous professionals (Figure V.7). The 2006 Schlumberger Business Consulting survey indicated that the amount of training and risk that companies are willing to take with new employees has a distinct impact on this time. In innovative companies, for example, geoscientists take complex technical decisions within three or four years, whereas more conservative companies require nine to twelve years before their recruits become autonomous.[13]

Mid-career hiring is not a long-term solution, because although one company "wins" a new employee, another has an opening to fill (Figure V.8). This also results in higher costs; for example each experienced hire that is lost costs a company the equivalent of a search fee to replace that person, or the effort to recruit and develop two new hires combined with the delay effect of time needed to develop them, or both.

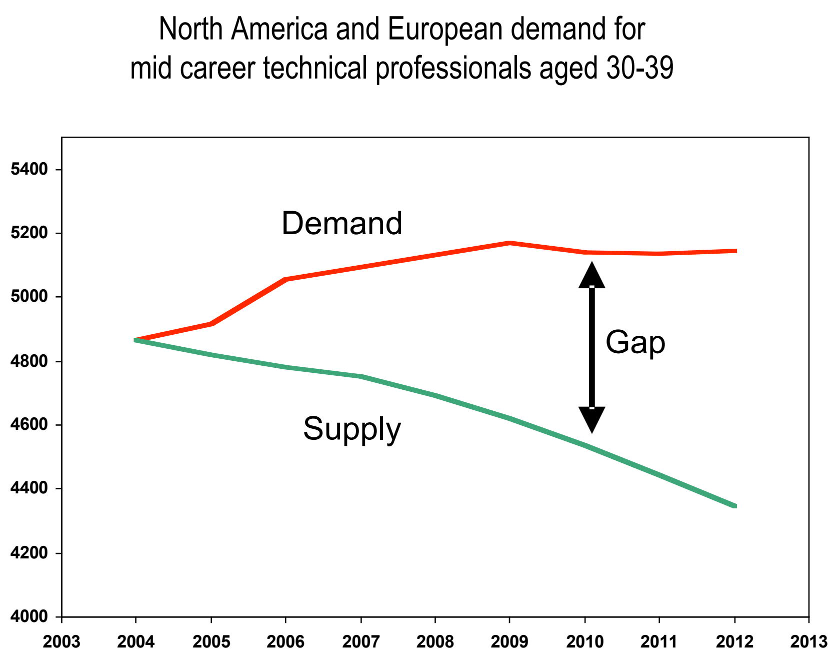


Figure V.8. Mid-career supply and demand.

Clearly the future of the industry requires aggressive recruitment and development of entry-level talent to support the projected levels of demand through 2030. A Deloitte study profiled the oil and gas industry workforce of the future.[14] Two immediate observations may be gleaned from Figure V.9. Migration of jobs to a workforce outside of the United States and technology-driven productivity gain will

[13] "Surviving the Skills Shortage—2006: Update of the Annual O&G HR Survey," Schlumberger Business Consulting.
[14] Sampath and Robinson, reference 3.

reduce the overall number of employees required to support the U.S. petroleum industry, however, the next generation workforce that must be groomed to take on the challenges of the future will require a concentrated effort within the academic community to deliver enough new graduate supply to meet projected demand.

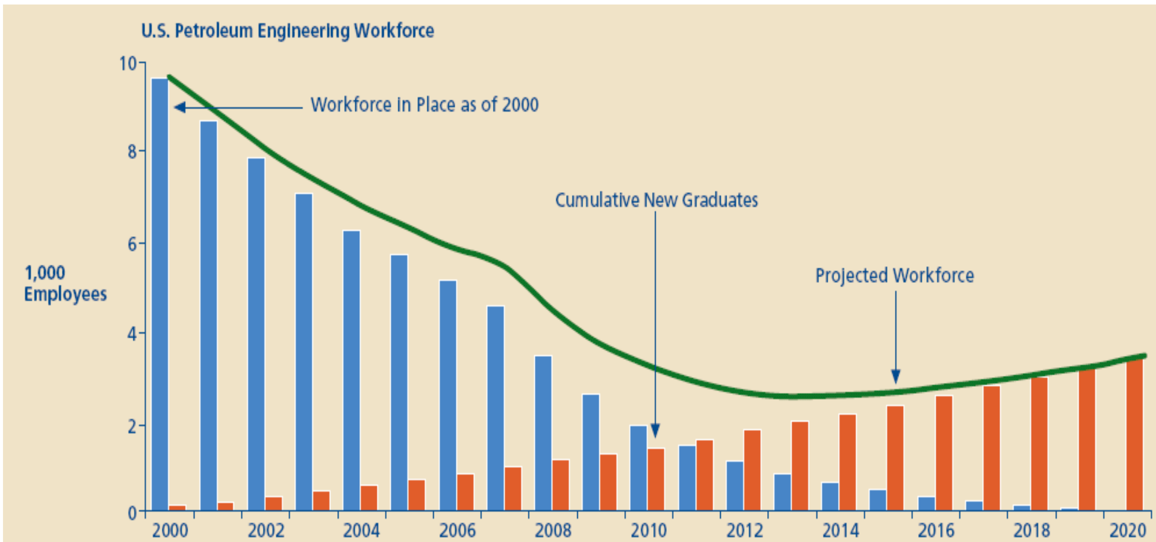


Figure V.9. The U.S. E&P workforce that was in place in 2000 will decline due to retirement and attrition, while the incoming graduates will be insufficient to fill the gap. [Sampath and Robinson, reference 3*, and the Society of Petroleum Engineers, 2003*].

Another consequence of a mature workforce distribution is labor cost, as reflected in higher wages and benefit costs. Wage inflation is transferred from service company to client, and from client to consumer, and impacts both the competitive nature of U.S. business as well as the retention of jobs and technology which otherwise must be sent offshore to sustain a short-term competitive advantage.

Disciplines \ Job Category	Geologist	Geophysicist	Petrophysicist	Reservoir engineer	Drilling engineer	Surface Engineer	Production engineer	Well/ Field engineer
Geology	•	•	•					
Geophysics	•	•	•					
Petroleum Engineering			•	•		•	•	•
Chemical engineering			•	•	•	•	•	•
Civil engineering					•	•	•	•
Electrical Engineering		•	•		•	•		•
Environmental Engineering					•	•		•
Mathematics/ Statistics/Physics		•	•					
Mechanical engineering				•	•	•	•	•

Source: American Petroleum Institute — Dedicated workforce (Geology, Geophysics, Petroleum Engineering) — Possible conversion (other rows)

Figure V.10. Potential for conversion from other disciplines for job categories in E&P. <source: American Petroleum Institute>

Another way to fill employment gaps is to hire from related disciplines (Figure V.10). Many engineering disciplines are already involved in petrotechnical work, such as chemical, mechanical, and electrical engineering. Geophysicists also come from physics and mathematics backgrounds. Today, geologists often train in environmental fields. Inducing new graduates or mid-career professionals to join the industry can relieve some of the pressure.

A. Engineering, Procurement, and Construction (EPC)

Studies specific to the status of EPC employment within the E&P industry are not available, so many of the conclusions relating to petrotechnical professionals are assumed to hold. The engineering disciplines included in the EPC industry are, in many cases, the same disciplines that are sought to substitute for petrotechnical professionals. In some companies, particularly service companies that work across a broad spectrum of industries, the cyclicality of the E&P industry is moderated, although EPC has its own booms and busts. Engineering disciplines most sought after by the EPC industry in support of oil and gas projects include:

- Chemical

- Civil/Structural
- Electrical
- Environmental
- Industrial
- Mechanical

Typically, undergraduate level degrees are required for employment and success in the industry. While some numbers of advanced technical degrees are required to foster the technical leadership and innovation required by the EPC industry to service its oil and gas clients, as a whole it is more common that the majority of technical personnel will obtain professional certification required to meet state regulatory licensing requirements versus advanced degrees in their discipline. In terms of post-graduate education, it is more common to find engineers earning degrees in a business-acumen related field to support career expansion into general management versus technical management roles.

Employment in a cyclical industry such as EPC boosts nationally growing individual trends towards concerns over job stability and the long-term employment outlook. Within the EPC environment, cyclicality produces a work experience characterized by alternating periods of heavy utilization and overtime, followed by (sometimes) unpredictable periods of under-utilization and regrettably, lay-offs. While salary and benefits are competitive, the unpredictability is often cited as a negative in terms of career choice, both for EPC and engineering in general. Cyclicality takes an organizational toll as well, driving periods of lay-offs and then hiring cycles, the latter of which can drive up compensation and retention expenses.

EPC employers also face the training challenge: the time required to adequately train and engage an entry-level engineer or designer. A new college engineering graduate requires approximately 10 years of experience and training to attain the necessary credentials to provide technical innovation and leadership. Much of the training is accomplished through on-the-job assignments and rotational experience, exposing the employee to different industries, technologies, project complexities and project life-cycle phases. In addition, technical, supervision and general management skills are gained along the way as the employee's eventual career aspirations and progress are attained (e.g., technical or general management, or business development). Designers in EPC typically require a three- to four-year investment, heavily focused on in-house training utilizing design technology.

Technology tools and enablers; leaps in communications capabilities; the need to execute work on tighter time and cost schedules; the availability of less expensive, qualified resources outside of the USA and the migration of projects to locations in remote locations all led the EPC industry to develop and excel at the usage of global engineering centers, particularly in emerging economy locations. These global engineering centers support home office execution and provide several advantages:

- 24x7 schedules, lower labor costs with little or no compromise on quality
- Lower total cost driven by generally cheaper overhead and infrastructure cost
- Opportunity to manage global workforce distribution and stability by moving work to the resources instead of the other way around
- Regional or local knowledge and content provides execution advantages when supporting projects outside the USA. Knowledge of local engineering or design practices, language and cultural benefits, even political capital gains are often realized.

The distribution of work on a work-sharing basis has become a universal practice within the EPC industry. With standardization of work practices, quality, technology and ease-of-handoff, this execution model has become widely accepted by oil and gas clients and is now firmly embedded as a requirement for delivery of contracted scopes of work within the established cost, risk, schedule and resource requirements that prevail today.

As many countries in Europe and Asia face a similar shrinking of the workforce and a number of nations appear poised to emerge on the global workforce stage as education, geopolitical stability and infrastructure concerns are overcome, engineering will continue to become a global commodity. This could signal a decrease in advantage provided by established engineering centers and the need to transition to new countries with associated start-up investments and challenges, as well as an overall erosion of the available competitive and qualified labor supply.

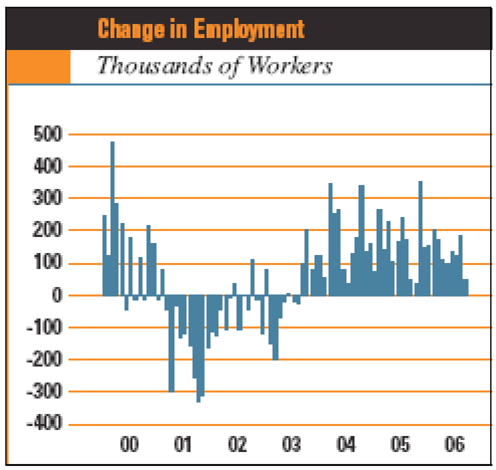
In fact, the industry is already finding that in certain emerging countries such as India, the engineering market is evolving so quickly that wage inflation and supply and demand issues are increasing at a dramatic pace, eroding many of the cost and execution advantages that made India a favored location for establishing execution centers. As a consequence, and with the movement of heavy capital infrastructure projects to other geographical regions, new execution centers are being opened in locations such as Eastern Europe, the Middle East and Africa.

Offshoring has other documented risks and disadvantages which impact U.S. interests and industry. From a policy and issues perspective, a competitive concern is the fact that experience and technology vital for the innovation process are slowly being transferred overseas to an emerging, younger workforce. Many veterans of the industry worry that tipping the balance too far will result in a loss of training and apprenticeship opportunity necessary for developing tomorrow's mid-level and senior technical leaders in the USA. The balance today finds technical leadership in the established U.S. and European operations centers leading technical feasibility and design studies with clients, but then submitting final plans and requirements to global execution centers for detailed engineering, detailed design, and other fundamental core basic requirements. However, as the current leadership retires, the innovation and senior technical knowledge is likely to emerge from these current entry-level core design and engineering activities that are being performed by professionals outside of the USA.

B. Field Crafts

A Wall Street Journal survey showed high-school-aged vocational students ranked "construction worker" 248th out of 250 as an occupational choice—only "dancer" and "lumberjack" scored lower. A Construction Industry Institute (CII) study shows the number of young people entering the construction workforce will continue to decline between 2002 and 2017. Traditionally, only people with a history of experience in construction (through family or friends) seek out construction for a management career. However, due to industry cyclicality, an increasing number of parents who work in construction, for example, are less likely to suggest a career in the industry. Children, seeing parents endure the cyclicality might make such a decision on their own.

While specific headcount data specific to the industry is not available, Figure V-B.1 identifies changes in overall construction employment and exhibits EPC resource cyclicality.



Source: McGraw Hill 2007 Construction Outlook

Figure V-B.1. Recent cyclicality in the construction industry.[15]

According to FMI, the USA entered a period of craft labor scarcity in 2005, with aggregate demand exceeding supply by 2% in 2005 for labor categories including structural ironworkers, rodmen ironworkers, operating engineers, interior and framing carpenters, drywall carpenters, general carpenters, electricians, glaziers, laborers, masons, painters, pipefitters/plumbers, roofers, and sheetmetal workers.[16] This downward trend is expected to continue, growing to a 15% deficit by 2008. The U.S. Bureau of Labor Statistics predicts an aggregate 18.2% growth in non-residential construction employment between 2004 and 2014, but only a 3% growth in the

[15] Construction Outlook 2007, McGraw Hill Construction (October 2006): 4.
[16] Heimbach et al, reference 4.

combined residential and non-residential construction labor pool (new entries minus those leaving the trades) during the same period, resulting in a 1.5% annual decline.[17]

Given these observations, the construction labor shortage is clearly a systemic problem.

C. Closing comments

The long bust has given the petroleum industry an image as a poor place to make a career. However, demand for oil and gas will last for many decades, and demand for people to find and produce the resource will outlast the lifespan of a career several times over.

In the USA, we need to interest as many young people as possible in technical and engineering careers to supply the future need. There is a long way to go, particularly in recruiting young women to pursue these fields. Industry, academia, and both state and federal governments need to work together to develop programs to interest high school seniors in studying technical topics. We will need all the young people that we can get.

Funding for research and development has been declining for years. Lack of funding for academic research programs, both by the federal government and by the industry, makes it difficult to convince students that the petroleum industry is a viable career path. Increasing funding will assure that the USA stays at the forefront of technology development in the world, and will also improve the image of the industry for students. We need to be able to attract the most talented people into our industry to tackle the tough challenges ahead.

Advances through the 1980s and 1990s have made the industry much more efficient. The declining headcount in Figure V.1 is coupled with increasing production of oil and gas. That trend will have to continue. However, solutions for future energy needs rely on application of advanced technologies in challenging environments, such as arctic and ultradeepwater. Additional professionals are required to invent those technologies, to develop and deploy them, and to manage the

[17] United States Bureau of Labor Statistics, www.bls.gov.

resources gained through their application. Without the people to apply advanced technologies, they will not yield additional energy supply. The people issue is fundamental to success in other areas.

VI. Appendix 1: Human Resources Issues Impacting the Engineering and Construction Industry Through the Year 2030

Principal author: Mark Landry, Senior Director, Human Resources, Fluor Corporation

A. Executive Summary

Engineering, Procurement and Construction (EPC) firms supporting the oil and gas industry face robust demand for services over the next 7 to 10 years. However, as with the petroleum industry, EPC firms face a myriad of human resource challenges that must be overcome to meet both the short- and longer-term demand for services though the year 2030. Engineering has become a global commodity. Workforce and population demographics, declining interest in the EPC and engineering profession, a decline in the number of engineering graduates in the United States versus sharp increases in enrollments internationally contribute to a rapidly evolving situation where progress must be made in increasing the number, quality, and diversity of available employee candidates if the U.S. dominance in the EPC market and support of oil and gas production is to be sustained.

Recommendations include: (1) greater collaboration between industry and education; (2) establishing energy and infrastructure as a national strategic priority in a manner similar to other historic Federal programs; (3) improve the immigration process; (4) support global mobility; (5) retain older workers; (6) capitalize on diversity; and (7) improve the overall image of the industry and profession.

B. Introduction

Significant research and commentary have been produced recently regarding the critical human resources issues impacting the oil and gas (O&G) industry, both in the United States and abroad. Those same observations and critical resource concerns impact the engineering, procurement, and construction (EPC) contractors who support the industry. With the exception of exploration and drilling personnel (e.g. petroleum engineers, geologists, etc.), EPC contractors are often in direct competition with their O&G clients for many of the same entry and mid-level resources, thus compounding the client-contractor paradigm and threatening the competitive advantage contractors rely upon when selling services to the O&G industry.

Availability of resources and quality of team are often cited as among the top three risks and competitive differentiators by EPC firms (figure VI-B.1 and VI-B.2).[18] Resolving these critical human resources issues is of paramount concern.

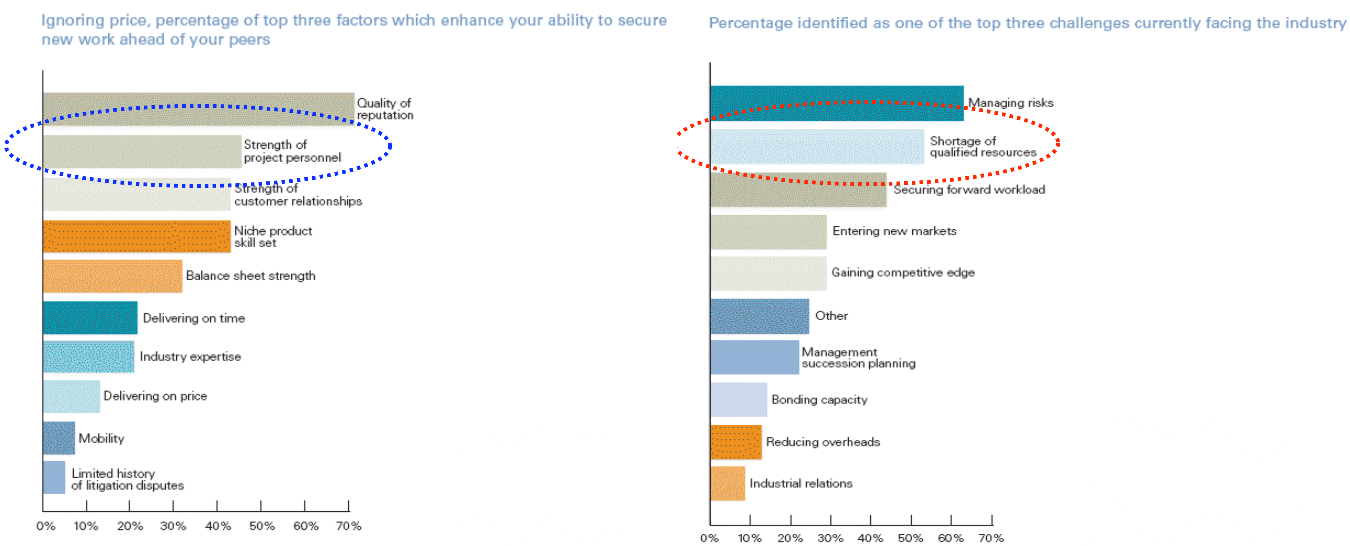


Figure VI-B.1 and VI-B.2. Human resources as a differentiator [KPMG, reference 18].

Both the O&G and EPC industries face a robust and likely unprecedented, period of opportunity over the next 8 to 10 years, and all indications suggest a longer-term

[18] *KPMG Global Construction Survey 2005*: “Risk Taker, Profit Maker?” KPMG International (2005).

investment cycle will emerge beyond that through 2030. There is also unprecedented potential for a human resource crisis:

- Analysts predict the world's energy supply will need to grow by more than 50% to meet demand through the year 2030. Most of this demand will come from outside the United States, and require local or regional supply solutions.
- U.S. oil consumption, natural gas consumption, and demand for electricity will increase by 33%, 50%, and 45% respectively over the next 20 years.[19]
- The recent surge in oil prices, energy demand, and capital investment does not reflect the practices of the past quarter-century, which had been characterized by generally subdued oil prices and relatively low infrastructure investment, resulting in an extended period of job loss, cost-cutting and industry retrenchment that has contributed to the overall disenchantment and negative perception of the industry by current and potential employees.
- The average age of workers in the petroleum industry is 49. EPC companies generally reflect the same demographics. A quarter of all U.S. employees possessing critical engineering and design skill-sets will be eligible to retire beginning in 2009.[20]
- The decline in employment and subsequent migration from the industry by mid-career professionals, the aging workforce, and an anticipated surge in college-level hiring to meet long-term demands have exacerbated the experience distribution curve and contributed to a growing discontinuity between the number of mid-level, mid-career employees (staff and management) versus entry-level and senior level staff. In response, EPC employers must focus heavily on retention, extending the tenure of retirement-eligible employees, maximizing the speed and efficiency of knowledge transfer between workforce generations and the recruitment and integration of non-traditional skill-sets into the industry.

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[19] Fisher and Seals, reference 6.
Report of the National Energy Policy Development Group, Overview of National Energy Policy, Washington, DC, GPO (May 2001).
[20] Beyer D: "Fixing the Talent Problem," *Oil & Gas Financial Journal* (September 2006).

Support of the O&G industry will require an intense focus on human capital, with heavy collaboration between industry, education and government. From a supply-chain perspective, the volume and quality of worldwide graduates in the engineering field (and especially specific engineering disciplines) has to be increased and captured; industry image has to be restored and its linkage to issues of national strategic importance stressed; and finally, careers have to be managed so that training, tools (technology), and retention are increased on a global scale to help smooth the impact of backlog cyclicality. In drafting these comments, it should be noted that specific EPC industry data were lacking, however, given the clear correlation between the EPC and oil and gas industries, many of the same research indicators pertaining to workforce demographics and distribution are presumed to apply to the EPC industry, and will be cited in support of issues raised in this commentary.

C. "Home-Office" Engineers and Designers

Comments in this report will pertain to *home-office* engineering and design resources, and will generally not reference construction or field–assigned personnel concerns, which will be addressed in a separate appendix. With that said the line between home-office and *field* execution is very blurred, particularly as activities transition from the home office (e.g. engineering, design, and procurement) to the field. The effective development of resources with appropriate experience requires assignments to the field, and so mobility and geography will be referred to in this context.

Home-office staff refers to those core engineering and design personnel whose careers are typically spent working within a permanently staffed office with sales, technical, and support staff engaged in supporting multiple clients, industries, and projects. Technical staff provides expertise, services, and support activities to project management, construction, procurement, and maintenance activities.

Engineering disciplines most sought after by the EPC industry in support of oil and gas projects include:

- Chemical

- Civil/structural
- Electrical
- Environmental
- Industrial
- Mechanical.

Typically, undergraduate level degrees are required for employment and success in the industry. While some numbers of advanced technical degrees are required to foster the technical leadership and innovation required by the EPC industry to service its oil and gas clients, as a whole it is more common that the majority of technical personnel will obtain professional certification required to meet state regulatory licensing requirements versus advanced degrees in their discipline. In terms of post-graduate education, it is more common to find engineers earning degrees in a business-acumen related field to support career expansion into general-management versus technical-management roles.

Designers traditionally have not been required to hold a college degree, although it certainly is beneficial and has proven to be more of a requirement in recent years, driven by the need to work with advanced design technology (CAD and other technology-based tools) and as a catalyst for career change and advancement outside the design fields. When recruiting, the industry looks for two-year degree programs or undergraduate engineering technology programs to provide the appropriate level of education for designers.

This core engineering and design employee resource base also provides the foundation from which the industry's critical project and construction management staff are developed. Careers typically follow a path of technical expert, project or construction management, and general management.

While not the focus of this study, it should of course also be noted that home-office staff comprise all the critical functions that support projects such as procurement (material management), contracts, project controls, finance, sales, HR, IT and the other various administrative functions.

D. Cyclicality and Headcount

As the EPC industry relies on its clients for projects that drive backlog, the cyclical nature of the O&G industry (figure VI-D.1 and figure VI-D.2), and other heavy construction sectors has historically driven cyclicality and subsequent levels of EPC resources. As a result, downturns in oil and gas are also reflected in the EPC companies servicing that sector, although not necessarily on an evenly correlated basis, as successful EPC companies will attempt to shift transferable resources to projects in other business sectors during O&G downturns. However, the overall unpredictable and cyclical nature of the industry, particularly over the past 10 years, produced corresponding significant resource management challenges for EPC firms, as evidenced by periods of heavy layoffs and re-hiring.

Figure VI-D.1. Employment in the oil and gas industry [Beyer, reference 20].

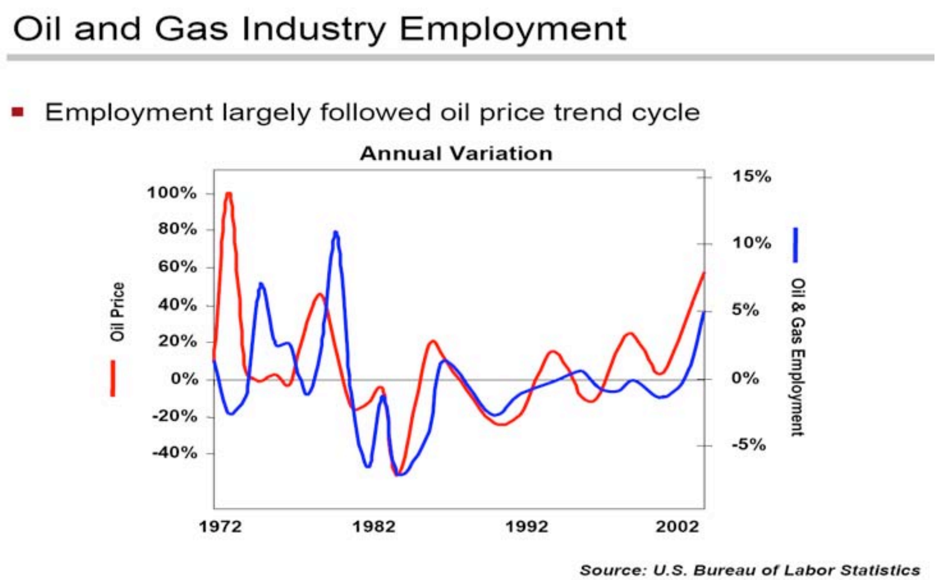
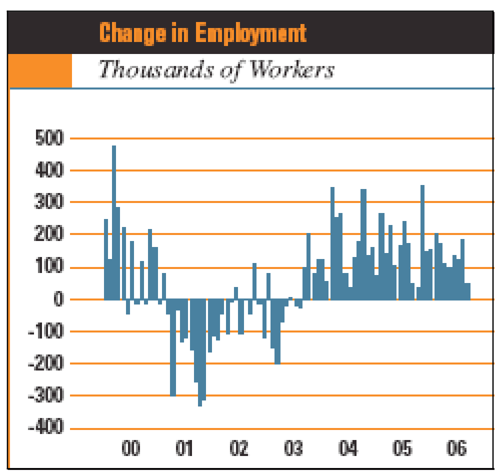


Figure VI-D.2. Oil and gas industry employment.[21]

While specific engineering headcount data specific to the industry is not available, Figure VI-D.3 identifies changes in overall construction employment and exhibits EPC resource cyclicality.[22]



Source: McGraw Hill 2007 Construction Outlook

Figure VI-D.3. Changes in EPC employment [McGraw Hill, reference 15].

Employment in a cyclical industry such as EPC boosts nationally growing individual trends towards concerns over job stability and the long-term employment

[21] U.S. Bureau of Labor Statistics.
Dudley B (President, Bechtel Oil, Gas & Chemicals): *Keynote Address*, 8th Annual Rice Global E&C Forum (Oct 11, 2005).
[22] McGraw Hill, reference 15.

outlook. Within the EPC environment, cyclicality produces a work experience characterized by alternating periods of heavy utilization (and overtime), followed by (sometimes) unpredictable periods of under-utilization and regrettably, layoffs. While salary and benefits are competitive, the unpredictability is often cited as a negative in terms of career choice, both for EPC and engineering in general.

Cyclicality takes an organizational toll as well, driving periods of layoffs and then hiring cycles, the latter of which can drive up compensation and retention expenses. Management of overhead to sustain growth and profitability for shareholders, and balancing periods of heavy workload (overtime or extended schedules) against slow periods directly impacts human-capital investment decisions, such as when and how to invest in training and development programs and management succession plans.

As has been cited in numerous related industry publications, over time this cyclicality has taken a significant long-term toll, not only on the number of professionals choosing to pursue or sustain a career in the EPC industry, but on the overall desirability of engineering as a profession.

Data from the National Science Foundation shows a sustained decline in the relative employment level of engineers over the last 5 decades.[23] This, when supported by the anecdotes of engineers in the profession, can paint a bleak picture for an aspiring college graduate contemplating a future in engineering or other science and technology fields in the United States.

[23] NSB, reference 11.
Lowell BL: *Estimates of the Growth of the Science and Technology Workforce,* Commission on Professions in Science and Technology (forthcoming).

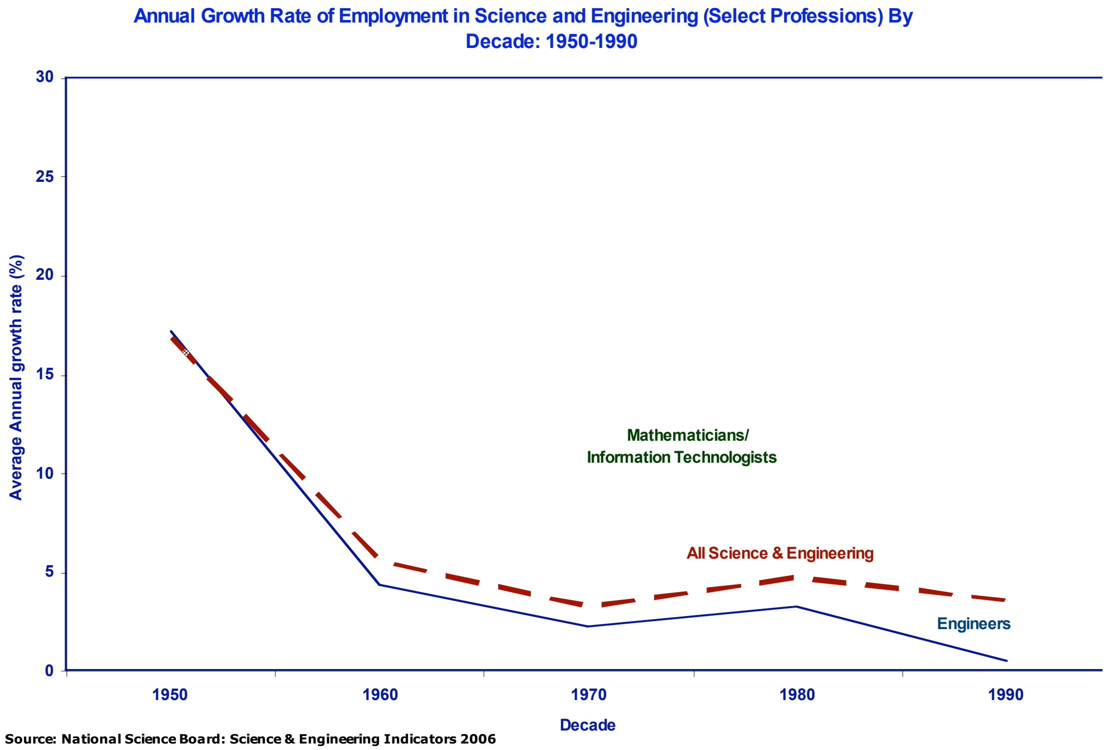


Figure VI-D.4. Annual growth rate of employment in science and engineering (selected professions) by decade: 1950 to 1990 [NSB, reference 11].

E. Industry Demographics

In addition to battling a national image problem, just as our industry enters a sustained "boom" cycle we are also faced with the unprecedented challenges of the "baby-boomer" retirement era and subsequent generational "shadows" that follow the boomers. The combination of a period of sustained negative employment, flight from the industry and aging of that portion of the workforce that was retained has contributed to documented reason for concern.

A 2006 study by Deloitte Research illustrates the workforce age issue impacting the O&G (and by extension EPC) industry.[24] As of 2003 data, approximately 55% of the O&G workforce was over the age of 45 (Figure VI-E.1). When compared to the workforce age distribution found at a typical (emerging) technology-focused industry,

[24] Sampath and Robinson, reference 3.

the looming retirement of critical staff over the next 10 years and corresponding issues of knowledge transfer between workforce generations, retention, and challenges of recruiting new talent that ostensibly favors careers in industries with a greater technology emphasis become immediately apparent.

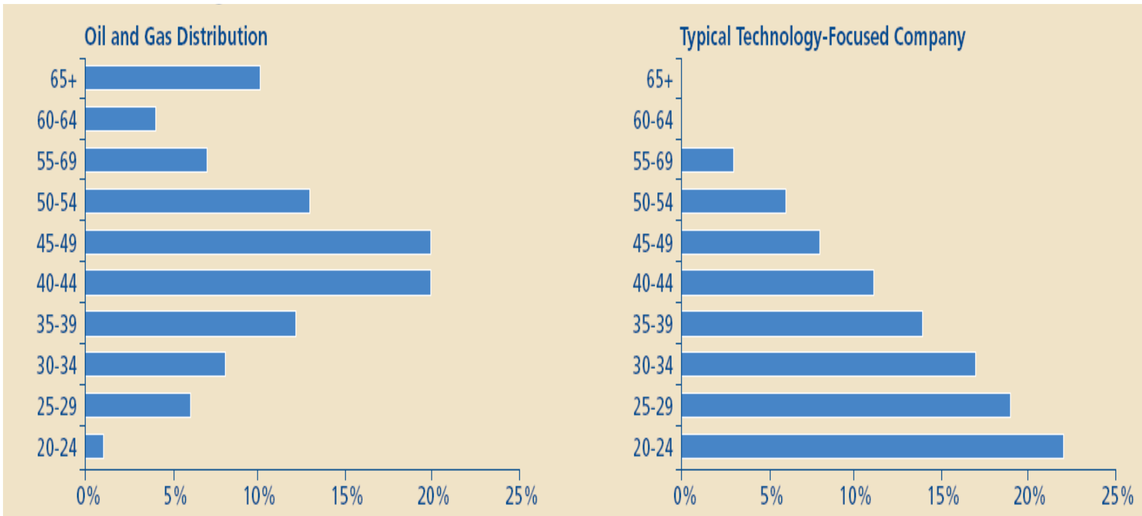


Figure VI-E.1. Workforce age distributions [Sampath and Robinson, reference 3].

Clearly the future of the industry requires aggressive recruitment and development of entry-level talent to support the projected levels of demand through 2030. The same Deloitte study profiled the O&G workforce of the future. Two immediate observations may be gleaned from Figure VI-E.2. Migration of jobs to a workforce outside of the United States and technology-driven productivity gain will reduce the overall number of employees required to support the U.S. petroleum industry, however, the next generation workforce that must be groomed to take on the challenges of the future will require a concentrated effort within the academic community to deliver enough new graduate supply to meet projected demand.

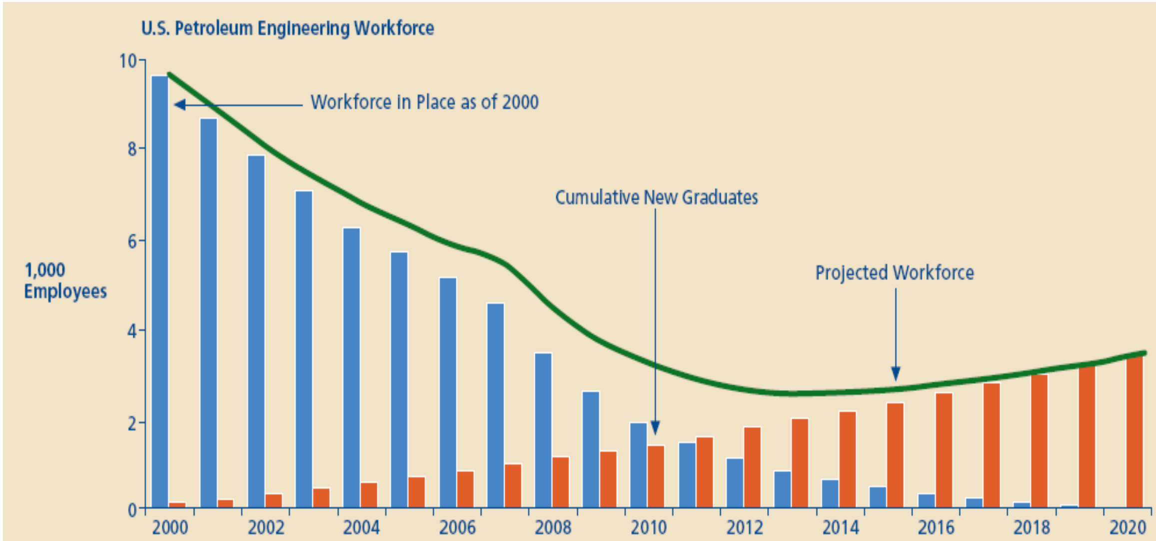


Figure VI-E.2. Oil and gas workforce projections [Sampath and Robinson, reference 3].

This new graduate supply must also possess an improved command of business and technical skills required for earlier impact and success upon transitioning to the work environment. A 2006 study by The Conference Board assessed "employers' perspectives on the basic knowledge and applied skills of new entrants to the 21st century U.S. workforce," concluding that important shortcomings existed between the basic knowledge and applied skills being delivered to graduates of high school, two-year and four-year college programs versus those required for success in the 21st century work environment.[25]

A summary of the critical basic and applied skills identified as necessary by employers is found in Table VI-E.1.

[25] The Conference Board: *Are They Really Ready To Work: Employer's Perspectives on the Basic Knowledge and Applied Skills of New Entrants to the 21st Century U.S. Workforce* (2006).

Basic Knowledge/Skills	Applied Skills
English Language (spoken)	Critical Thinking/Problem Solving
Reading Comprehension (in English)	Oral Communications
Writing in English (grammar, spelling, etc.)	Written Communications
Mathematics	Teamwork/Collaboration
Science	Diversity
Government/Economics	Information Technology Application
Humanities/Arts	Leadership
Foreign Languages	Creativity/Innovation
History/Geography	Lifelong Learning/Self Direction
	Professionalism/Work Ethic
	Ethics/Social Responsibility

Table VI-E.1. U.S. employers' perspective of basic & applied skills required for success in the 21st century work environment [The Conference Board, reference 25].

Also from the study:

- Over 57% of recently surveyed CEOs cite education and workforce preparedness as being a "very important" or "most important" policy issue, with nearly 73% also rating global competitiveness as being a "very important" or "most important" factor when considering workforce preparedness.[26]
- Workers aged 35-44 will decrease by 10 % and those aged 16-24 will increase by 15% between the years 2000-2010.[27]
- "Between 2000 and 2015, about 85 percent of newly created U.S. jobs will require education beyond high school."[28]

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[26] The Conference Board, reference 25.
The Business Council Survey of Chief Executives: CEO Survey Results (February 2006).
[27] The Conference Board, reference 25.
U.S. Bureau of Labor Statistics: *Occupational Outlook Quarterly* (Winter 2001-02).
[28] The Conference Board, reference 25.
Gunderson S, Jones R, and Scanland K: *The Jobs Revolution: Changing How America Works,* Copywriters Incorporated, a division of The Greystone Group, Inc. (2005).

Workforce Readiness Report Card for New Entrants to Workforce

Assessment of new workforce entrant readiness on "very important" skills (basic knowledge and applied skills rated as "very important" by a majority of employer respondents). "Very Important" skills are placed on the Deficiency/Excellence Lists if at least 1 in 5 respondents report entrant readiness as "deficient"/"excellent."

High School Graduates

Deficiency		Excellence	
Written Communications	80.9%	No skills are on the Excellence List for new entrants with a high school diploma.	
Professionalism/Work Ethic	70.3		
Critical Thinking/Problem Solving	69.6		
Oral Communications	52.7		
Ethics/Social Responsibility	44.1		
Reading Comprehension	38.4		
Teamwork/Collaboration	34.6		
Diversity	27.9		
Information Technology Application	21.5		
English Language	21.0		

Two-Year College/Technical School Graduates

Deficiency		Excellence	
Written Communications	47.3%	Information Technology Application	25.7%
Writing in English	46.4		
Lifelong Learning/Self Direction	27.9		
Creativity/Innovation	27.6		
Critical Thinking/Problem Solving	22.8		
Oral Communications	21.3		
Ethics/Social Responsibility	21.0		

Four-Year College Graduates

Deficiency		Excellence	
Written Communications	27.8%	Information Technology Application	46.3%
Writing in English	26.2	Diversity	28.3
Leadership	23.8	Critical Thinking/Problem Solving	27.6
		English Language	26.2
		Lifelong Learning/Self Direction	25.9
		Reading Comprehension	25.9
		Oral Communications	24.8
		Teamwork/Collaboration	24.6
		Creativity/Innovation	21.5

"Very Important" Skills Considered for:

High School Graduates Report Card (% very important): Professionalism/Work Ethic (80.3%); Teamwork/Collaboration (74.7%); Oral Communications (70.3%); Ethics/Social Responsibility (63.4%); Reading Comprehension (62.5%); English Language (61.8%); Critical Thinking/Problem Solving (57.5%); Information Technology (53.0%); Written Communications (52.7%); Diversity (52.1%)

Two-Year College/Technical School Graduates Report Card (% very important): Professionalism/Work Ethic (83.4%); Teamwork/Collaboration (82.7%); Oral Communications (82.0%); Critical thinking/Problem Solving (72.7%); Reading Comprehension (71.6%); Written Communications (71.5%); English Language (70.6%); Ethics/Social Responsibility (70.6%); Information Technology (68.6%); Writing in English (64.9%); Lifelong Learning/Self Direction (58.3%); Diversity (56.9%); Creativity/Innovation (54.2%)

Four-Year College Graduates Report Card (% very important): Oral Communications (95.4%); Teamwork/Collaboration (94.4%); Professionalism/Work Ethic (93.8%); Written Communications (93.1%); Critical Thinking/Problem Solving (92.1%); Writing in English (89.7%); English Language (88.0%); Reading Comprehension (87.0%); Ethics/Social Responsibility (85.6%); Leadership (81.8%); Information Technology (81.0%); Creativity/Innovation (81.0%); Lifelong Learning/Self Direction (78.3%); Diversity (71.8%); Mathematics (64.2%)

Percentages calculated from among the number of respondents to each question.

Number of respondents varied for each question, ranging from 347 to 357 for high school graduates; 351 to 360 for two-year college/ technical school graduates; 400 to 413 for four-year college/university graduates.

Table VI-E.2. Workforce readiness report card [The Conference Board 2006, reference 25].

Results from the study on workforce readiness by level of education show areas of deficiency that must be resolved to meet U.S. industry needs and for the U.S. to sustain productivity levels required to remain competitive in the global marketplace (Table VI-E.2).

Another consequence of a mature workforce distribution is labor cost, as reflected in higher wages and benefit costs. The wage inflation is transferred from service company to client, and from client to consumer, and does impact both the competitive nature of U.S. business as well as the retention of jobs and technology which otherwise must be sent offshore to sustain a short-term competitive advantage.

F. Training Investment

A universal challenge, and certainly one facing EPC employers, is the time required to adequately train and engage an entry-level engineer or designer. A new college engineering graduate requires approximately 10 years of experience and training to attain the necessary credentials to provide the technical innovation and leadership required. Much of the training is accomplished through on-the-job assignments and rotational experience, exposing the employee to different industries, technologies, project complexities, and project life-cycle phases. In addition, technical, supervision, and general management skills are gained along the way as the employee's eventual career aspirations and progress are attained (e.g. technical or general management, or business development) (see Figures VI-F.1 and VI-F.2).

Designers typically require a 3- to 4-year investment, heavily focused on in-house training utilizing design technology.

In all cases, the first 6 months of experience, training, and orientation are geared simply to gaining the knowledge required to navigate company-proprietary systems, procedures, and practices that form the foundation for services delivered to clients.

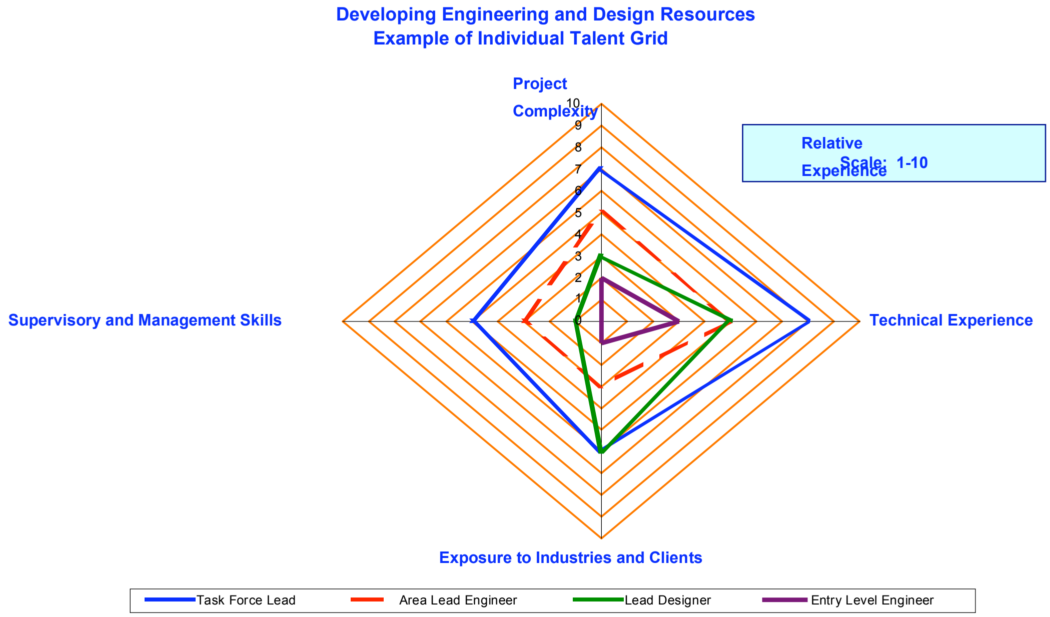

Figure VI-F.1. Developing engineering and design resources [Fluor Corporation].

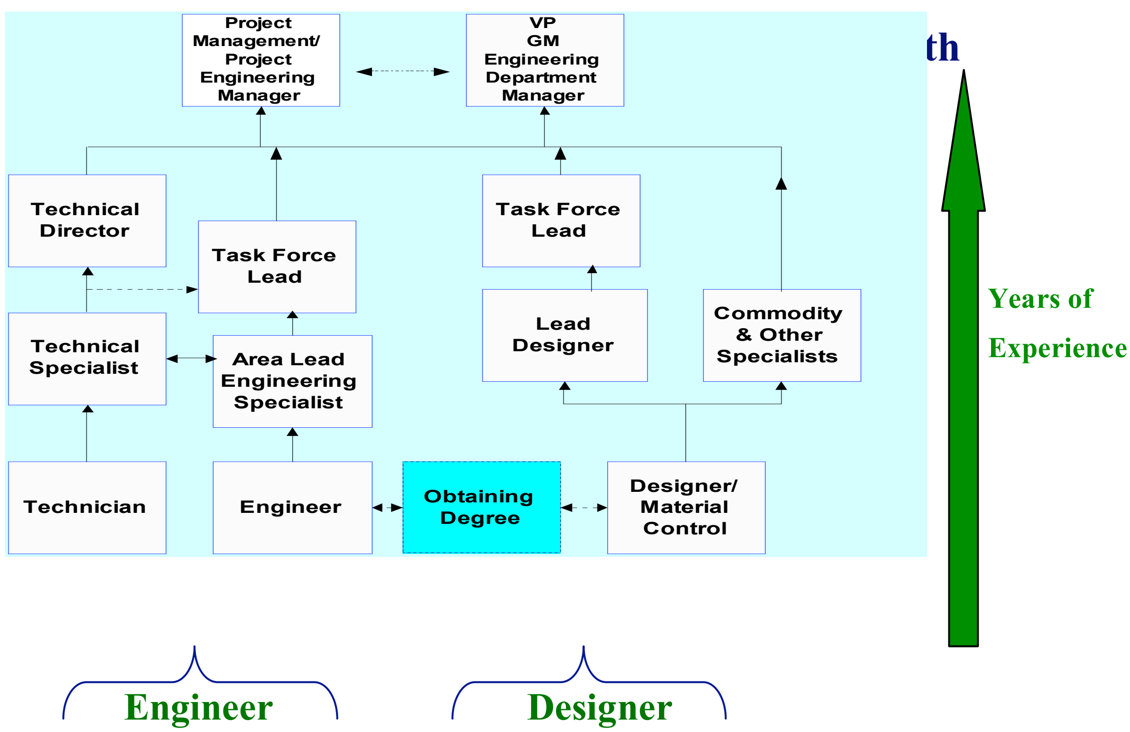

Figure VI-F.2. Typical engineering or designer career path [Fluor Corporation].

Any solution for the future must account for the training and development lead time and investment required to empower new hires with the knowledge and skills required to perform at levels demanded by the volume, pace, and sophistication of work. When overlaid against the workforce-age issue and pending retirements, firms must possess an efficient method for enhancing technology, capturing and transferring knowledge, and retaining the required level of institutional and industry knowledge long enough to complete the transfer. Corporate investment in the future must also include a more robust, professional training and development strategy to combat the rapidly decreasing knowledge lifespan as technology and innovation propel change at an ever-increasing pace.

G. Engineering Goes Global

Technology tools and enablers; leaps in communications capabilities; the need to execute work on tighter time and cost schedules; the availability of less expensive, qualified resources outside of the United States; and the migration of projects to locations in farther and more remote locations all led the EPC industry to develop and excel at the usage of global engineering locations, particularly in emerging economic regions. These global engineering locations support home-office execution and provide several advantages:

- 24x7 schedules, lower labor costs with little or no compromise on quality
- Lower total cost driven by generally cheaper overhead and infrastructure cost
- Opportunity to manage global workforce distribution and stability by moving work to the resources instead of vice-versa
- Regional or local knowledge and content provides execution advantages when supporting projects outside the United States. Knowledge of local engineering or design practices, language and cultural benefits, and even political capital gains are often realized.

The distribution of work on a work-sharing basis has become a universal practice within the EPC industry. With standardization of work practices, quality, technology and ease of handoff, this execution model has become widely accepted by O&G

clients and is now firmly embedded as a requirement for delivery of contracted scopes of work within the established cost, risk, schedule, and resource requirements which prevail today.

As many countries in Europe and Asia face a similar shrinking of the workforce and a number of nations appear poised to emerge on the global workforce stage as education, geopolitical stability, and infrastructure concerns are overcome, engineering will continue to become a global commodity (Figure VI-G.1).[29] This could signal a decrease in advantage provided by established engineering centers and the need to transition to new countries with associated start-up investments and challenges, as well as an overall erosion of the available competitive and qualified labor supply.

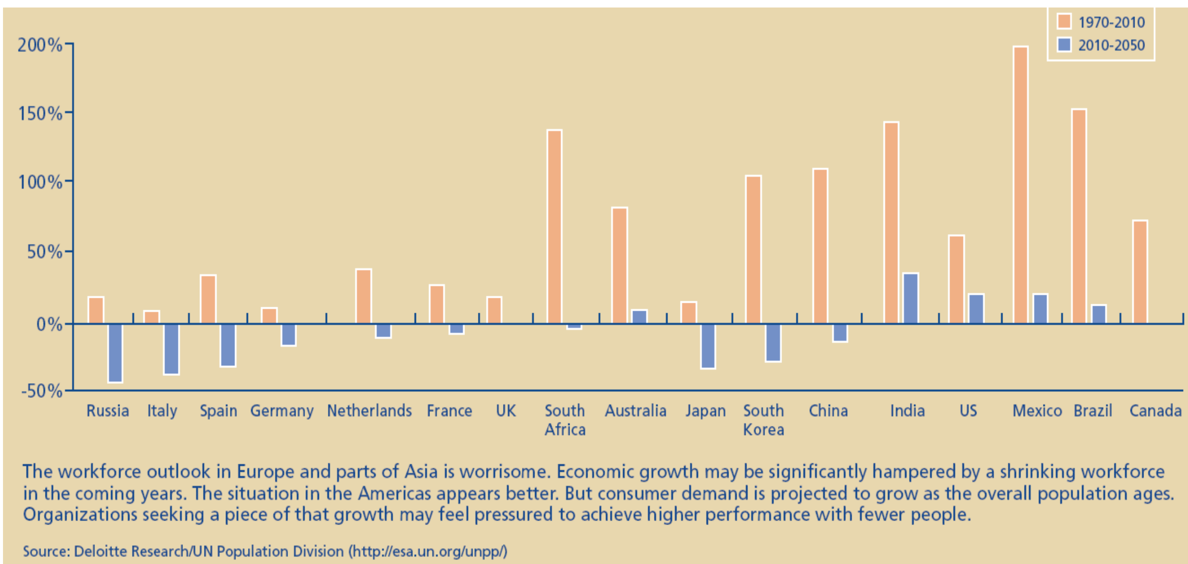

Figure VI-G.1. Projected change in the working-age population (15 to 64) 1970 to 2010 and 2010 to 2050 [Deloitte Research, reference 29].

In fact, the industry is already finding that in certain emerging countries such as India, the engineering market is evolving so quickly that wage inflation and supply and demand issues are increasing at a dramatic pace, eroding many of the cost and execution advantages that made India a favored location. As a consequence, and with

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[29] Deloitte Research: *It's 2008: Do You Know Where Your Talent Is? Why Acquisition and Retention Strategies Don't Work* (2006).

the movement of heavy capital infrastructure projects to other geographical regions, new execution centers are being opened in locations such as Eastern Europe, the Middle East, and Africa.Offshoring has other documented risks and disadvantages which impact U.S. interests and industry. From a policy and issues perspective, a competitive concern is the fact that experience and technology vital for the innovation process are slowly being transferred overseas to an emerging, younger workforce. Many veterans of the industry worry that tipping the balance too far will result in a loss of training or apprenticeship opportunities necessary for developing tomorrow's mid-level and senior technical leaders in the United States. The balance today finds technical leadership in the established U.S. and European operations centers leading technical feasibility and design studies with clients, but then submitting final plans and requirements to global execution centers for detailed engineering, detailed design, and other fundamental requirements. As the current leadership retires, where will the innovation and senior technical knowledge emerge if many of the entry-level, core design and engineering activities are being performed outside of the United States?

This trend has not been missed by engineering students enrolling in colleges and universities. Figures from the National Science Board's *Science and Engineering Indicators 2006* (see Figure VI-G.2) research illustrate the disparity in engineering degree enrollments for select countries.[30]

Workforce migration and immigration will be critical areas in crafting a comprehensive industry solution through 2030.

[30] NSB, reference 11.

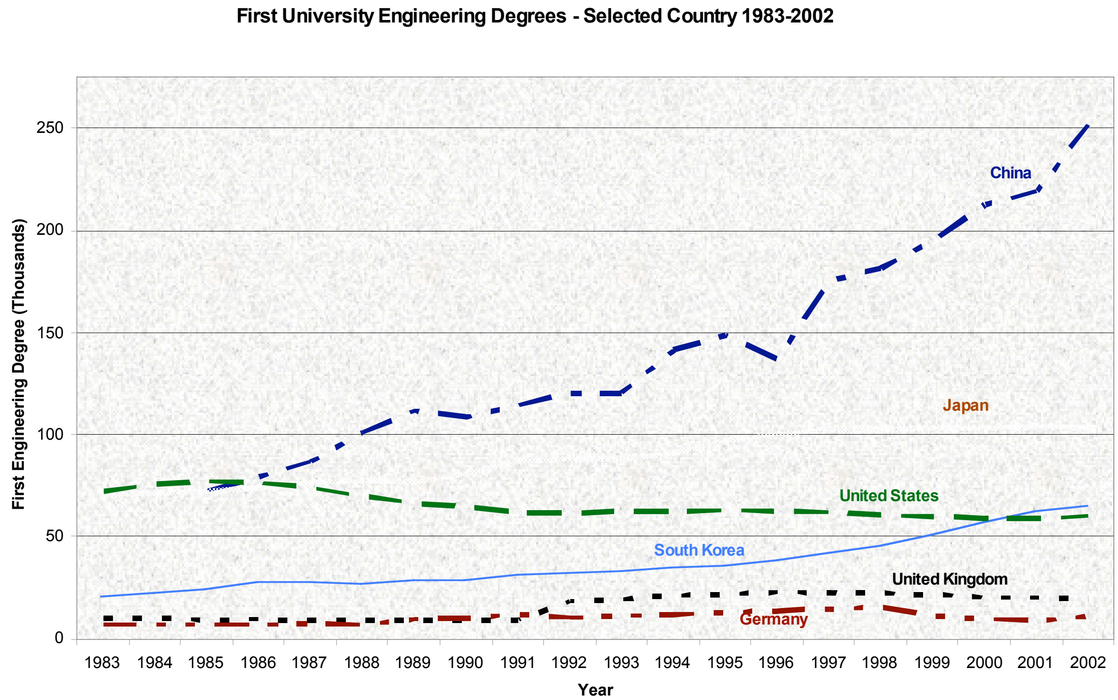

Figure VI-G.2. First university degrees in selected countries, 1983–2002 [NSB, reference 11].

H. "The Perfect Storm in EPC"

Against a backdrop of poor industry image, declining engineering employment and opportunities, and the double-edged sword of an aging workforce in both the industry and the national census arrives the perfect storm of multi-sector upswing and backlog opportunity for EPC firms. This storm is driven by the combination of high global energy demand and emerging economies, sustained commodity prices, geopolitical turmoil and decades of neglecting the national energy infrastructure (Figures VI-H.1 through VI-H.6).

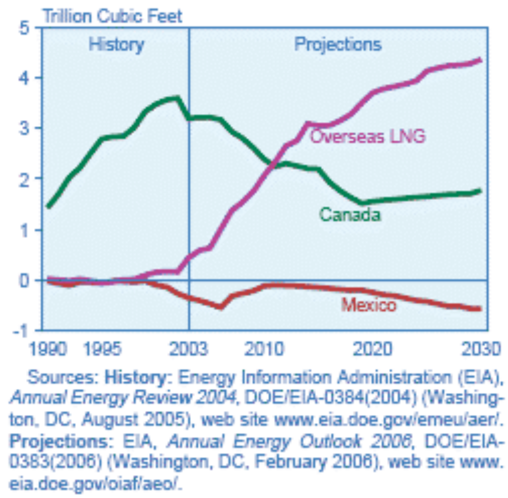

Figure VI-H.1. U.S. natural gas supply by source, 1990 to 2030.[31]

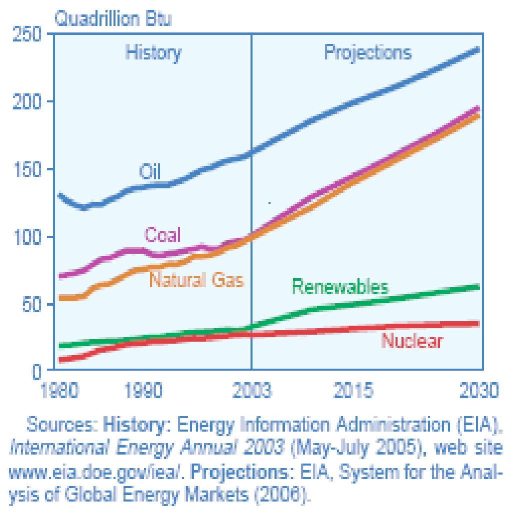

Figure VI-H.2. World marketed energy use by energy type, 1980 to 2030.[32]

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[31] For historical data, see EIA: *International Energy Annual 2003* (May–July 2005). Available at www.eia.doe.gov/iea/.
For projections, see EIA: *System for the Analysis of Global Energy Markets* (2006).

[32] For historical data, see Energy Information Administration (EIA): *Annual Energy Review 2004*, DOE/EIA-0384 (2004), Washington, DC (August 2005). Available at www.eia.doe.gov/emeu/aer/.
For projections, see EIA: Annual Energy Outlook 2006, COE/EIA-0383(2006), Washington, DC (February 2006). Available at www.eia.doe.gov/oiaf/aeo/.

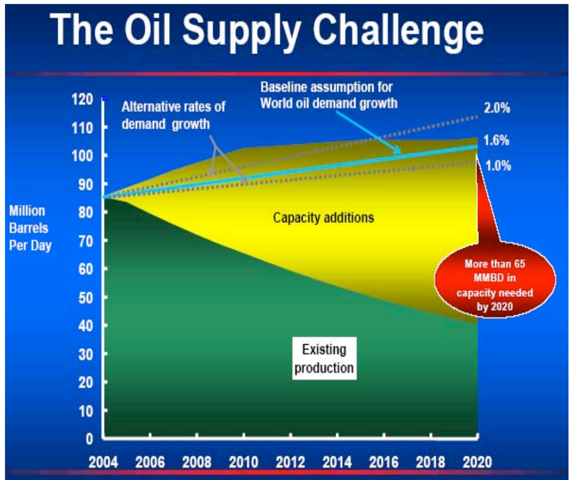

Figure VI-H.3. The oil supply challenge.[33]

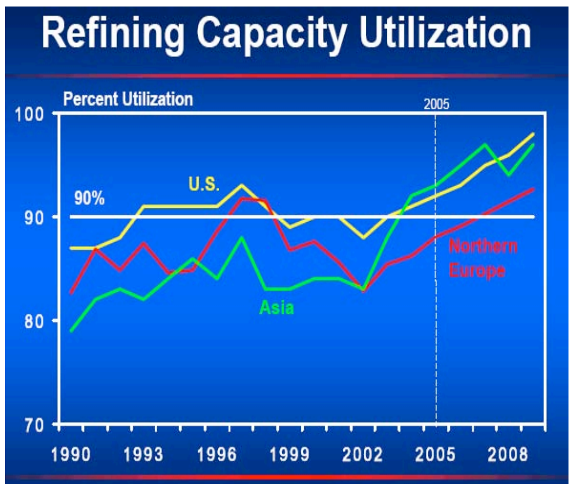

Figure VI-H.4. Refining capacity utilization.[34]

[33] ConocoPhillips presentation: Howard Weil Energy Conference (2006).
[34] Purvin & Gertz, Inc. (2006).

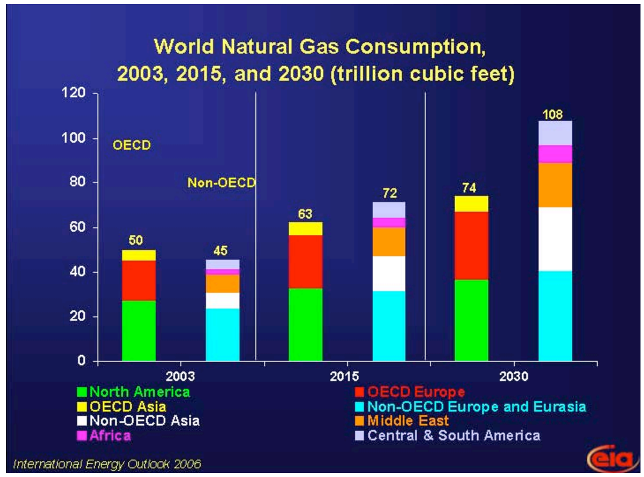

Figure VI-H.5. World natural gas consumption.[35]

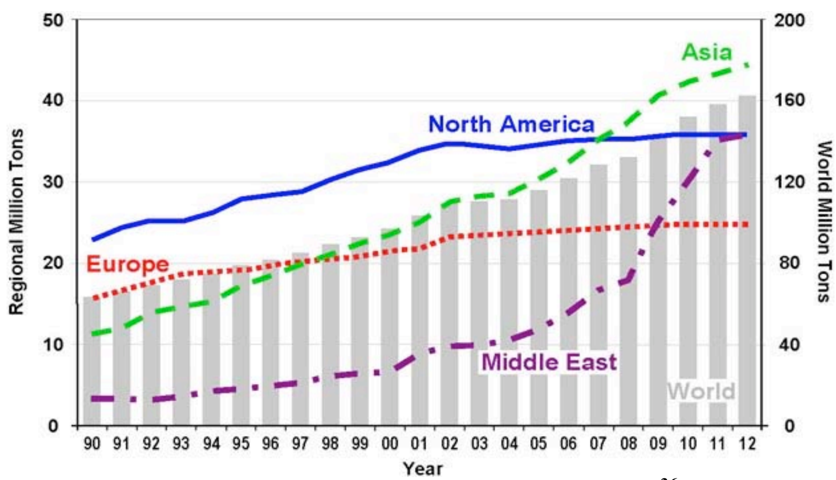

Figure VI-H.6. Chemical products demand.[36]

While not all cited demand forecasts extend through 2030, given the confidence in industry energy-consumption models, global population growth, and corresponding infrastructure and technology demands, a reasonable assumption is that the EPC industry is on the verge of a sustained upward multi-segment cycle. Consensus estimates of the scope of the current up-cycle are in the 7- to 10-year range, depending upon source being cited, with some sources predicting a longer up-cycle.

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[35] U.S. Department of Energy/Energy Information Administration (2006).
[36] CMAI, Inc. (2006).

I. Recommendations

No single tactical approach will answer the myriad of human resources issues facing the industry. Nor do the data suggest this is a short term (i.e. less than 5-year) problem. Certainly the current backlog forecasts suggest that we are facing a solid 8- to 10-year cycle in energy and chemical-related activities alone, driving growth- and execution-related challenges through 2016. When energy demand, geopolitical and demographic factors, and need for infrastructure refurbishment and new investment are factored in, it is reasonable to conclude that demand on EPC resources will be sustained beyond the ten-year horizon, with some predicting longer.

Industry solutions need to be strategic, address multiple stakeholders and concerns, and target a broad range of resource tactics. In general, the human resource strategy for EPC must focus on multiple supply chains including retention, retirees, work-sharing, hires from other industries, and of course, new college graduates.

1. Greater collaboration between industry and education

The number and quality of engineering and other technical graduates from two- and four-year university programs must be improved. On a positive note, the number of U.S. engineering-degree enrollments has been increasing since 1999 (Figure VI-I-1.1). However, according to National Science Board statistics, since 1980 the United States has been losing ground in the number of overall tertiary education recipients (Figures VI-I-1.2 and VI-I-1.3), especially relative to China and India, where the greatest increase has occurred. Noticeable too is that as with the United States, other G-8 countries such as Russia, The United Kingdom, Germany, and Japan are also showing a decline in tertiary-education achievement over the same time period. This decline, when compared to increases amongst emerging countries such as China, India, Brazil, and Thailand, comes at a period when researchers have concluded the number of jobs that will require advanced education is increasing. What will be the impact of this shift in supply of tertiary-level-educated new workers on where and how future work is executed?

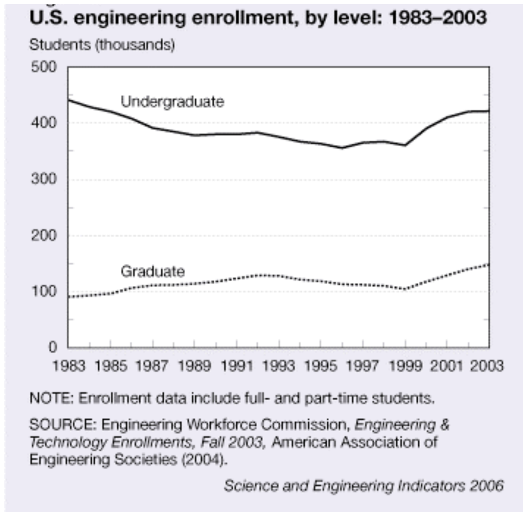
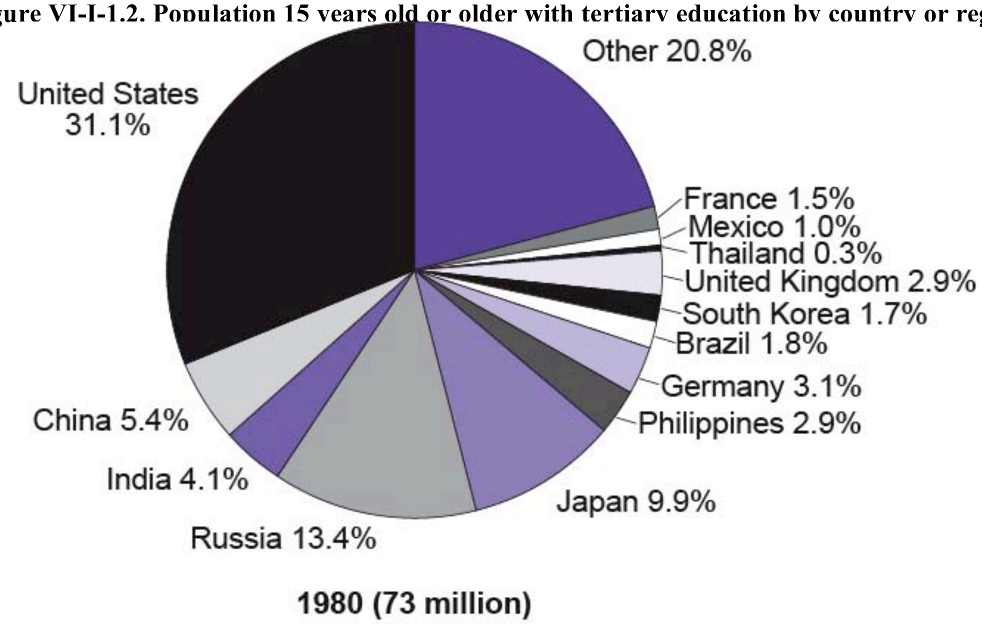


Figure VI-I-1.1. U.S. engineering enrollment, by level: 1983 to 2003.[37]

Figure VI-I-1.2. Population 15 years old or older with tertiary education by country or region:



Source: National Science Board, Science & Engineering

[37] Engineering Workforce Commission: *Engineering & Technology Enrollments, Fall 2003*, American Association of Engineering Societies (2004).

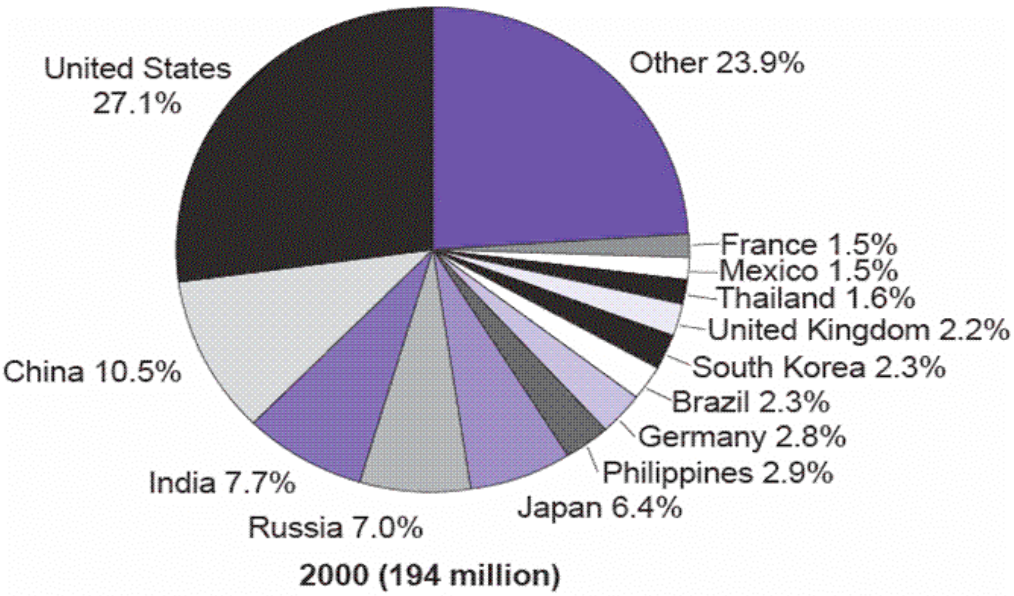


Figure VI-I-1.3. Population 15 years old or older with tertiary education by country or region: 2000 [NSB, reference 11].

Specific to those engineering disciplines most sought after by the EPC industry (i.e. chemical, civil and structural, electrical, and mechanical), enrollments appear to be trending downward, suggesting a need to focus communication and awareness of industry opportunities and needs at the high school and college academic-department level, as well as identifying the specific drivers behind a declining interest in these fields. On first impression, the trends are not surprising, given the national economic passion towards high-tech, communications and other R&D-intensive industries versus the traditional manufacturing and heavy-industry base that continues to migrate offshore. However, if the O&G sector is to be supported using U.S. labor, the trend needs to be reversed.

On the subject of partnership between industry and education, the changing nature of tertiary education must also be acknowledged. Jamil Salmi of the World Bank cited the three significant influences impacting the role and function of tertiary education in the 21st Century: a) economic globalization, b) the increasing importance of knowledge as a driver of (economic) growth, and c) the information and communication revolution.[38] A nation's economic growth and prosperity are driven by the ability to "acquire and apply technical and socio-economic knowledge," and economic growth today is as much a consequence of "knowledge accumulation as capital accumulation," with globalization and the exponential enhancements in information- and communication-technology driving progress. Higher education and industry must collaborate to design facilities and curricula that recognize and leverage these influences and drivers. Educational institutions are today, and will continue to become, more global in nature (i.e. enrollment diversity, facilities, and collaboration with partner universities around the world), connected (i.e. wired, distance learning, and high-tech delivery) and focused on knowledge transfer than ever before. Knowledge transfer is not just the basic passage of learnings from teacher to student (or experienced to inexperienced), but refers also to the lateral sharing of knowledge, theory, and principals across different fields of study that in the past had not been linked. Examples include micro-biology, genetics, and engineering; project management and R&D; and medicine and mechanical engineering. Interdepartmental studies are being experimented with in greater frequency by higher education around the world. This cross-collaboration bodes well not only for the future of innovation and technology, but also for attracting a greater number of students to the fields of design and engineering, as well to ease the transferring of skills across multiple industry and commercial applications.

This economic shift to knowledge economies and the reality that jobs in the future will require a higher level of education are helping spur the growth of tertiary education in OECD countries such as Brazil and Mexico.

The other realization and impact to business is that the knowledge lifecycle has shortened dramatically. Corporations must remain cognizant of the need for and availability of continuing education, especially in technology fields. The role of professional development teams and "corporate universities" will increase as required

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[38] Salmi J: *Tertiary Education in the Twenty-First Century Challenges and Opportunities*, The World Bank, Human Development Department LCSHD Paper Series No. 62 (June 2000). See http://wbln0018.worldbank.org/lac/lacinfoclient.nsf/145d45c4b49a8bb88525673600695e5f/2d9645fd1eaab499852569ed005ccbc3/$FILE/62.pdf.

to maintain and retain a knowledgeable professional workforce, in partnership with technical schools and universities using distance learning and communications technology to collaborate in sharing data and learning opportunities.

Partnerships with technical schools, colleges and universities need to be sustained and enhanced, and in a manner that reflects the evolution taking place. When factoring infrastructure requirements and the social impact of an aging population (i.e. changes in demand, quantity, types, and location of services to support retiring boomers and the maturing gen-Y), this partnership stands to reap excellent benefits and returns.

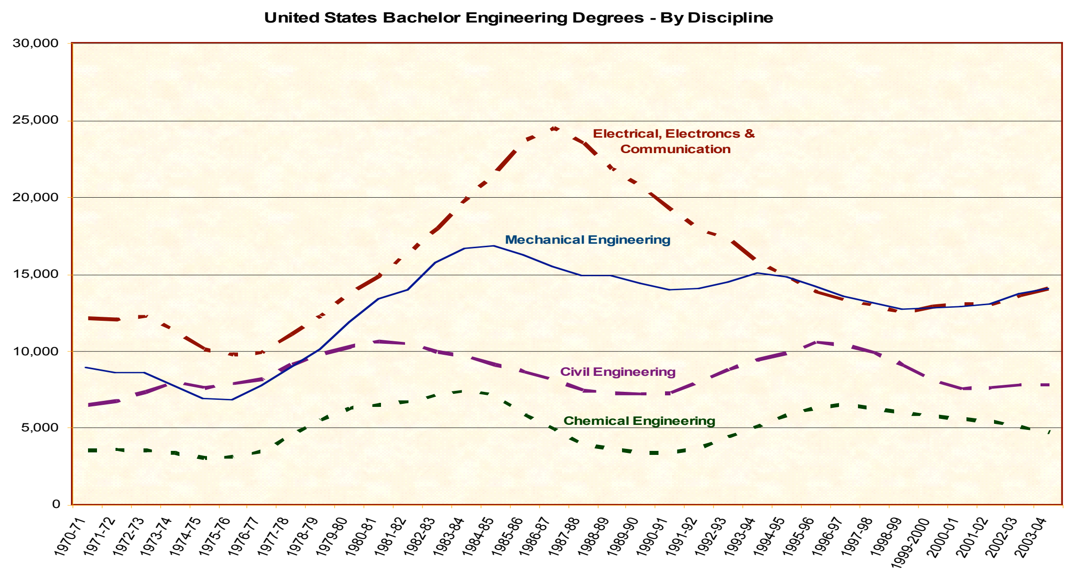

Figure VI-I-1.4. U.S. bachelor engineering degrees, by discipline.[39]

2. Make energy (oil and gas) and infrastructure a national strategic priority

Industry and technology benefit from the focus, funding, and direction of a national initiative such as the Federal Aid Highway Act of 1938 and 1954 under Presidents Roosevelt and Eisenhower, or the national space program established under President Kennedy. A similar national focus on energy for the future, or the

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[39] U.S. Department of Research Data.
NSB, reference 11.

status of critical national infrastructure, would help establish a framework of national strategic priority for industry, government, and education to use as a catalyst for investment in resources, infrastructure and technology required to address energy needs through 2030 (Table VI-I-2.1).

Area	Grade	Trend (since 2001)
Roads	D+	↓
Bridges	C	↔
Transit	C–	↓
Aviation	D	↔
Schools	D–	↔
Drinking Water	D	↓
Wastewater	D	↓
Dams	D	↓
Solid waste	C+	↔
Hazardous waste	D+	↔
Navigable waterways	D+	↓
Energy	D+	↓
America's Infrastructure GPA	D+	
• Total Investment		$1.6 Trillion (estimated five-year need)

Table VI-I-2.1. America's aging infrastructure, 2003.[40]

Additionally, a national-energy focus and strategy would enhance the image of the oil and gas industry and help alleviate public concerns, while also addressing a real issue facing the United States against exponential growth in demand for energy, steel, and other natural resources by the emerging economies.

Given that the EPC firms support all infrastructure design, engineering, and construction, a national focus on broad infrastructure improvement and development would support the industry by helping to level out cyclicality, engage a large number of workers and continue to improve the overall perception of the engineering and construction career path.

3. Increase and improve the immigration process

As evidenced by data in Figure VI-I-3.1, VI-G.1, and VI-G.2, the large number of bachelor level engineering graduates outside the United States, coupled with the aging work-force, means the migration of employees and work assignments across borders will be a necessary tactic for many nations to contend with. The United States

[40] National Academy of Sciences: *The Engineer of 2020: Visions of Engineering in the New Century, 2004,* and adapted from American Society of Civil Engineers (2003).

should examine its current immigration process and reception of foreign students and workers, whose participation will be necessary to meet domestic workforce demands. Without a strong immigration platform, the other logical response will be a continuation of the export of work and knowledge to available labor supply outside the United States.

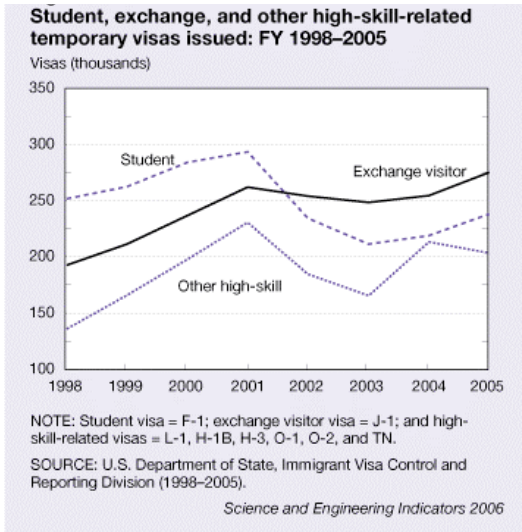

Figure VI-I-3.1. Student, exchange, and other high-skill-related temporary visas issued: fiscal year 1996 to 2005.[41]

4. Support mobility

Figure VI-I-4.1 illustrates the forecasted, worldwide, construction demand by primary industry sector over the next five years. It comes as no surprise that the boom cycle being experienced by the EPC companies is neither a regional nor a sector phenomenon, but rather that the demand and deployment of resources will be global, despite the challenges of geography, environment, or political stability.

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[41] U.S. Department of State: Immigrant Visa Control and Reporting Division 1998–2005. See NSB, reference 11.

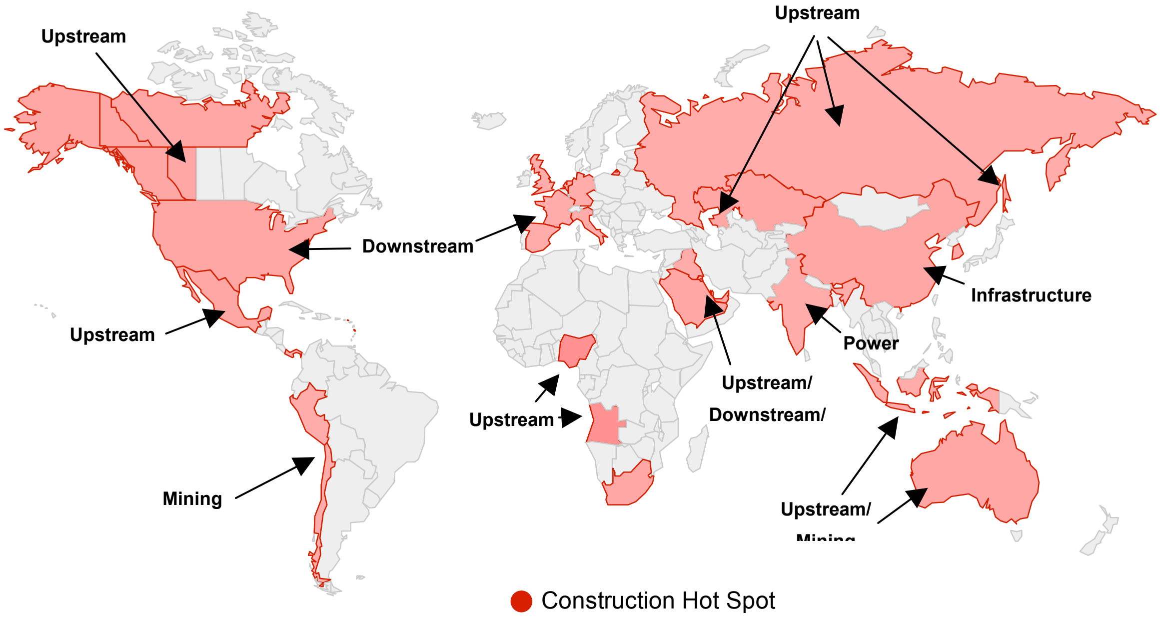


Figure VI-I-4.1. Construction hot spots.[42]

What has developed as a concerning trend within the EPC industry is that while advances in travel, communications, access, and knowledge have truly made the world a smaller place and this generation the most well traveled of any in the world's history, those same dynamics and other important considerations such as personal safety, standards of living, quality of work/life balance, and dual careers have combined to restrict the mobility of today's workforce versus that of the last three or four decades. When assignments are accepted, they are most frequently taken on single or unaccompanied status with the demand for frequent leaves and return trips home.

Energy demands will require that natural reserves in the most challenging environments be tapped, and that refining and transportation infrastructure be placed accordingly to leverage resources recovered from geographically remote areas. As has been pointed out, while there will be continuing heavy reliance on a non-U.S. workforce, the EPC industry requires mobility of its key resources.

Negative changes to the U.S. tax code pertaining to expatriate income, such as those enacted recently as part of the Tax Increase Prevention and Reconciliation Act

[42] Fluor Corporation (2005).

of 2005, further hinder the mobility of U.S. employees supporting international O&G-recovery efforts and impede the competitiveness of U.S. EPC firms, or force the use of personnel from outside the USA. Presently, the United States is one of the few countries that taxes personal income on a worldwide basis regardless of residence and in the manner applied by the IRS tax code, which totals all worldwide income, then provides to qualifying individuals the opportunity to exclude a portion of income attributed to certain assignment related income and expenses. The recent tax-code revisions reduced the amount filers are able to exclude and deduct.

EPC experience indicates that the issue of declining mobility for the types of assignments required to execute work on behalf of clients is not just a U.S. phenomenon (ignoring personal income-tax-related issues). Therefore substituting resources from other countries is not an end-all solution by virtue of limited supply and time required to adequately transfer knowledge and experience across global boundaries.

5. Support retention of older workers

The personal-wealth environment in the United States over the last 8 to 10 years, where we saw the explosion of paper wealth in the equity markets during the dot-com boom, followed by the post-9/11 implosion of the market, then into the real-estate-driven reemergence of wealth, has made it hard to predict the intentions of the baby-boomer generation regarding retirement.

Certain facts with regard to the aging workforce are very clear. People in the United States are generally living longer, healthier lives than ever before, and expectations of retirement have changed. “Retirement” itself is being redefined, from a lifestyle of sedentary leisure to a period of activity, rejuvenation, and second (or third) careers.

A trend in the EPC industry through the late 1990s was retirement from the industry at an earlier age. This slowed during the post-9/11 years, and with the current work load it appears to have leveled off.

The relevance of this information is that exit of the baby-boomer generation from the workforce appears to occur at an earlier age than traditional workforce models suggest. To continue to support the industry, companies must aggressively tackle the issue of maturing workforce retention, including capture and retention of institutional and technical knowledge.

From a policy standpoint, health- and welfare-related policies must continue to support engagement of the aging workforce through phased retirement, part-time, and self-employment opportunities. The partnership between industry and government on issues such as healthcare and retirement coverage, cost, and viability must continue with a focus on the significant demographic changes that are occurring.

Industry must continue to focus on workforce management, generational diversity issues, and the capture and transfer of knowledge between generations in a structured and programmatic manner.

6. Recognize and capitalize upon diversity

An integral component and consequence of all the human-capital issues noted will be the opportunity and the requirement to improve and leverage diversity in the workplace. Statistically, the number of female engineering bachelor degrees relative to similar degrees by male undergraduates is increasing (Figure VI-I-6.1), as is the racial make-up of entry-level workforce, when the U.S. population ages 20-24 for the periods 1985-2020 is considered (Figure VI-I-6.2).

This trend toward greater racial and cultural diversity is equally, if not more evident within the science and engineering community as shown in Figure VI-I-6.3, the minority share of science and engineering bachelors degrees in the period 1985-2002.

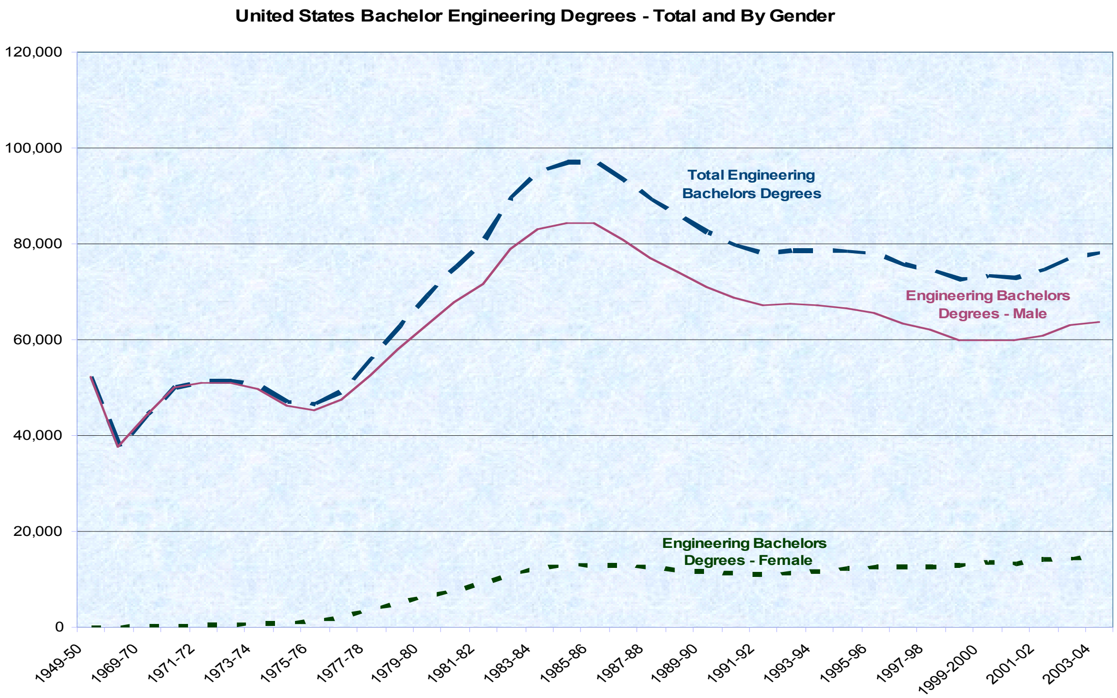


Figure VI-I-6.1. U.S. bachelor engineering degrees, total and by gender.[43]

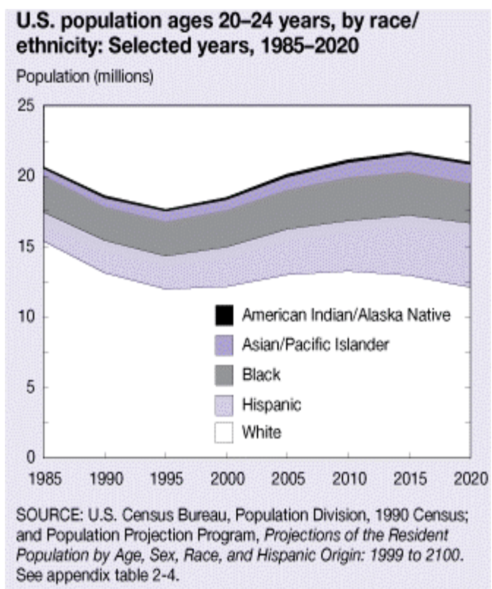


Figure VI-I-6.2. U.S. population ages 20 to 24, by race or ethnicity: selected years from 1985 to 2020.[44]

[43] U.S. Department of Education Research Data.
NSB, reference 11.
[44] U.S. Department of Education Research Data.

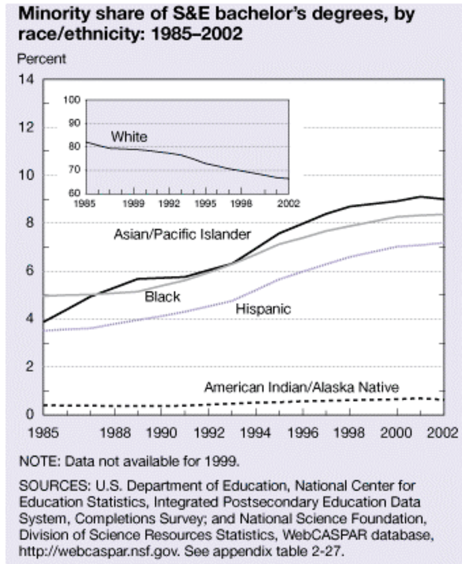


Figure VI-I-6.3. Minority share of S&E bachelor's degrees, by race or ethnicity: 1985 to 2002.[45]

From a home-office EPC perspective, engaging a greater proportion of a diverse employee base within the workforce is a necessity predicated by demographics alone, in addition to the obvious business, cultural, and social advantages. Yet historically, EPC is an industry that has tended to under-capitalize in this area. Assuming a migration not only toward more diversity as defined by U.S. standards, but also global workforce diversity, then the ability to understand, engage, embrace, and leverage the workforce of the future is a near-term requirement.

The growing proportion of younger workers with a different set of core values, capabilities, work styles, and expectations of career and workplace influenced by a youth spent connected 24x7 will dramatically impact the way new employees are engaged, work is conducted, and retention is accomplished. While many of the core values remain consistent between generations, their priority and influence on daily behaviors and motivators varies. For example, the chart below from 2006 Deloitte Research (Table VII-6.1) illustrates some of the fundamental workplace elements valued by generation Y, and the corresponding "wants" translated from these

NSB, reference 11.
[45] U.S. Department of Education Research Data.
NSB, reference 11.

elements.[46] Priorities such as open social networks, sense of purpose, and meaningful assignments speak directly to the issue of industry- and profession-image enhancement required to draw gen-Y members into the EPC profession. Contrasted against the workplace experience that many of the current EPC management endured and found success in, bringing the expectations of these generations and organizational levels together and reconciling them will be a requirement for success in any industry, but especially in EPC. Furthermore, these are not just U.S. profiles, but rather hold true to varying degrees in many of the mature operating locations around the world.

Fundamental Workplace Element	Gen-Y Needs/Wants Included in This Category	
Flexibility	• long-term career development • access to mentors and leaders • work/life flexibility	• tech-savvy work environment • open social networks
Balance	• long-term career development • sense of purpose and meaning in work	• access to mentors and leaders • work/life flexibility
Respect	• long-term career development • sense of purpose and meaning in work	• work/life flexibility • open social networks
Access to people and knowledge	• access to mentors and leaders • tech-savvy work environment	• open social networks
Access to technology	• work/life flexibility • tech-savvy work environment	• open social networks
Opportunities for constant evaluation	• sense of purpose and meaning in work • access to mentors and leaders	• open social networks

Table VII-6.1. Generation-Y workplace culture [Deloitte Research, reference 3].

7. Improve the image of the industry and profession

The previous recommendations all support the broader goal of enhancing the image and reputation of the EPC industry and its associated professional careers. As has been cited in various research pertaining to workforce issues in the petroleum industry, EPC must reverse a decades-long trend of declining impressions of the stability, technical innovation, earnings opportunity, and social mores of the EPC industry versus other career choices. For those that have experienced a career in the industry, many positives exist, including career challenge, the opportunity to work with a multitude of clients in very diverse industries and global locations, the opportunity to travel and experience cultures and professional environments outside

[46] Sampath and Robinson, reference 3.

the home environment, and probably of most significance, the opportunity to positively influence and contribute to social and economic development by using knowledge, skills, and effort to design, engineer, and construct infrastructure around the world as a personal legacy.

Success in reversing current industry perceptions and overcoming these human capital challenges will require, and be measured over a number of varying activities such as:

- Participation in career counseling and education in elementary and secondary schools, and internships to provide early exposure to potential future employees
- Industry collaboration in lobbying, communication, and media opportunities to articulate employment needs and career opportunities, and to generate an enthusiasm for the industry
- Creation and communication of a national infrastructure agenda
- Engaging industry veterans in the role of community ambassadors and mentors to emerging generations and women and minorities
- Enhancement of the industry's focus, knowledge, understanding and success in diversity issues to ensure the workplace of the future welcomes and champions the needs of motivators of the emerging and different workforce
- Speeding up intra-disciplinary (intra-departmental) collaboration and mergers by identifying industries and professions with complimentary skill sets, and targeting professionals in those industries for cross-over opportunity
- Enhancing the technology and high-tech nature of our industry and leveraging those enhancements to attract new workers and improve productivity
- Success in making the necessary workplace adaptations in work/life balance and technology-enabled remote participation to tap a generation of part-time, stay-at-home, or otherwise alternative work-force.

J. Conclusion

While the EPC industry will share in the national challenge of meeting future workload demands and resource supply, a proactive, broad, strategy and tactical approach—that recognizes a global supply of labor, the opportunity to enhance productivity through technological and work-process changes, and evolution of the workplace to maximize the attraction and retention of human resources—provides hope the challenge will be overcome.

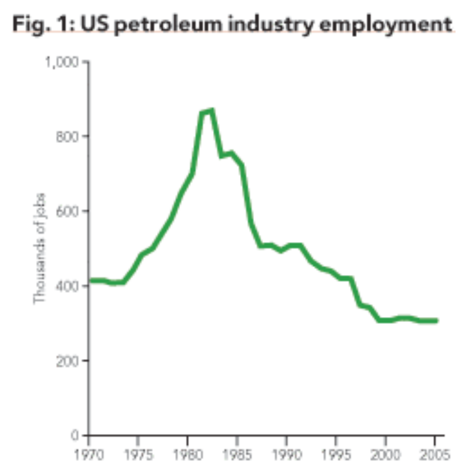
Heavy collaboration between industry, education, local and national governments, and international bodies will be required, if only to adapt more quickly to the global forces and influences that are already impacting all business and commerce. EPC and the O&G industry can no longer afford to remain an isolated archaic industry segment but must rally together to streamline the investment, technology, schedule, risk profile, and resource strategy required on a global basis to meet energy demand. Preferably this will be achieved through a national strategic agenda and will provide support to level cyclicality and appropriately allocate spending, effort, and priorities around the globe in sync with national politics and diplomatic policy.

Education in the United States must make a major step-change in terms of format, institutional structure, learning, and output that leverages current technology and enablers to produce a workforce armed to meet demands of the future rather than one oriented toward needs of that last decade.

VII. Appendix II: Supplier Capacity Considerations Field Staff and Craft—Framing Questions

A. Historical and Current Employment

Approximations vary, but concur that there have been significant employment losses due to industry cyclicality and resultant layoffs (Figure VII-A.1). Most estimates point to industry consolidation as the primary driver, responsible for up to 1,000,000 job losses between the early 1980s and today, with half of those in the United States. In 1999, the ten largest oil companies reduced their workforces by a combined 38,000 workers—this at the end of a 12-year decline that saw an average 5.2% annual reduction in the industry.



Source: API Employment Survey, 2005

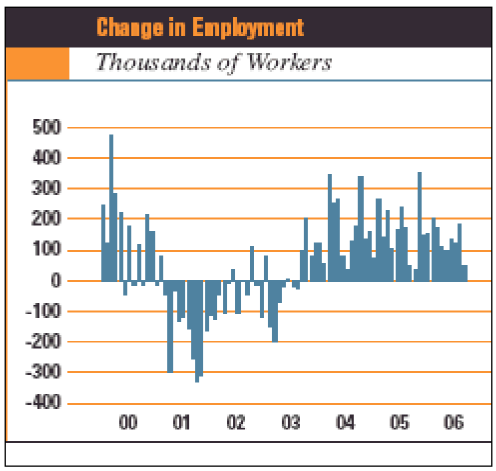
Figure VII-A.1. U.S. petroleum industry employment.[47]

Anecdotal evidence suggests that a significant portion of those who left the industry did not return, due to the challenges presented by industry cyclicality. Stable

[47] API. Reference 2.

employment is increasingly viewed as a requirement, both by experienced workers and students training for future careers.

The Engineering and Construction (E&C) industry also suffers from an image problem due to cyclicality (Figure VII-A.2). While larger firms move resources between industries during market shifts, specialists with non-transferable skills, or employees of smaller firms more dependent on specific markets, may be released. While some of these individuals may seek employment in another firm serving different markets, others frequently choose to become consultants or leave the industry altogether.



Source: McGraw Hill 2007 Construction Outlook

Figure VII-A.2. EPC industry cyclicality.[48]

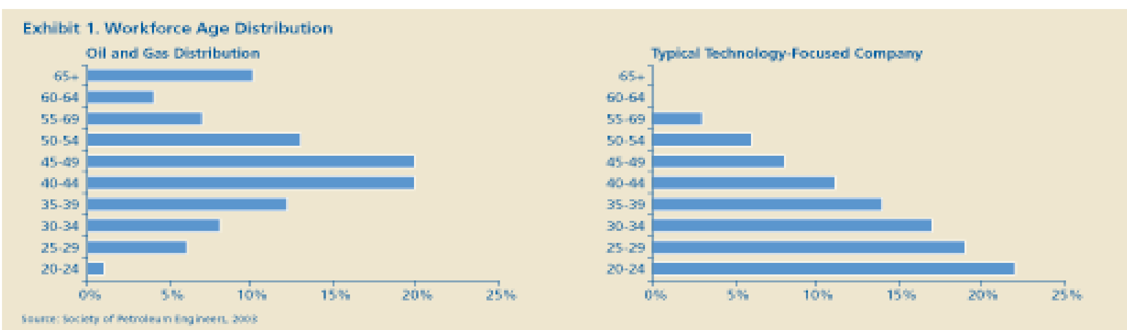
A poor public image is a significant contributor to the industry's inability to attract new employees. Many perceive oil companies to be exploitative of natural resources, while working conditions for construction personnel are often considered dirty and potentially dangerous in comparison with other professions. In addition to instability due to cyclicality, studies have found that construction is perceived as physically strenuous manual labor in an environment exposed to the elements, while being subjected to poor treatment with low pay and lacking a clear career path. A Wall Street Journal survey showed high school-aged vocational students ranked

[48] McGraw Hill, reference 15.

"construction worker" 248th out of 250 as an occupational choice—only "dancer" and "lumberjack" scored lower.[49]

According to a Deloitte study, reasons for decline in enrollment in petroleum engineering university programs include perceptions that the petroleum industry offers short-term jobs vs. careers, few attractive opportunities at junior levels, tenure-based advancement vs. meritocracy, and little work/life balance.[50]

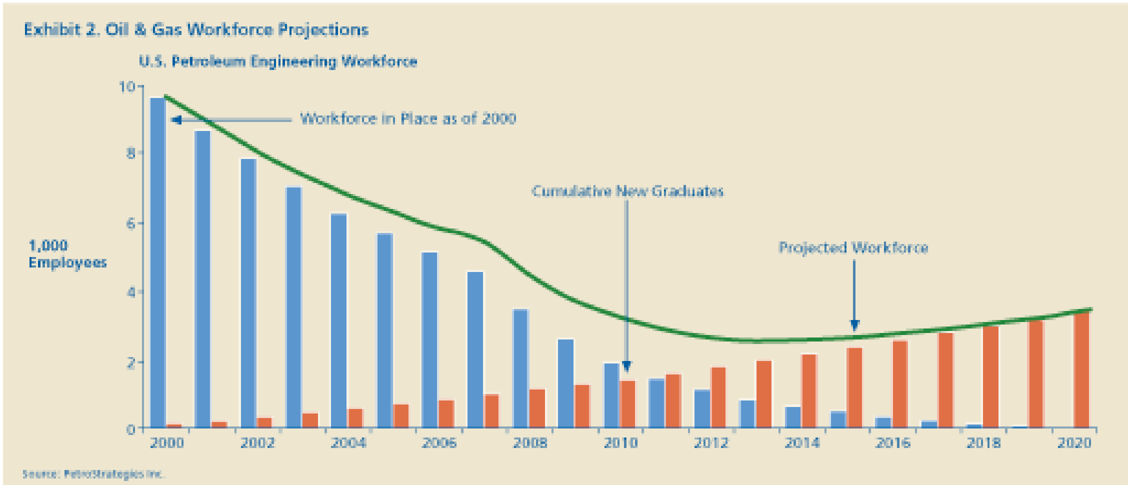
It is important to note that challenges the petroleum and construction industries face in recruiting workers are just one part of a much larger industry-wide shortage of workers. As an example, a NASA study was quoted in a recent report by Deloitte stating that in the USA, colleges will graduate only 198,000 students in the science and engineering fields (5% of undergraduate students) to fill the shoes of two million baby boomers that will retire between 1998 and 2008.[51] This depicts not only an overall shortage, but also a projected change in the demographic makeup of the future working population (Figures VII-A.3 and VII-A.4).



Source: Deloitte, Society of Petroleum Engineers

Figure VII-A.3. Workforce distribution in oil and gas versus a typical technology company.[52]

[49] CareerJournal.com. "We Ask: What Are Some of the Best and Worst Jobs?" (June 14, 2005). http://www.careerjournal.com/salaryhiring/hotissues/20050614-intro1.html.
[50] Sampath and Robinson, reference 3.
[51] Sampath and Robinson, reference 3.
[52] Beyer, reference 20.



Source: Deloitte, Petrostrategies Inc.

Figure VII-A.4. Workforce projections for oil and gas industry.[53]

A recent Engineering & Construction Contracting Association (ECC) presentation diagnosed the industry with a serious image problem.[54] Process industries, which include some of the largest companies in the USA, are generally regarded by public perception as being:

- Unfriendly toward employees, as evidenced by frequent layoffs, coerced early retirements, long work hours, diminished employee benefits, with little effort given to career development and advancement
- Bureaucratic and impersonal with little top-to-bottom communication
- Overly concerned with stock price, too little concerned with employee welfare
- Unconcerned for community, as reflected by environmental, safety, and social issues.

Historically, process-industry companies were viewed as pioneers and innovators. Today, the public sees high gas prices, and unsafe and environmentally unfriendly chemical plants, among other issues. While contractors were previously

[53] Sampath and Robinson, reference 3.
Petrostrategies, Inc., www.petrostrategies.org.
[54] Forman R: "The Ultimate Challenge: Expanding and Replacing Our Engineering and Design Capabilities," Engineering & Construction Contracting Association, The New Seller's Market, San Antonio (September 14, 2006). Available at http://www.ecc-conference.org/38/index.html.

depicted as innovative, creative engineers and bold “can do” constructors, their image has been tarnished by repeated allegations of overcharges on government projects and illegal payments.

B. Future Employment

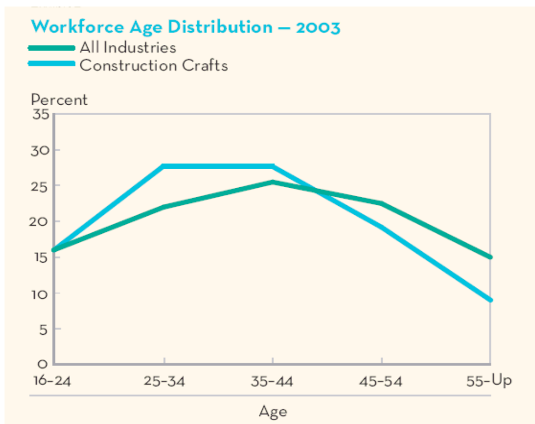
Domestic growth is expected to continue across the construction spectrum, with several nationally focused organizations and think tanks predicting an extended 20 to 25 year investment period in infrastructure and general real estate development. Renovation of existing facilities to meet increasingly stringent environmental standards will also increase demand. This will exert greater pressure on the domestic economy as baby boomers retire and skilled labor for construction and suppliers experiences only moderate growth.

With specific regard to staff, the U.S. Bureau of Labor Statistics (BLS) forecasts that the number of job openings through 2014 for construction managers will exceed the number of qualified individuals seeking to enter the occupation.[55] The increasing complexity of construction projects is boosting the demand for management-level personnel within the industry. Employment of construction managers is expected to increase about as fast as average for all occupations through 2014. An increasing number of graduates in construction-related fields, such as engineering or architecture, are entering construction management after gaining field experience or after completing graduate studies in construction-management or building science. Traditionally, many workers advance to construction-management positions through experience, but as construction processes grow increasingly complex, employers are placing more importance on education. Research indicates that interest in construction-management programs is not a persistent problem, as is the decline in interest of more technically based engineering degrees.

While craft-employment stresses may be mitigated by specific strategies, including automation and the use of remote, modular fabrication, the annual need for

[55] United States Bureau of Labor Statistics (BLS): “BLS Occupational Outlook Handbook, Construction Managers,” Available at http://www.bls.gov/oco/ocos005.htm.

entrants of craft workers into the construction industry will be 185,000 persons, according to the Construction Labor Research Council, as stated in an FMI study.[56] This need will be almost evenly divided between growth and replacement. Numerous sources have noted an expected shortage in skilled labor due to impending retirement of the labor force and lack of new recruits to fill the void. The Construction Labor Research Council states the construction industry in 2005 has more craft workers in their prime working years (25 to 44) compared to other industries, yet these workers tend to leave construction at an earlier age than do their counterparts in other industries (Figure VII-B.1).



Source: FMI, Construction Labor Research Council

Figure VII-B.1. Worforce age distribution.[57]

A Construction Industry Institute (CII) study shows the number of young people entering the construction workforce will continue to decline between 2002 and 2017.[58] Traditionally, only people with a history of experience in construction (through family or friends) seek out construction for a management career. However, due to industry cyclicality, an increasing number of parents who work in construction, for example, are less likely to suggest a career in the industry—or children, seeing parents endure the cyclicality will make the decision on their own.

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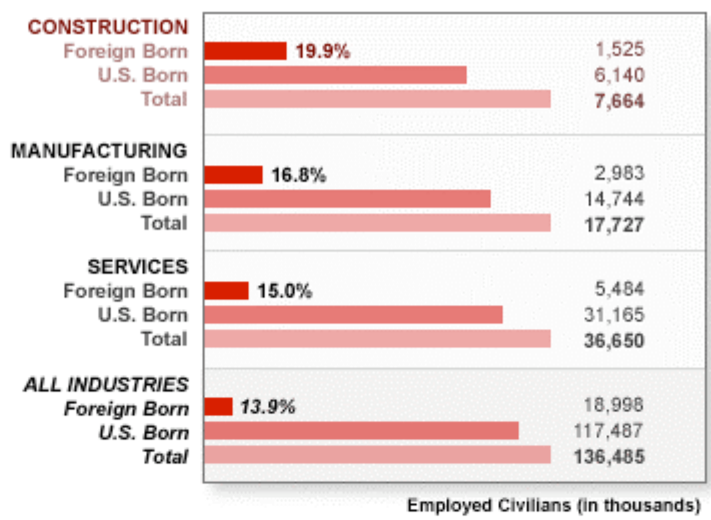
[56] Heimbach et al, reference 4.
[57] Heimbach et al, reference 4.
[58] Heimbach et al, reference 4.

Given the results above, the construction labor shortage is clearly a systemic problem.

C. Domestic versus International Employment

In addition to the domestic overview in Section B, other forces are exerting pressure on the domestic labor situation. The construction industry was the second-largest domestic employer of unauthorized foreign nationals in 2004, employing 17% of the 6.3 million unauthorized workers in the United States. While many of these are craft workers in the residential construction sector, their undocumented status frequently prevents them from "graduating" to positions in other sectors, even for those who master a trade and are comfortable with English.

In general terms, comparing field labor in the United States to international locations, the domestic situation is one of a limited number of candidates, while international sites face a lack of people with the requisite skills (Figure VII-C.1).



Source: Lowesforpros.com, Bureau of Labor Statistics

Figure VII-C.1. Employed civilians in selected fields, U.S. versus foreign.[59]

Following September 11, 2001, U.S. immigration policy changed, making the student visa process more difficult, and effectively discouraging international students

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[59] Lowesforpros.com (http://www.lowesforpros.com).
United States Bureau of Labor Statistics (BLS) (http://www.bls.gov).

from studying in the United States. Because some who study in the USA apply for skilled-labor visas upon graduation and enter the domestic workforce, legislative changes have resulted in fewer foreign nationals with language skills capable of filling staff roles managing multinational teams. This has also reduced the number of individuals in international locations who have been exposed to the methodologies and tools in use by U.S. construction companies.

Internationally, continued growth of developing economies will drive demand for construction labor to meet the needs of expanding industry bases, transportation networks, and increasingly demanding consumers. While general construction labor may be available on a national or regional basis, highly-skilled craft workers and staff will likely continue to be in demand. Labor "portability" is one probable outcome of this situation. Evidence of this can be seen in Figure VII-C.2, which refers to supply and demand applicable in the United States.

Source: FMI, CII

Figure VII-C.2. Construction labor surplus, selected time periods.[60]

D. Technology Influence on Employment

"Intellectual technology" is also influencing the quantity and type of worker sought. Increasingly, computational tools are used to model and simulate facility operation, reducing the amount of labor and rework required. The growing shortage of skilled labor will lead to the implementation of innovative solutions and an increased pace of technology adoption throughout the construction industry to increase productivity. Another anticipated trend is lower cyclicality due to

[60] Heimbach et al, reference 4.

standardization of technology across energy projects, beginning with oil and gas, followed by power and nuclear resurgence.

The increasing use of technology in construction work places additional demands on the level of skills needed among both field craft and staff. Projects demand higher technical competence, also creating a demand for improved training and education. The limited quantity of technically literate construction resources is also expected to exacerbate the inflationary impact of the labor shortage (Table VII-D.1).

Potential Spot Shortages by Occupation

Occupation	Summary of Expected SHORTAGE* Level in 2012	Summary of Expected DEMAND** for New Plus Replacement Workers
Architects		L
Engineers	M	
Civil Engineer		L
Civil Engineering Technician		L
Environmental Engineer		H
First Line Supervisors-Managers		L
Operating Engineers		L
Construction Managers	M	L
Cost Estimators	H	M
Safety Managers	L	
Quality Control Managers	L	
Superintendents	VH	
Foremen	VH	
Project Managers	H	
Middle Management	M	
Senior Management	M	
Carpenters	VH	L
Electricians	H	M
Construction Laborers	M	L
Plumbers, Pipelayers, Pipefitters, and Steamfitters	VH	M
Welders, Cutters, Solderers		H
Painters; Construction and Maintenance	M	L
Heating, AC, Fridge Installer		H
Sheet Metal Workers	H	M
Cement Masons, Concrete Finishers, and Terrazzo Workers	VH	H
Roofers	M	M
Drywall Installers, Ceiling Tile Installers and Tapers	M	M
Brick Masons, Block Masons, Stone Masons	VH	L
Structural Metal, Iron, and Steelworkers	H	M
Carpet Installer		L
Insulation Workers	M	M
Plasterers and Stucco Masons	H	L
Glaziers	M	M
Crane-Tower Operators		L
Paving, Surfacing, and Tamping Equipment Operators	M	L
Boilermakers	VH	M

* For Shortages:
VH 80% or more of the respondents expected moderate or severe shortages
H 70% to 79% of the respondents expected moderate or severe shortages
M 54% to 69% of the respondents expected moderate or severe shortages
L Less than 54% of the respondents expected moderate or severe shortages

** For Demand Increases:
H The demand for replacement and new workers in 2012 represents 45% or more of the 2002 workforce
M The demand for replacement and new workers in 2012 represents between 35% and 45% of the 2002 workforce
L The demand for replacement and new workers in 2012 represents 35% or less of the 2002 workforce

Source: FMI Study of Labor Shortages, U.S. DOL

Table VII-D.1. Potential spot shortages by occupation.[61]

Modularization, or prefabrication, has been used in the past to cope with labor shortages. Streamlining the construction process at the job site allows for quality- and logistics-controlled production of labor-intensive portions of work in controlled environment. This allows skilled labor to work in a centralized location with greater

[61] Heimbech et al, reference 4.

total efficiency, as the resources are not dedicated to a single project but may alternate between projects with no time lost traveling from one dedicated site to another. This also results in lower costs, both in wages and travel, as well as opening the market to specific skilled labor that would resist relocation.

E. Field-Craft Employment

Domestically, the overall number of individuals entering the E&C industry is declining, due to the factors listed above (Figure VII-E.1). At the same time, demand is increasing and large numbers of skilled workers are expected to retire over the near term. Shortages are expected in qualified, skilled labor, both by occupation and by region.

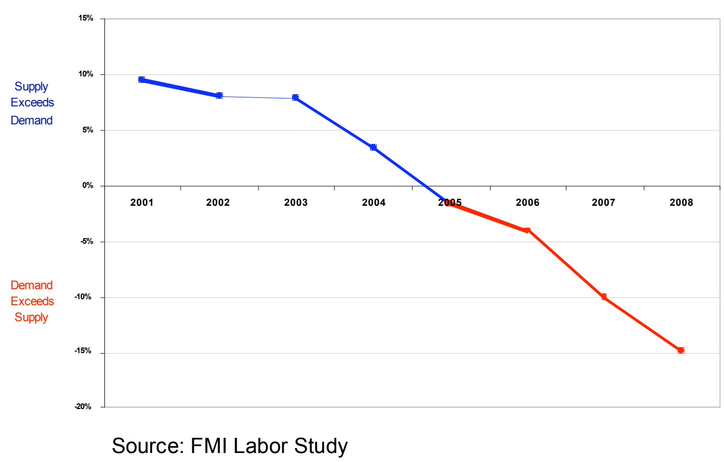

Figure VII-E.1. US craft labor supply versus demand.[62]

According to FMI, the United States entered a period of craft labor scarcity in 2005, with aggregate demand exceeding supply by 2% in 2005 for labor categories including structural ironworkers, rodmen ironworkers, operating engineers, interior and framing carpenters, drywall carpenters, general carpenters, electricians, glaziers, laborers, masons, painters, pipefitters and plumbers, roofers, and sheetmetal workers.[63] This downward trend is expected to continue, growing to a 15% deficit by 2008. The U.S. Bureau of Labor Statistics predicts an aggregate 18.2% growth in

[62] Heimbech et al, reference 4.
[63] Heimbech et al, reference 4.

non-residential construction employment between 2004 and 2014, but only a 3% growth in the combined residential and non-residential construction labor pool (new entries minus those leaving the trades) during the same period, resulting in a 1.5% annual decline.[64]

F. Craft versus Staff Employment

Craft workers are primarily attracted by compensation and benefits, while staff may place emphasis on other considerations such as job security, relocation, and opportunities for advancement, in addition to compensation. Image issues and cyclicality negatively affect entrants of both groups.

G. Other Industry Construction Employment

This picture differs from other industries such as infrastructure and residential construction, which are not seen to have the significant swings that the petroleum industry has. However, competition for resources with these industries will likely increase, with craft shortages expected across all industries (Table VII-H.1). Domestic infrastructure investment and maintenance have not kept pace with growth, having now reached a point where sustained capital expenditure is needed in roads, rail, bridges, transit, aviation, navigable waterways, dams, drinking water, wastewater, the power grid, solid waste, hazardous waste, schools, and public parks and recreation—all categories that received a grade of "C" or below from the American Society of Civil Engineers' 2005 U.S. Infrastructure Report Card.[65] General real estate development is expected to experience strong investment in the 2005 to 2025 period. Finally, competition with maintenance operations will also rise, as petroleum-facility production rates increase, requiring more frequent maintenance.

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[64] U.S. Bureau of Labor Statistics (BLS): "BLS Occupational Outlook Handbook, Construction Laborers." Available at www.bls.gov/oco/ocos248.htm.
[65] American Society of Civil Engineers: *2005 Report Card for America's Infrastructure* (2005). Available at http://www.asce.org/reportcard/2005/index.cfm.

Source: FMI Study of Labor Shortages

Table VII-H.1. Potential spot shortages by occupation and geography.[66]

H. Impact of Location on Employment

Meeting upstream demand will require locating new fossil fuel deposits in increasingly remote or technically demanding locations, then extracting and processing the deposits with increased attention to increasing environmental concerns. Mobility may be a challenge to project execution in rural locations, based on workers' preferences. Given a choice of industries, some construction roles do not require the same mobility as the petroleum industry. It should also be noted that, unlike upstream, downstream jobs are generally not located in remote areas. Because these refineries tend to be within greater proximity to urban areas, the challenges of staffing these projects is less onerous.

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[66] Heimbech et al, reference 4.

Unionization is also an issue, with many unions reticent to significantly expand enrollment in the event of a downturn that could affect membership. This impacts projects through the availability of workers for closed-shop execution. Today, unions represent less than 20% of the workforce, compared with more than a third 50 years ago.

I. U.S. Administration Actions

The U.S. Administration should develop a comprehensive approach to mitigate the risks labor issues pose to both the field construction labor and suppliers' skilled labor. A clear near-term shortfall will grow to have long-term implications for domestic project execution over the next decade, in the absence of intervention. As no change in this trend is anticipated by current projections, it is likely the crisis will continue to exacerbate beyond the ten-year window of most studies.

Results of economic-aid intervention around the world have shown that incentivizing positive behavior produces better results than disincentivizing negative behavior. The United States should focus on providing positive reinforcement and rationale for entering the construction industry.

1. Short-term issues

Several options exist to address short-term labor issues. As much of the domestic residential-construction labor comprises unauthorized workers, recent discussions of immigration reform could have negative impacts on labor availability, should legislators choose to automatically deport undocumented workers. This could create a scarcity in residential construction, driving up wages and increasing competition, primarily for field craft. Conversely, expanding the skilled-labor visa program would open the United States to temporary workers, decreasing the gap between demand and supply and lowering inflationary pressures. This will likely have the greatest impact on craft workers, but documented status will also allow foreign workers to increase skills and "graduate" to higher positions, which they are currently hindered from doing.

A more radical approach would involve establishment of a program targeting occupations of national importance by creating tax incentives for certain employment categories. Such a program could offer larger incentives for those individuals entering the trades during the skills-acquisition period, reducing incentives as workers gain experience and wages increase.

2. Increase attractiveness

In addition to individual tax incentives mentioned above, efforts to increase the awareness of career opportunities in construction would have a positive effect on attracting new entrants to the field.

The administration could also begin to frame the construction industry as vital to the future of the country, raising the visibility of construction. Just as the New Deal public works projects elevated the construction of national infrastructure, much of it still in use today, to a societal imperative, or the Space Race of the 1960s encouraged a substantial increase in engineering graduates, emphasizing the importance of skilled trades in building tomorrow's cities alters the perception of construction as an unattractive, manual occupation. This opens the door for youth who do not pursue a college degree, and with limited career options, to be involved in the remaking of their hometowns and cities.

3. Increase supply

Supply consists of two primary groups—domestic and international labor.

Domestic labor may increase through skills training such as the Vocational and Technical Education for the Future Act, and the Skills to Build America's Future Initiative (similar to the national imperative concept above, but driven by industry and organized labor). Additional funding or tax breaks for university programs and tax incentives for companies to hire and train new employees as compensation for lower productivity of the trainees may also have a positive impact, although these suggestions target organizations rather than the workers themselves. Targeting retiring craft workers to enter university or technical school programs as instructors would help ensure knowledge transfer to the next generation of construction workers.

Further development of programs such as Helmets to Hardhats and nonviolent offender initiatives to offer vocational training to offenders while incarcerated could be expected to increase supply. Other domestic actions include adoption of a nationally-approved construction education system, such as the National Construction Curriculum for craft or a curriculum developed and approved through a collaborative effort led by the government and including industry organizations such as the Construction Industry Institute (CII), Construction Users Roundtable (CURT), Associated Builders and Contractors (ABC), The Associated General Contractors of America (AGC), and The National Center for Construction Education and Research (NCCER).

International labor has, thus far, been excluded from participating in the domestic construction trades. Barriers to labor portability function as tariffs or trade restrictions on services, artificially sustaining higher prices. Should it be proven that efforts to increase domestic supply continue to fall far short of demand, the United States must, as a society devoted to the concept of the free market, increase access to international skilled labor. This would then be a vital mechanism to alleviate inflationary pressures.

VIII. Appendix III: Supplier Capacity Considerations Equipment & Materials—Framing Questions

A. Historical and Current Capacity

The supply base is reluctant to allocate significant investment during the current growth market, expected to last 5 to 7 years, after finding themselves with overcapacity during the decline following expansion during the last growth period. While current shop loads are averaging 70 to 100% of capacity, shop capacity over the last ten years has averaged 60%, leading many suppliers to view today's activity as an opportunity for increased profitability rather than capacity growth.

Commodity	2003 Price Increase (Actual)	2004 Price Increase (Actual)	2005 Price Increase (Actual)	2006 Price Increase (YTD)	2005 Delivery Time (Weeks) (Actual)	2006 Delivery Time (Weeks) (YTD)	Shop Loads
Fabricated Structural Steel	-3%	30-40%	5-10%	10-15%	8-20	26-40	75-100%
Pressure Vessels and Heat Exchangers	2%	12-18%	8-15%	6-12%	24-72	50-160	70-100%
Compressors	1%	5%	6%	5-10%	12-60	30-85	70-100%
Pumps	7%	5%	6%	4-10%	6-60	12-70	75-95%
Pipe Material – Seamless	7%	40-70%	20-30%	10-32%	8-40	20-70	90-100%
Pipe Material – Welded	7%	50-70%	20-30%	10-32%	10-30	20-50	80-100%
Valve Material	2%	6-10%	10%	10-50%	12-36	20-60	60-100%
Control Systems	4%	2-3%	2%	2-16%	2-46	5-40	70-90%
Electrical	1-2%	2-8%	4-10%	8-44%	1-52	1-56	80-100%
Logistics - Domestic	7%	6%	8%	3.5%	N/A	N/A	N/A
Logistics - International	4%	-3%	9%	10%	N/A	N/A	N/A

Source: Fluor Construction & Procurement

Figure VIII-A.1. Historical lead times and shop loads for selected materials [Fluor].

During the low activity of the last decade, industry consolidation through mergers and acquisitions among suppliers was high, resulting in a lower number of suppliers in major materials categories. Rationalization of facilities during this period also contributed to the supply limitations seen today. Merger-and-acquisition activity has also impacted the industry by voiding several long-term contractor-supplier relationships.

Globalization has benefited contractors and clients by lowering equipment and materials costs and by increasing flexibility and efficiency in supply chains, particularly for companies operating in multiple regions. However, execution risks have also increased, due to reasons such as long lead and delivery times, delivery reliability, unforeseen add-on costs such as taxes and import-export charges, unknown supplier performance, lack of quality guarantees, and differences in local laws and regulations that may or may not protect a company to the same degree as when engaging in business in the United States. Rapid growth in developing countries is also increasing demand for construction, introducing greater competition for equipment and material resources.

It should also be noted that, even among finished-good suppliers who are not experiencing labor- or production-capacity issues for their products, many are competing for raw materials with other equipment manufacturers. The current constraints span the raw materials, finished materials, and equipment sectors.

The market has clearly moved to a resource-constrained position. As an example of this shift, when polled at a recent Engineering & Construction Contracting Association (ECC) conference, 93% of owner organizations said they believe we are in a sellers market, compared with 87% of contractors and 78% of suppliers.[67] This includes equipment, for which demand is growing rapidly. According to Equipment World, the top ten purchasers of U.S. equipment grew by double to triple digits in 2005.[68]

B. Future Demand

The International Energy Outlook 2006, published by the Energy Information Administration, forecasts world oil demand to grow from 80 million barrels per day (bpd) in 2003 to 98 million bpd in 2015 and 118 million bpd in 2030.[69]

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[67] Cabano, reference 5.
[68] Menard J: "U.S. Construction Equipment Exports Up 35 Percent," *Equipment World* (March 2, 2006). Available at http://www.equipmentworld.com.
[69] U.S. DOE—Energy Information Administration: *International Energy Outlook 2006* (June 2006).

Until recently, an imbalance between supply and demand similar to today's market was a short-term issue, with decline in demand occurring within a window that allowed the markets to regain equilibrium. The current imbalance, however, augurs a systemic crisis. With global demand rising, sustained domestic demand across diverse sectors, and limited growth in availability of skilled domestic labor to increase production, we could well be at the beginning of an expansion period marked by inflationary pressures spanning raw materials, finished goods, and equipment (Figures VIII-B.1 and VIII-B.2). Because production quality and efficiency are also critical to the success of any supplier or category, the expected shortage of skilled labor in many sectors will magnify the crisis, as end users of the materials and equipment compete with suppliers for talent.

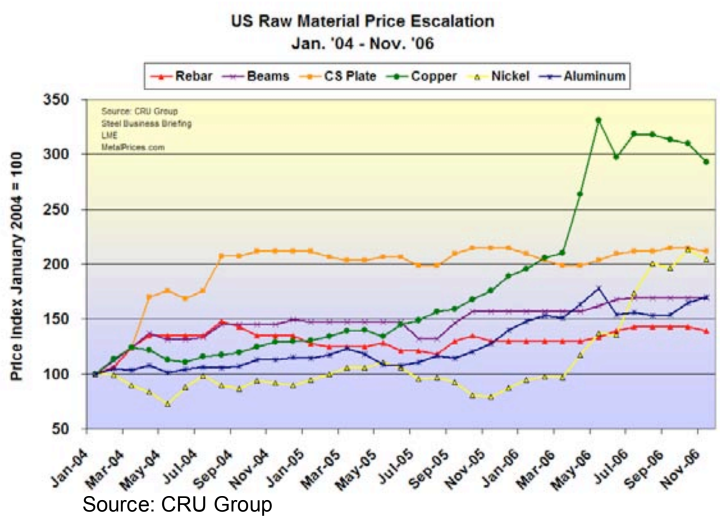

Figure VIII-B.1. U.S. raw-material price escalation from January 2004 through November 2006.[70]

[70] For beams and rebar: CRU Group, see http://www.crugroup.com.
For CS plate: "Steel Business Briefing," see www.steelbb.com,
For copper, nickel, and aluminum: London Metal Exchange, see www.lme.com and www.MetalPrices.com.

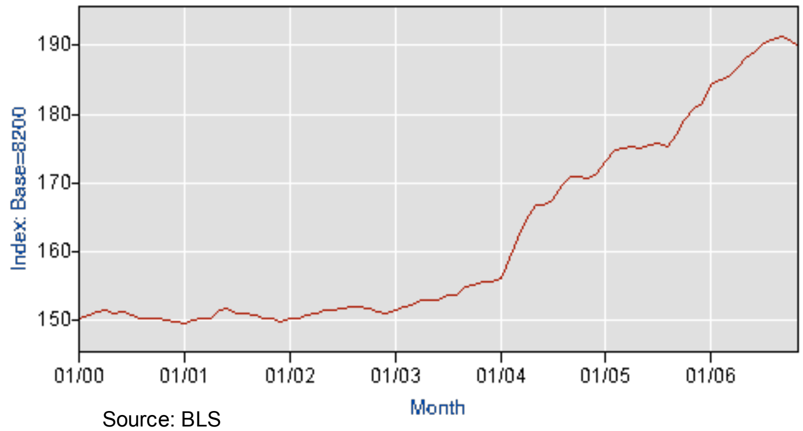

Figure VIII-B.2. Producer price index, materials and components for construction.[71]

The result is that owners and contractors are finding it necessary to order materials and equipment earlier to ensure project schedule viability. Delaying decisions by even a few days can result in months added to the construction cycle. A possible solution to this crisis is staggered end users' procurement. By organizing and prioritizing industry purchases, lead times could be held to reasonable levels and the demand peak maintained at a lower level and expanded over a longer period.

Where supply continues to lag demand, this may initially be due to short-term decisions based on overly-cautious supplier decision making. As the gap develops into a long-term issue, questions arise about how to best attract investment to the mining of raw materials and manufacture of finished goods and equipment. In the energy sector, demand is expected to remain high as it shifts across industries, beginning with the current oil and gas expansion. Growing demand in the generation and distribution of power will come next, followed by an expected resurgence of the nuclear industry. A focus on renewable energy sources and production will be sustained through each of these phases.

Because pressures on the supply chain include equipment and material manufacturers, as well as raw material suppliers, other sectors are facing escalating costs and delivery times due to dependencies on the same basic components as the oil and gas industry. For example, in the USA, FMI Management Consultants estimates

[71] U.S. Bureau of Labor Statistics: "Inputs to Construction Industries," under the Index Number: PCUBCON--BCON, see http://data.bls.gov.

roughly $1.5 trillion will be spent on construction and infrastructure renewal projects in the next five years (highways, bridges, rail, etc).[72] Upgrades are also needed for sewer, wastewater, and mass transit facilities, among others.

Additionally, the global power market will undergo expansion, including within the United States. According to World Energy Council, more than $1 trillion will be invested in non-hydro renewable technologies by 2030.[73] Domestically, increasing demand is anticipated as the power market shifts from oil and gas to electricity from coal facilities, and finally to nuclear.

Other high-demand industries include mining and discrete manufacturing and consumer goods. Finally, continued research and investment in biotechnology and pharmaceuticals will result in demand resurgence. These are concurrent demands that will continue to impact supply and limit excess capacity.

Suppliers differ in their interpretation of future market opportunities, in part because anticipated growth may be in sectors that do not require goods that they produce. Other factors include geographic limitations in the markets served and expectations that new competitors will emerge, particularly in rapidly growing export nations such as China and India, that will alleviate demand pressures and cap pricing growth. However, as mentioned above, many suppliers are highly conservative in business planning because of recent experience with expansions based on market predictions that proved incorrect, leading to widespread overcapacity and business failures. The following subsections are analyses of category forecasts based on supplier feedback and industry expertise.

1. Steel

Steel demand in the near term is expected to be very high, and especially for structural sections and plate, due to the expected increase in non-residential construction activity. Demand for certain classifications are not as strong, such as flats, which has decreased along with automotive sales and efforts to lower auto

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[72] Heimbach et al, reference 4.
[73] World Energy Council: *World Energy in 2006* (2006): 36. Available at http://www.worldenergy.org/wec-geis/global/downloads/wei/wei2006_no_covers.pdf.

weight stemming from higher gasoline prices. Long term, supply is expected to increase as China becomes a global steel producer and India emerges as a global market shaper with projected new capacity and resources depth, outpacing demand and reducing prices.

2. Pressure vessels, heat exchangers, and air coolers

Operating at full capacity with growing raw-material shortages and limited skilled labor, some suppliers have quickly expanded in response to aggressive demand for finished goods. However, a significant percentage of suppliers in this category are proceeding cautiously, evaluating the potential return on investment conservatively. To compensate for skilled-labor scarcity, vendors are utilizing accelerated training schedules, offering higher compensation to attract talent from competitors, or purchasing automated equipment that requires a less skilled labor force. Raw-materials mills are expanding to meet the demand, but full operation of new capacity will require up to four years.

3. Pumps and compressors

Pump and compressor manufacturers report ability to meet increased demand by expanding shift work and investing in capacity once demand warrants the investment, but are limiting capital expenditures until new orders reach a sustained level significantly above existing production capabilities. Both pump and compressor manufacturers forecast a manageable increase over the next decade.

4. Pipe, valves, and fittings

Many piping classifications are experiencing extremely long lead times driven by the supply-demand gap. One group of mills producing large-diameter carbon-steel pipe in the United States, Europe, and Japan is booked for the next year, well above their typical backlog period. Likewise, the power industry's appetite for large-diameter, seamless, low-alloy piping is increasing lead times. Additional capacity will be coming on-line in the near term in the United States, Japan, and China, but is expected to do little more than maintain current lead times as demand growth continues.

5. Electrical

Most electrical manufacturers consider the expected future demand to be a short-term issue and have no plans to expand their production capacity. They feel the issue can be alleviated with escalated pricing and extended lead times.

6. Control systems

Control systems fall into two categories: valves and distributed control systems (DCSs). The long-term issue with control valves remains the casting supply base and the ability to provide volume and quality required by project activity. Despite these pressures, no major expansion or capacity growth is expected in the near future. Short-term DCS issues include quality and availability of semiconductor chipsets and printed control boards for primary manufacturers. Long term, DCS suppliers face limited growth in availability of skilled domestic labor for system design, development, and installation. It is unlikely the availability of semiconductor chipsets and similar computing components will increase, given the dearth of capital investment in the microelectronics sector. The labor component threatens to be much more influential, crippling the category's growth potential, as mentioned earlier in this document.

7. Excavation and construction equipment

The construction equipment market continues to experience unprecedented demand, with availability largely influenced by the supply of steel and tires. Lead times for some vehicles, such as bulldozers and heavy mining trucks, has shown slight improvement, although certain categories still require planning in terms of years rather than months.

C. Domestic versus International Supply and Demand

Domestic growth is expected to continue across the construction spectrum, with several nationally-focused organizations and think tanks predicting an extended 20 to 25 year investment period in infrastructure and general real-estate development. Renovation of existing facilities because of age or to meet increasingly stringent environmental standards will also increase demand. This will exert greater pressure on the domestic economy, as the baby boomers retire and skilled labor for construction and suppliers experiences only moderate growth. During this same period, emerging markets will continue their development, driving demand for materials and equipment higher (Figure VIII-C.1). While unevenly distributed geographically, with regions such as Africa expected to continue to experience lower-than-average economic growth, demand will be greater than average in the two most populous nations, China and India, while also lifted by the aggregate of other expanding economies. Middle Eastern demand will also continue as world consumption of petroleum increases.

A shift in supply is also probable, as China expands manufacturing capacity in an effort to become a net exporter in targeted categories.

Global Construction Expenditures *10 Year Forecast* (in billions of dollars)

	2005	2010 Forecast	2015 Forecast	CAGR
Global	**6570**	**8320**	**10691**	**5.56%**
North America	**1302**	**1415**	**1581**	**2.18%**
U.S.	1075	1158	1278	1.94%
Canada & Mexico	227	257	303	3.26%
Western Europe	**1071**	**1166**	**1284**	**2.04%**
Asia Pacific	**3105**	**4410**	**6205**	**8.00%**
Japan	441	490	535	2.17%
China	1625	2590	3975	10.45%
Other	1039	1330	1695	5.59%
Latin America	**341**	**404**	**481**	**3.90%**
Eastern Europe	**337**	**422**	**528**	**5.12%**
Africa/Middle East	**416**	**503**	**612**	**4.38%**

Source: Freedonia Group

Figure VIII-C.1. Global construction expenditures.[74]

[74] Freedonia Group: "Market Environment—World Cement to 2010:" chart.

D. Technology Influence on Supply Chain

Technology continues to influence the ability of suppliers worldwide to participate in global markets, decreasing time and costs of production, communications, and logistics. The development of lighter materials allows lower logistics costs and has increased the number of locations manufacturers could choose for facilities. Automation technologies have improved efficiency by reducing labor requirements and increasing quality and productivity.

Communications advances, most notably the Internet, have opened global markets and connected suppliers and purchasing agents in even the most remote locations. This tool alone has resulted in expanding lists of available suppliers, as well as increased ability to determine supplier qualifications. The *E-Procurement Benchmark Report*, the fourth report in a series published by Aberdeen Group beginning in 1998, noted a number of improvements across companies' procurement performance based on utilization of e-procurement, including a 36% increase in spend in accordance with company policies and procedures and reduction in maverick spending, and a 75% time reduction and 48% cost reduction in requisition-to-order cycles.[75] Comparing pre- and post-e-procurement snapshots, companies increased spend under management from 40 to 55% and decreased maverick spending from 40 to 25%. During that same period, average requisition-to-order costs dropped by more than $30 (from $63.20 to $32.28) and requisition-to-order cycles decreased by more than 8 days (from 12.4 days to 3.2 days).

Technological progress in radio-frequency identification (RFID), combined with communications improvements, allow real-time tracking of shipments, decreasing loss of materials while enhancing schedule accuracy. Computational and modeling advancements have resulted in maximization of available logistics resources, ensuring high utilization rates and less empty space in transport vehicles.

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[75] Aberdeen Group: *The E-Procurement Benchmark Report* (August 2006).

E. Current Capacity versus Future Demand

Current supplier capacity will not meet future demand. The oil and gas market is expected to reach a plateau within the next 5 to 7 years; however, demand from non-associated industries will continue to grow, especially in advanced developing nations. Supply-side mitigation options require either increased capacity on the part of existing suppliers—which may occur over the broader term as demand remains high—or through the development of new suppliers both domestically and internationally. However, new suppliers must meet the same quality standards of existing manufacturers.

It should be noted that future investment in capacity will be driven by cost per delivered unit—that is, the combined costs of production and logistics. Each category will have its own discrete point of equilibrium along the production-transportation continuum, but the general premise is that suppliers who cannot reduce labor costs through automation and technology will seek locations with the lowest cost of labor for required skills in the closest proximity to the ultimate destination of the product. This means that future investment in many categories will continue the offshoring trend, particularly as growth shifts the locations of projects. Quality surveillance by clients and contractors will become increasingly important, as new suppliers and facilities develop in non-traditional locations.

F. Supply-Chain Vulnerabilities

Should another cataclysmic event occur, such as Hurricane Katrina, that adversely affects domestic refining production, or significant unrest develops in a major oil-producing country, current worldwide demand will hinder recovery efforts because of limited spare capacity among oil and gas suppliers.

Under normal circumstances, supply-chain vulnerabilities will require greater planning for maintenance of oil and gas facilities to ensure the availability of spare parts. Energy-sector expansion of oil, gas, and power will expose weak points in the supply chain, particularly over the next decade. In a broader sense, an increasing percentage of equipment subcomponents are manufactured in countries with neutral, or worse, stances toward the United States. Should a situation arise that negatively affected one of these countries, supply of vital parts could be cut off. The United States must also compete with rising domestic demand in countries that are increasingly important suppliers, such as China and India. Production in these locations could be shifted to support internal needs rather than those of consumer nations, such as the United States.

Logistically, at beginning of 2006, the availability of ships that carry project cargo continues to be of concern. Trends indicate as much as 34% of the current fleet of project cargo vessels will be scrapped during the period from 2006 to 2009. With the upturn in the capital-projects market, a shortage of vessels with a lifting capacity of greater than 700 MT is expected. Currently, there are only 11 of these vessels in the world and indications are that, during the period of late 2007 to 2009, there will be more cargo in this weight range than ships to handle it.

G. U.S. Administration Actions

The U.S. administration must develop a holistic approach to mitigate the material- and equipment-supply risk. This includes a comprehensive policy to encourage trade with developing nations and domestic investment in the industries that support the growth sectors. The location of key suppliers must also be influenced to ensure production of necessary components remains within the U.S. sphere of influence. Encouragement of alternative energy sources and new technologies that lower energy demand and emissions would also be beneficial, reducing the need for new facilities and raising the threshold of discharge that forces existing plants to perform environmental upgrades.

Increased communication between those purchasing materials and equipment could alleviate some of the pressure on suppliers. A national organization that worked to ensure information flow could take a lead in organizing orders, perhaps smoothing demand over a longer period.

1. Short-term issues

Lowering trade barriers and tariffs on necessary materials and equipment would limit price inflation and compensate, at least partially, for the minimal expansion anticipated across the supply base. Expansion of the skilled-worker visa program or establishment of a new program to specifically permit material- and equipment-industry labor to work temporarily in the United States would ensure adequate resource availability for production.

2. Moderate demand

With regard to energy, demand reduction through alternative energy sources could lessen inflationary pressures. For equipment, however, moderating domestic demand would have, at best, only a short-term impact on supply, being offset by anticipated global demand. Further, it may increase the rate of offshoring as domestic facilities relocate to reduce production and logistics costs.

3. Increase supply

Long term, the United States should foster investment in the equipment and materials sectors through incentives at the federal, state, and local levels. Particularly for equipment, these are products that the USA. can continue to competitively manufacture, once logistics costs and time requirements are included in project estimates.

The USA must also maintain an open stance toward international trade, which allows new suppliers to develop internationally, limiting domestic inflationary pressures.

IX. Additional References

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