Paper ID #6180

# Engineering Education in the United States, Quo Vadis?

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# Engineering Education in the United States, Quo Vadis?


## Abstract

How many B.S. graduates in engineering are needed in the United States over the next 20 years? The answer to this seemingly simple question ranges from "as many as we can possibly produce" to "about the same number that are being produced by U.S. universities today". But, forecasting the actual number required is really quite complicated.

There are apparently huge efforts underway across the nation to stimulate the number of students in K-12 who prepare themselves to enter STEM programs in colleges and universities following graduation from high school. But this seems to be an open-ended effort with no targets set for measuring success.

Despite dire warnings from the news media, perhaps there is no problem for industries, governments and service organizations that must acquire the engineering talent needed over the next 20 years, after all. In fact, at the urging of engineering employers in practically all technology economic sectors, the U.S. Congress is debating the liberalization of visa and green card policies for foreign nationals who hold degrees in STEM fields. This solution should pose fewer difficulties in the future in terms of credentialing since ABET is now heavily involved in accrediting engineering programs at foreign universities, and NCEES is dutifully following along after ABET to provide routes to professional licensure in the U.S. for graduates from accredited foreign university programs.

Further, limited resources for engineering education at U.S. colleges and universities could pose fewer problems because of the existence of distance learning technologies, massively open online courses (MOOCs), and financial incentives provided by institutions to faculty members, departments and schools that teach or offer entire engineering degree programs on-line.

So, what does this mean for the engineering educational system in the U.S. – where are we headed (Quo Vadis)? The author is convinced that there are huge policy issues that must be identified, studied and analyzed in order to develop plans for the future of engineering education in the U.S. This paper identifies and discusses some of these issues in an attempt to bring them into sharper focus.


## Introduction

According to a 2011 article in Time magazine[1], "everyone from President Obama to the United States Chamber of Commerce is worried about whether we're producing enough STEM graduates from our colleges and universities." American companies are quite concerned about impending shortages of workers to fill science, technology, engineering and mathematics jobs in the future. Shortages of workers trained in these fields could logically impede the growth of technology, lower competitiveness with other industrialized nations, and thereby exacerbate the decline of the U. S. economy.

Likely, all engineering educators who are at all interested in policy matters have read that China and India are producing from 5 to 10 times the number of engineers per year than are produced in the U.S. However, a Duke University study[2] found that when the data regarding the number of graduates of engineering programs in India and China are carefully parsed, those nations do not count engineering graduates in the same way as it is done in the U.S. Thus, when "apples to apples" comparisons are made, the Duke researchers concluded that there is relative parity among the U.S., China and India regarding the number of engineers graduated per year, at least for the time being.

Further, the Duke study[2] found that there are shortages in specific engineering disciplines, but not overall. It hypothesizes that if there is a shortage of engineers, then the salaries paid to them would have increased more than the rate of inflation over the past two decades, and that is not the case.

The Time article[1] claims that the U.S. has been obsessed with the production of STEM graduates since the 1950's in order to be competitive with the Soviets during the Cold War years.

Meanwhile, Congress is proceeding to enact initiatives designed to stimulate the production of STEM majors through passage of legislation such as the 2007 America Competes Act. This legislation is designed to produce more, and better qualified, teachers in STEM areas for K-12. The idea is that this legislation will lead to more high school graduates ready to enter colleges and universities in the U.S. and prepare for careers in STEM fields.

The NSF and agencies of the federal government are awarding large grants to colleges and universities to build STEM pipelines that will supply the needs of the nation. But this seems to be an open-ended effort with no targets established for measuring success.

And, suppose these stimulative programs are wildly successful and large numbers of qualified high school graduates gain admission to engineering education programs in the near term. Do U.S. colleges and universities have the physical capacity and resources to provide high quality, ABET accredited, engineering education to hordes of students? Engineering educators have surely read studies with the premise that the engineering professoriate has grayed, balded, and retired, or are about to retire (i.e., baby boomers), in record numbers. They have seen reports that, or experienced the brutal reality of, state supported colleges and universities that are essentially now just "state located" because financial support for higher education from the states has declined sharply over the past several years. In fact, it was recently reported that state support for public research universities has fallen by 20 percent between 2002 and 2010, with some universities losing from 30 to 50 percent of their state funding.[3]

It is not easy to assemble the data to estimate the number of engineers that may be needed in the U.S. for the future. In fact, there are so many macro factors that could significantly impact such forecasts that it may be an exercise in futility to even attempt to make them. Nevertheless, given the importance of engineers to the future of the economic advancement of the nation, the U.S. must come to grips with the question of how many engineers are needed, and to establish policies to ensure that this critical demand is met.

Accordingly, colleges and universities must understand and agree to support these policies because it is obvious to those of us engaged in engineering education that the degree “faucet” cannot be turned on immediately if it is determined that a drastic increase in the number of graduates per year is required.

**<u>The Supply Side</u>**

So, what does the supply and demand for engineers look like? On the supply side, we can turn to the ASEE for current and historical data.[4] Figure 1 shows the history of full-time enrollment in engineering bachelor’s degree programs in U.S. colleges and universities from 2002 through 2011.

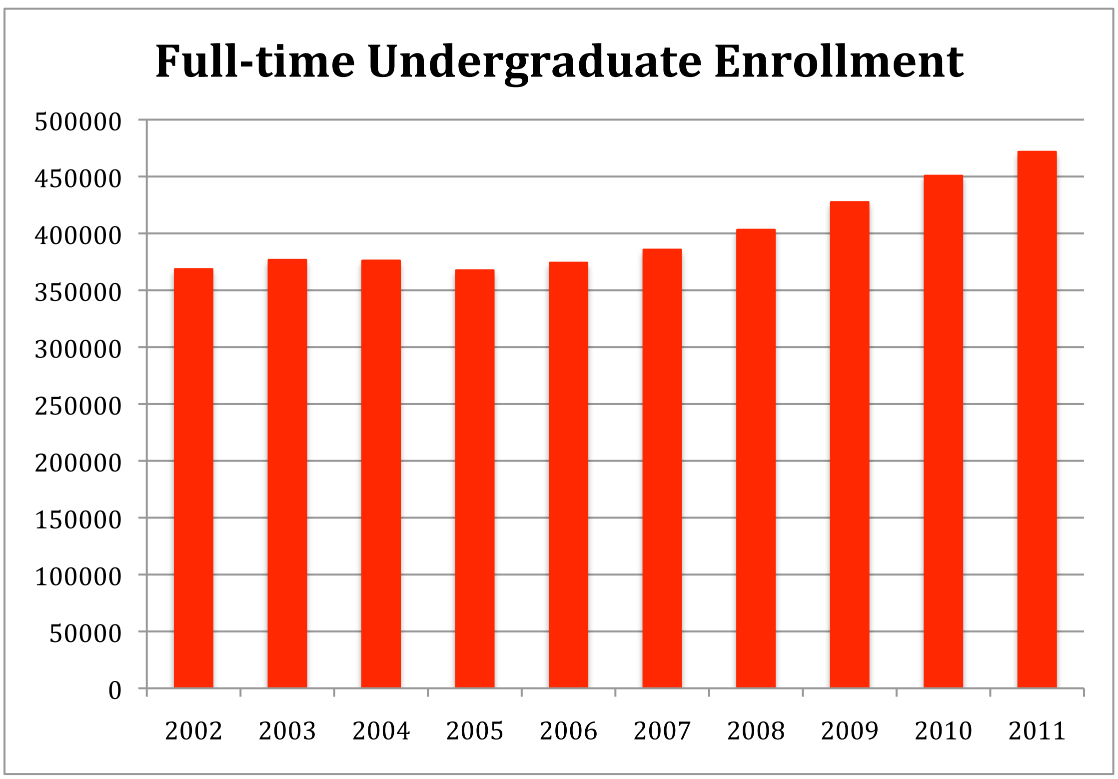


Figure 1. ASEE data for full-time undergraduate engineering enrollments (excluding computer science)

Notice that, contrary to what may be a commonly held belief, at least among some in the popular press, undergraduate enrollments in engineering have steadily increased, rather than decreased, over the six year period from 2006 through 2011, following a modest dip in 2005. The average increase in undergraduate engineering enrollment reported since 2005 has been 4.67% per year. The compounded growth at this average rate per year would amount to the enrollment of approximately 770,000 engineering students in the U.S. between 2012 and 2020.

The percentages of women, blacks and Hispanics enrolled in baccalaureate engineering programs have also continued to increase over time, but are still less than their proportions to the population. The latest ASEE statistics[4] for enrollments in 2011 are shown in Figures 2, 3 and 4 below.

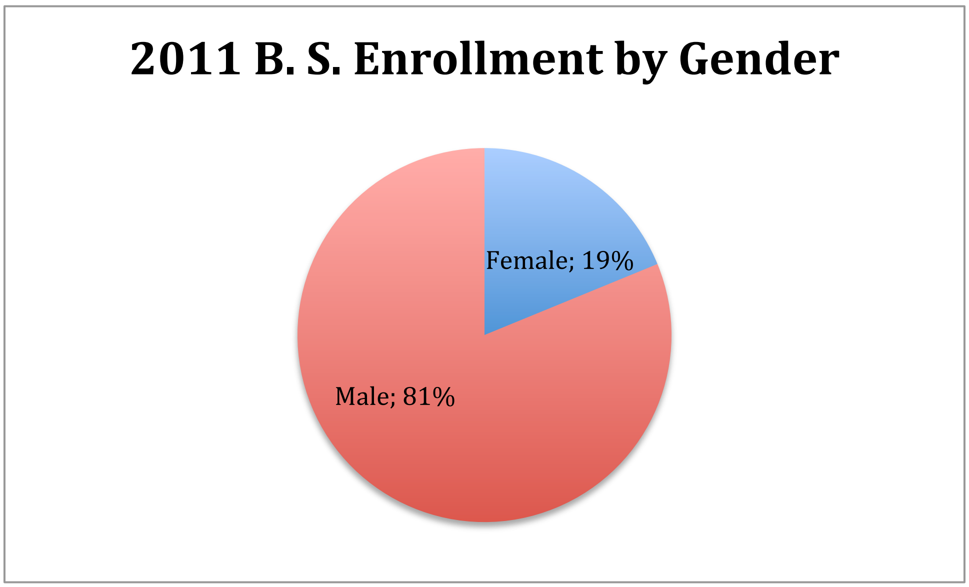


Figure 2. ASEE data for full-time undergraduate engineering enrollment by gender

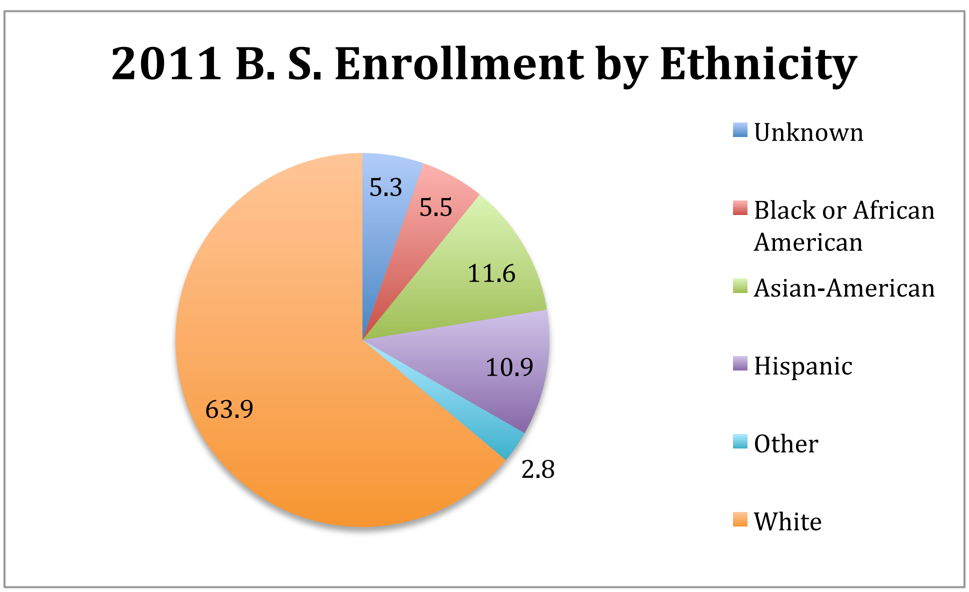


Figure 3. ASEE data for full-time undergraduate engineering enrollment by ethnicity

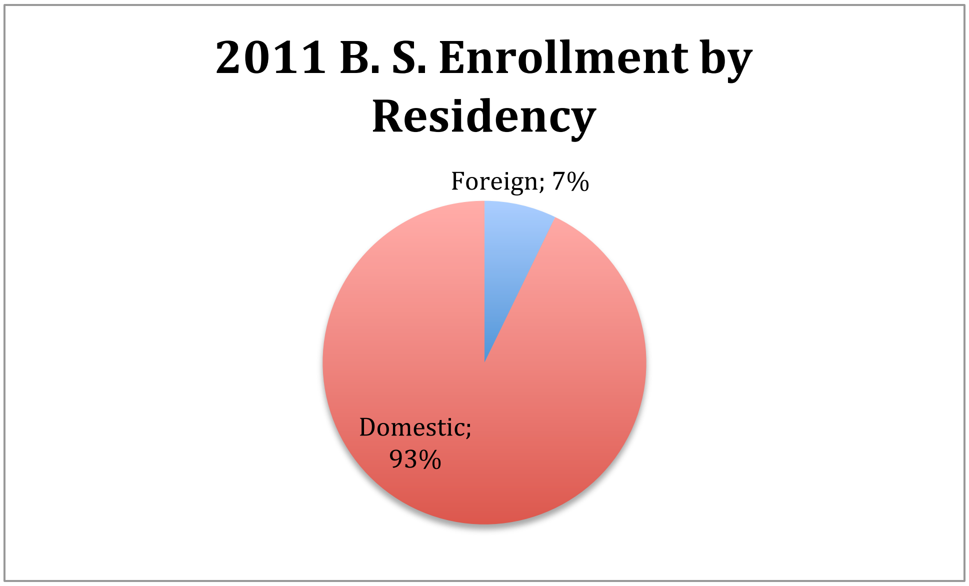


Figure 4. ASEE data for full-time undergraduate engineering enrollment by residency

While it is difficult to find reliable, cumulative, and current data regarding the number of B.S. in engineering graduates from U.S. colleges and universities, the National Science Foundation collects and publishes such data, although the most recent tables only reflect cumulative degree production data from 1966 through 2008[5]. This data is shown in Figure 5 below for the period 2002 through 2008.

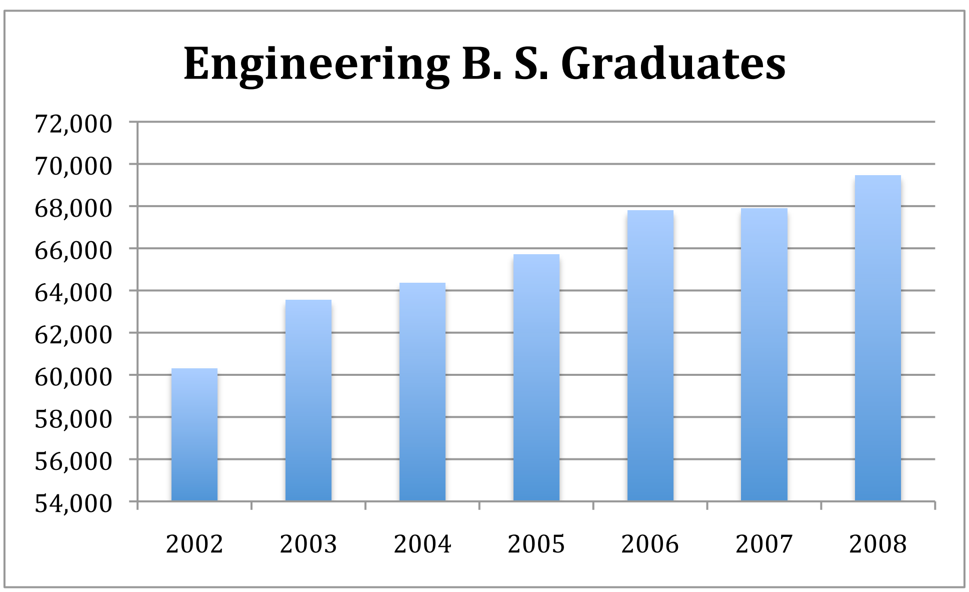


Figure 5. NSF data for the total number of B.S. engineering graduates produced in the U.S. per year (Note: The ordinate scale begins at 54,000 for ease of reading the data and observing the trend, only)

If the data in Figures 1 and 5 are compared for the years 2005 through 2008, the average B.S. in engineering graduation rate is 17.7% of full-time undergraduate enrollment in engineering.

Now, if the average graduation rate of 17.7% per year were used to predict the number of B.S. engineering degrees awarded for 2011 using the ASEE full-time enrollment data, we would expect there to have been 83,496 graduates.

Interestingly, the most recent report from the ASEE[4] states that 83,001 bachelor's degrees were awarded in engineering in 2010-11. Thus, our prediction using the average annual graduation rate of 17.7% of total enrollment is only 0.6% higher than the actual number of B.S. graduates reported by ASEE.

Nevertheless, 83,001 graduates in 2010-11 represents a substantial increase of 19.51% over the B.S. degree production in 2008, as shown in Figure 5, and this is remarkable. Figure 5 shows that the number of B.S. degreed engineers produced from 2002 through 2008 increased by 15.15%, so in just two years, that number has increased by 19.51%!

**The Demand Side**

On the demand side, we can look at the most recent report of the U.S. Department of Labor, Bureau of Labor Statistics (BLS)[6]. The total employed workforce in the U. S. is shown in Figure 6.

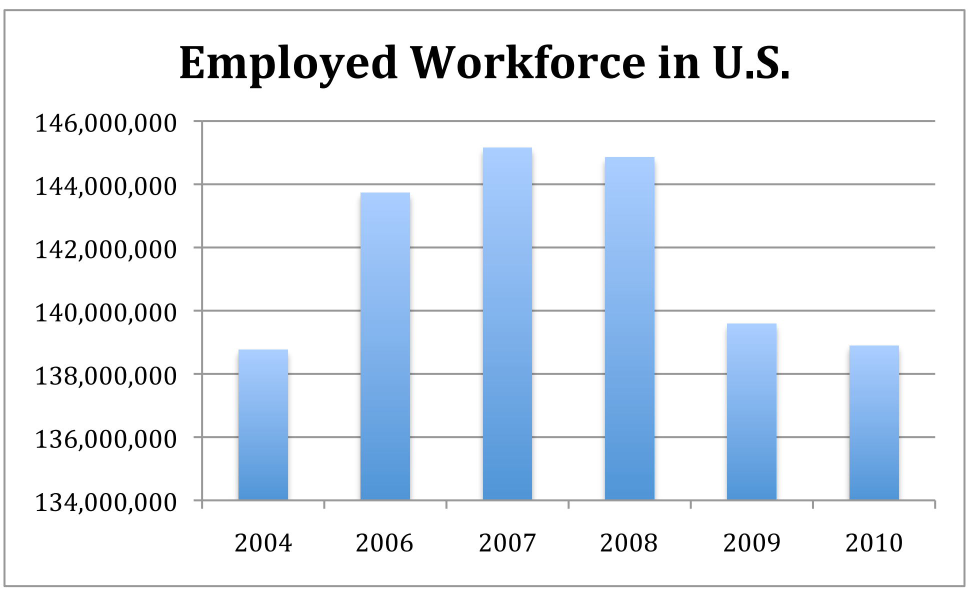


Figure 6. BLS data for the total employed workforce in the U. S. (Note: The ordinate scale begins at 134,000,000 for ease of reading the data and observing the trend, only)

As is commonly, and painfully known to most citizens, the deep recession in the U.S. economy that began in 2008 has had a desultory affect upon the employed workforce in the nation. This is clearly evident in Figure 6.

The total engineering workforce in the U.S. is shown in Figure 7 below. And, it is apparent that the same trend that is illustrated in Figure 6 for the total employed workforce is evident for the engineers employed in the country, as well. In the period 2004 through 2008, there was a steady increase in employed engineers, rising from 1,487,810 in 2004 to 1,626,330 in 2008, a 9.3% increase. This mirrored the rise in the total employed workforce between 2004 and 2007 of 5.02%.

However, beginning in 2007, there has been a decline in the total employed workforce of 4.31% (Fig. 6), and a commensurate decline in the employed engineering workforce of 4.4% since the peak in 2008 (Fig. 7). In other words, the decline in total workforce led the decline in employed engineering workforce from 2007 – 2010.

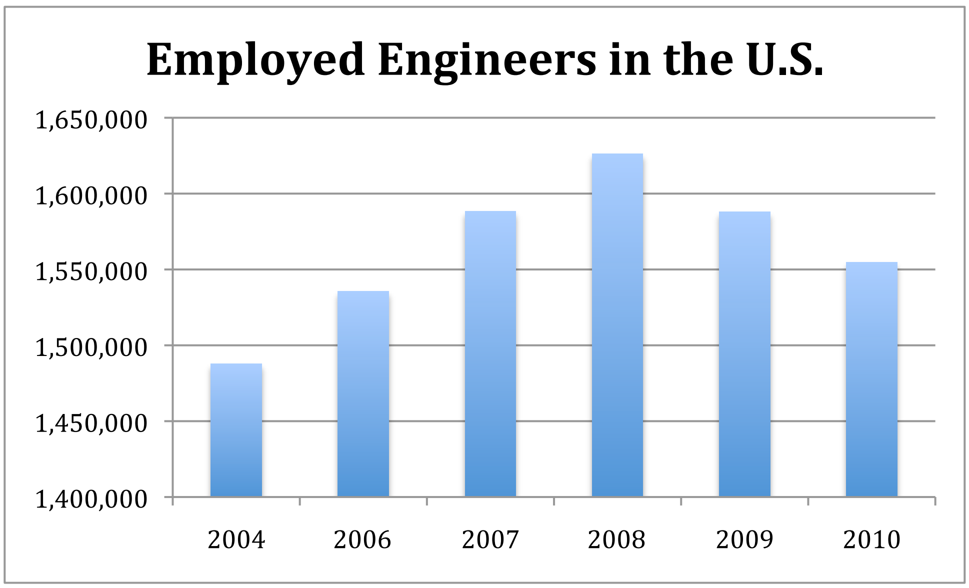


Figure 7. BLS data for the employed engineering workforce in the U. S. (Note: The ordinate scale begins at 1,400,000 for ease of reading the data and observing the trend, only)

The percentage of engineers in the workforce in the U.S., as a percentage of the total employed workforce, is shown in Figure 8 below. From this figure, we see that the percentage of engineers in the total workforce peaked in 2009 at 1.14%, but had declined to 1.12% by 2010. This indicates that engineering employment lags total employment in the U. S. That is, when the total employment declines, it takes from one to two years for engineering employment to show similar declines.

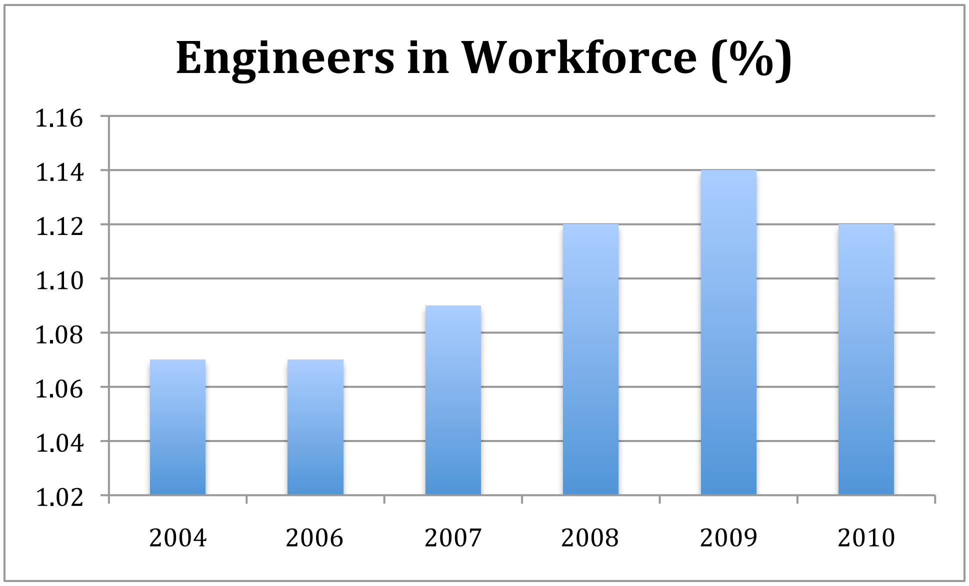


Figure 8. BLS data for the percentage of engineers in the U. S. workforce.

The Bureau of Labor Statistics (BLS) predicts an increase of 11% in total employment between 2010 and 2020 for the architecture and engineering occupational group[17]. The BLS states that much of the employment growth in this group will be due to recovery from the recession. But, as will be indicated later in this paper, this prediction may be counter to that by recent Congressional Budget Office ones.

So, if we begin with the BLS data for 2010 that states there were 1,554,780 engineers employed in the U. S., then by 2020, it is estimated that 1,725,805 will be employed, or just 171,026 more, an average of 17,103 more B.S. engineers per year over ten years.

In 2008, NSF produced its Science and Engineering Indicators report that presented some interesting conclusions that will bear heavily upon policy decisions regarding the number of scientists and engineers needed in the U.S. over the next decade.[7] These are:

- Retirements from the S&E labor force are likely to become more significant over the next decade. Twenty-six percent of all S&E degree holders in the workforce are age 50 or older, and among S&E doctoral degree holders, 40% are age 50 or over. By age 62, half of the S&E degree holders have left full-time employment, with half of doctoral degree holders leaving full-time employment by age 66.
- The importance of foreign-born scientists and engineers in the S&E enterprise in the U. S. continues to increase. Twenty-five percent of all college-educated workers in S&E occupations in 2003 were foreign born, as were 40% of doctoral degree holders in S&E. At least 41% of the foreign-born university educated in the U.S. in 2003 had their highest degree from a foreign educational institution. And, about half of S&E postdocs earned their doctorates outside of the U.S.
- The capability for doing science and engineering work has increased throughout the world. Between 1994 and 2004, R&D employment outside of the U.S. by U.S.

firms increased by 76% compared with a 31% increase in R&D employment by the same firms inside the U.S.

- The percentages of women, blacks and Hispanics in S&E occupations have continued to increase over time, but are still less than their proportions to the total population.

Additionally, the average cost of tuition, room and board at a four-year public school, even after accounting for financial aid, has risen an inflation-adjusted 42% in the past decade, while during this same period inflation-adjusted incomes of middle class families fell.[19] At elite private universities, tuition and required fees for undergraduate students will top $40,000 in 2013. So, we must wonder whether such growth in the cost of higher education in the U.S. is sustainable, and what impact the increased costs of an engineering education will have upon the enrollments and the number of graduates from U.S. institutions per year.

**<u>Observations</u>**

Depending upon the myriad exogenous and endogenous factors leading to economic recovery in the U.S. and the world, it is difficult to predict whether the increases in B.S. engineering program enrollments in the U.S. can be maintained. If the U.S. economy continues to teeter into and out of recession over the next eight to ten years as it has over the past four, the total employed workforce is likely to continue to decline.

The Congressional Budget Office (CBO) has recently released its 2013 economic forecast.[20] Figure 9 from that report shows the total revenues and outlays by the federal government from 1962 through 2013, with a prediction of these quantities through 2023. Notice the wide gap between revenue and expenditure from 2008 through 2012, which has corresponded to the loss of employment shown in Figures 6 and 7. And, although narrowed somewhat, the substantial gap persists in the CBO estimates for 2013 through 2023.

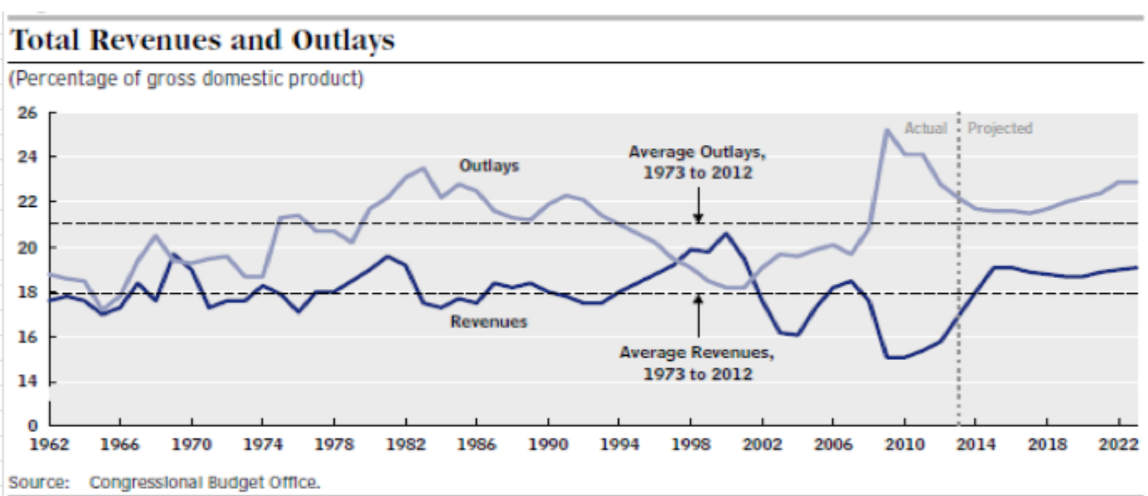


Figure 9. Historical and predicted total revenues and outlays by the U.S. government as a percentage of GDP.

The CBO report also presented data and a forecast of unemployment in the U.S., as shown in Figure 10. It shows that the rate is forecast to plateau at about 8 percent until 2014, decrease rapidly between 2014 and 2016, and then plateau again at just below 6 percent from 2017 through 2023.

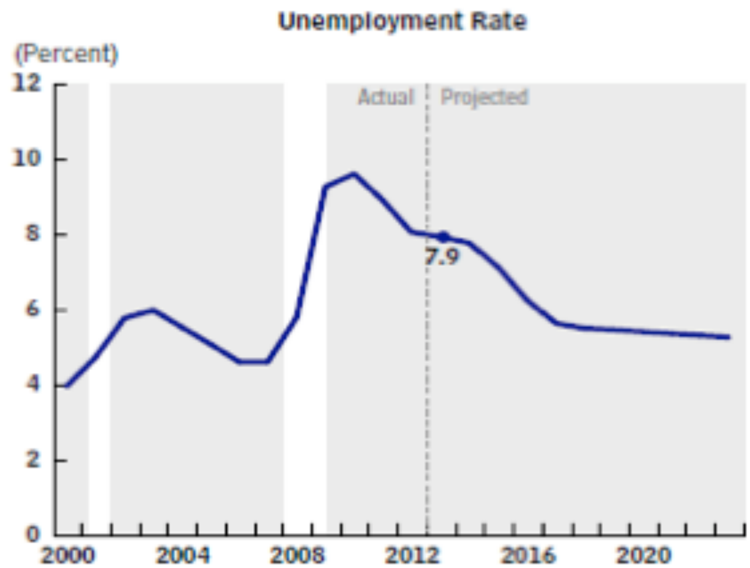


Figure 10. Historical and predicted unemployment rate in the U.S.

If there is a decline in total employment, then there will likely be a decline in employed engineers, as is illustrated in Figures 6 and 7. A decline in the demand for engineers will likely lead to fewer students interested in preparing for careers in engineering. And, this will obviously negatively effect enrollment in engineering programs at U.S. colleges and universities.

Certainly not all of the 80,000 or so B.S. graduates per year will practice engineering upon graduating, nor will they necessarily keep practicing engineering for very long following graduation. Hence, the impact on the economy of increasing numbers of retirements from the engineering labor force will be exacerbated.

Consequently, public policy attention must be paid to maintaining, or increasing, B.S. engineering degree program enrollments. This must be done through stimulating K-12 students to prepare for the study of engineering. More female students, black students and Hispanic students must be encouraged to study engineering. And, more foreign national students must be encouraged to come to the U.S. to study engineering and stay here to work upon completion of their degrees.

There are a number of reports in the news media and technical journals that enrollments in engineering programs in the U.S. are increasing. This is quite likely due to the focus on

STEM programs and other initiatives across the country such as those presented in the next section.

**Influential Initiatives**

Huge efforts are underway across the nation to stimulate the number of students in K-12 who prepare themselves to enter STEM programs in colleges and universities following graduation from high school.

In a sustained effort to blunt the perceived STEM shortage problem for the future, industries, governments and service organizations that must acquire the engineering talent they need over the next ten to twenty years have urged the U.S. Congress to consider liberalizing the visa and green card policies for foreign nationals who hold degrees in STEM fields from U.S. colleges and universities. These organizations have lobbied U.S. policymakers to address the departure from this country of thousands of talented immigrants who cannot obtain permanent residency in the U. S.

On November 30, 2012, it was reported[8] that the U. S. House of Representatives voted to cancel the annual diversity visa lottery and give those immigration visas to foreign-born individuals who earn advanced degrees in high-tech fields from U.S. institutions. This legislation was aimed at increasing the number of visas available to students who graduate from American universities with advanced degrees in STEM subjects by up to 55,000 per year. U.S. technology companies such as Apple, Microsoft, IBM and Hewlett-Packard supported this House action.

However, on December 5, 2012, it was reported[9] that Democrats in the U.S. Senate blocked consideration of the House bill because it would have given resident visas, i.e., 'green cards', to immigrants who obtain masters and doctoral degrees in the STEM fields by eliminating another visa program that benefits less-educated people, particularly those from Africa.

It was reported[10] in November 2012 that approximately 20,000 Chinese students have enrolled in U.S. universities, an increase of 23%. The Chinese call these students "sea turtles" because they go abroad to study in the U.S. then return home with good English skills and a broader cultural perspective in order to get good jobs with western companies.

The NSF has recently announced a cooperative activity with members of the High Tech Education working group of the President's Council on Jobs and Competitiveness, led by Intel and GE. The objective of this initiative is to stimulate comprehensive action at universities and colleges to help increase the annual number of new B.S. graduates in engineering and computer science by 10,000. The "Graduate 10K" initiative especially encourages projects designed to increase retention among women and other groups of traditionally underrepresented student groups that pursue engineering and computer science degrees.[11]

There have also been recent reports in the media that states and universities are initiating steps to address what they perceive as future shortages of engineers and diminishing resources needed to produce more of them.

Purdue University has announced that it plans to hire more than 100 engineering faculty members, and boost enrollment by 10 percent over the next five years.[12] A task force reporting to the governor of Florida has recommended a controversial plan that will allow students enrolled in high demand disciplines like STEM to pay a lower differential tuition than students enrolled in other academic disciplines.[13] Texas A&M University has announced plans for growth of its engineering enrollment to 25,000 students by 2025.[18] Texas A&M currently has more than 11,000 engineering students enrolled, and the announced growth in enrollment will be achieved by transforming engineering education and enhancing curricula through technology-enabled learning as well as an extensive Professor of Practice program that will enable industry leaders to return to the classroom.

Meanwhile, ABET is now heavily involved in accrediting engineering and computer programs in foreign universities.[14] It now accredits 268 programs at 55 institutions in 22 countries outside of the United States, and interest in ABET accreditation is increasing on the part of foreign institutions. Approximately 20% of the visits made by teams from the Engineering Accreditation Commission (EAC) of ABET in 2010 were to review programs in foreign institutions for accreditation.

The National Council of Examiners of Engineers and Surveyors (NCEES) is dutifully following along after ABET to provide the opportunity to sit for the Fundamentals of Engineering (FE) and Professional Engineering (PE) exams to graduates of EAC of ABET accredited foreign university programs. FE and PE examinations are now offered in Canada, the Emirate of Sharjah, Egypt, Japan, South Korea, Saudi Arabia, and Turkey[15]. And, there is a growing interest in making the examinations available to engineering graduates from many other foreign universities.

Although the impacts of ABET accreditation of foreign programs, and graduates from them who pass the NCEES FE and PE exams are certainly unclear at this point, it is not difficult to imagine that foreign graduates who achieve the credentials afforded by these initiatives will gain substantial advantages in seeking employment with U.S. companies or governmental entities that need engineers or computer scientists. This could serve to reduce the number of B.S. engineering graduates needed in the future from U.S. colleges and universities.

A fast growing alternative to using the limited resources available on U.S. college and university campuses is the development and adoption of distance learning technology. Many institutions provide financial incentives to faculty members, departments and schools that teach courses, or offer entire engineering degree programs on-line. Institutions usually charge higher tuition for courses offered on-line. And, there is an expectation among proponents of distance education that fewer “bricks and mortar” facilities on campuses, as well as fewer faculty members, will be required to teach a larger student body and generate more B.S. or master’s degrees in engineering.

And, another initiative just beginning to unfold in higher education is the announcement of partnerships between leading research institutions and private companies to offer free Massive Open Online Courses (MOOC's). The offering of MOOC's is causing controversy in engineering education circles over such issues as maintenance of course quality, cheating on examinations, fraud resulting from people other than enrolled students sitting for exams, accreditation and certification, the counting of MOOC's toward engineering degree program fulfillment at universities that do not originate the courses, and a reported gulf between student enrollment in MOOC's and the number who actually successfully complete them.

ABET is beginning discussions about the accreditation of on-line degree programs. Specifically, if it is possible for students to earn a B.S. degree in engineering on-line, possibly without ever setting foot on a campus, how can the EAC of ABET assess such programs to ensure that the basic and program criteria are met that would warrant accreditation? And, how can on-line students obtain the laboratory experience required by most engineering degree programs?

## Conclusions

So, the crucial policy question is, how many B.S. graduates in engineering are really needed in the United States over the next 20 years? As has been shown in this paper, the answer to this seemingly simple question ranges from "as many as we can possibly produce" to "about the same number that are being produced by U.S. universities today".

The real answer to this question can have a major influence on the economy of the U.S. because inaccurate estimates can alternatively result in shortages of engineers that can lead to the demise of our technological leadership and competitiveness in the world, or to large numbers of unemployed or underemployed engineering graduates.

The mission of the ASEE Public Policy Division (PPD) "is to foster the understanding of policy issues with significant technological components among engineering faculty, students and professionals in government and industry." The author considers the ability to forecast the number of engineering graduates needed in the U.S. over time to be a critical policy issue that should be undertaken by the PPD. This issue is squarely within the PPD mission, and the author proposes that PPD establish a working group to produce an annual forecast of the number of engineering graduates needed over the subsequent five-year period.

It would be wonderful if an econometric index, forecasting function or model could be derived and used to predict the number of engineering graduates that will be required to keep the U.S. economically competitive over time. It is likely that a competitor nation such as the People's Republic of China, whose current and previous two chairmen of the communist party all have degrees in engineering, has such a model.

Dr. Charles Vest, President of the National Academy of Engineering, has said that in the future, American engineers will constitute a smaller and smaller fraction of the profession, as more and more engineers are educated and work in other nations, especially in Asia and South Asia. For the U.S. to succeed, we must discover new scientific knowledge and technological potential through research, and drive sophisticated technological development faster than anyone else.[16]

We in the U.S. are behind in our ability to forecast how many engineers we will need in the future, but one thing is certain: We need to focus on this important public policy issue, now!

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