

ENGINEERING

Overview

The engineering labor force differs markedly from the scientific labor force. This section discusses engineering as a degree and work category, then examines two engineering specialties, electrical engineering and chemical engineering.

The bachelor's degree is the entry-level professional degree and the one held by the vast majority of employed engineers. A master's degree or the 5-year engineer degree is an important credential, unlike most of the sciences where the master's degree is merely a stepping-stone to a Ph.D. or a consolation for not continuing doctorate study.

The six largest engineering specialties, in approximate rank order according to the Bureau of Labor Statistics estimates, are electrical and electronic, with over 500,000 engineers in the labor force and more than 22,000 degrees awarded in 1985, mechanical, civil, industrial, chemical, and aeronautical and aerospace. These specialties include about 80 percent of all engineers.¹¹²

The labor market varies considerably among engineering specialties. The market for electrical engineers may boom, while aerospace engineers are unable to find jobs. Within each engineering specialty, new skills may be in critical demand while others are

112. Estimates of the number of engineers employed in the United States compiled by the two major sources of **labor force** data, the Bureau of Labor Statistics (**BLS**) and the National Science Foundation (**NSF**), differ greatly due to differences in definition and data collection:

| | BLS(1985) | NSF(1986 est.) |
|--------------------|-----------|----------------|
| Electrical | 544,000 | 581,300 |
| Mechanical | 272,000 | 513,700 |
| Civil | 221,000 | 365,700 |
| Industrial | 178,000 | 150,900 |
| Aeronautical | 95,000 | 111,600 |
| Chemical | 64,000 | 163,100 |
| TOTAL ENGINEERS | 1,683,000 | 2,560,600 |

NSF data from National Science Foundation, Science Resources Studies Division, preliminary 1986 data, Table B-1, unpublished data.

outmoded. New specialties, such as materials, bioprocess, or computer engineering, often emerge as offshoots of a traditional specialty and fall between the cracks of existing data collection, making it difficult to track their progress.

^t Industrial requirements for engineers change rapidly to take advantage of new technologies or to match swings in production. To satisfy this changing demand, education of new engineers is complemented by retraining and migration (field mobility). Much of this migration occurs within the engineering population, as a growing engineering specialty draws upon others and changes the distribution among specialties. Market forces are particularly influential in the career choice of young engineers. There is a relatively stable total pool of engineers.

Education/Supply of Engineers

- Together with computer science, engineering has been the fastest growing area of study since the early 1970s. But growth has slowed as the job market settles from boom into slower growth and as the supply of 18-year-olds starts downward. The largest increase has been in bachelor% awards, which doubled between 1975 and 1985 from 38,000 to over 77,000.¹¹³ During that same period, average growth in bachelor% awards in all fields was less than 20 percent.
- Engineering bachelor's graduates nearly doubled their share of all bachelor's degrees between 1975 and 1985, from 4.5 percent to 8 percent. The years 1984-85 mark a turning point in engineering: the slowdown in bachelor% degrees and the upswing in Ph.D.s. Master's awards continue their steady climb.

113. Engineering Manpower Commissions Engineering and Technology Degrees (Washington, DC: American Association of Engineering Societies, published annually). Unless otherwise noted, engineering degree data are from the Engineering Manpower Commission. The Commission data at all degree levels tend to be slightly higher than data reported by the National Research Council and the U.S. Department of Education's National Center for Statistics, but follow a similar pattern.

- The unprecedented surge in undergraduate engineering enrollments of the 1970s is settling down as college students respond to the downturn in the job market, particularly in the electronics and computer industries. Freshman enrollment started down in 1983.
- Projections based on current undergraduate enrollment levels, coupled with the declining college age population, indicate a substantial decline in the number of bachelor's engineering awards in the late 1980s, down from the 77,000 awarded in 1985 to 70,000-72,000 in 1989; the trend is expected to continue downward through the 1990s.¹¹⁴
- Engineering Ph.D.s, like the sciences, peaked in 1970-72 and then declined rapidly. The substantial decline in engineering Ph.D. awards relative to bachelor's awards in the 1970s testifies to the powerful influence of the attractive job market for bachelor's and master's level engineers.
- Over the past 3 years, engineering doctorate awards have increased and regained their 1975 level. Slightly over 3,100 engineering Ph.D.s were awarded in 1985.¹¹⁵ Graduate enrollments have been rising since 1978, signaling a continuing increase in engineering Ph.D. awards at least into the early 1990s, up to about 4,000.
- Very few engineering students undertake postdoctoral study. There are currently about 1,200 postdoctoral students, over 60 percent of whom are foreign.

114. Commission on Professionals in Science and Technology, Washington, DC, unpublished data. Enrollment and degree data are from the U.S. Department of Education, National Center for Statistics; freshmen intentions from Cooperative Institutional Research Program, The American Freshman: National Norms for Fall, 1985 (Los Angeles, CA: Higher Education Research Institute, December 1985).

115. The National Research Council reported 3,165 engineering Ph.D.s in 1985; Engineering Manpower Commission reported 3,383. National Research Council, Office of the Scientific and Engineering Personnel, unpublished data from annual survey of doctorate recipients from United States universities, and Engineering Manpower Commission, Engineering and Technology Degrees, op. cit.

Employment/Demand for Engineers

- Engineering has been one of the fastest growing occupations in the 1980s.¹¹⁶ In 1986, there were 2,560,600 engineers employed in the United States. Over 90 percent are employed in science and engineering (S/E) positions. Women make up slightly more than 3 percent of the engineering S/E work force. Only about 3 percent of employed engineers hold doctorates. About 80 percent of S/E employed engineers work in business/industry.¹¹⁷
- The labor market for an engineering specialty largely depends upon the diversity of the labor market and the economic health of key industry employers. For example, only one-third of chemical engineers work in the chemical industry, while three-quarters of aerospace engineers work in the aircraft industry.¹¹⁸ Mechanical engineers work in a variety of settings, and seem able to weather business cycles by shifting to related jobs. Demand for more petroleum or nuclear engineers, on the other hand, rides the roller coaster of the energy and resource industries which dominate their market.
- Universities and colleges trying to hire faculty to handle high undergraduate enrollments face a continuing shortage of Ph.D. engineers interested in academic positions, particularly in electrical and computer engineering. Universities and colleges employ only 4 percent of all engineers, but about one-third of doctorate engineers.

Engineering Technicians and Technologists

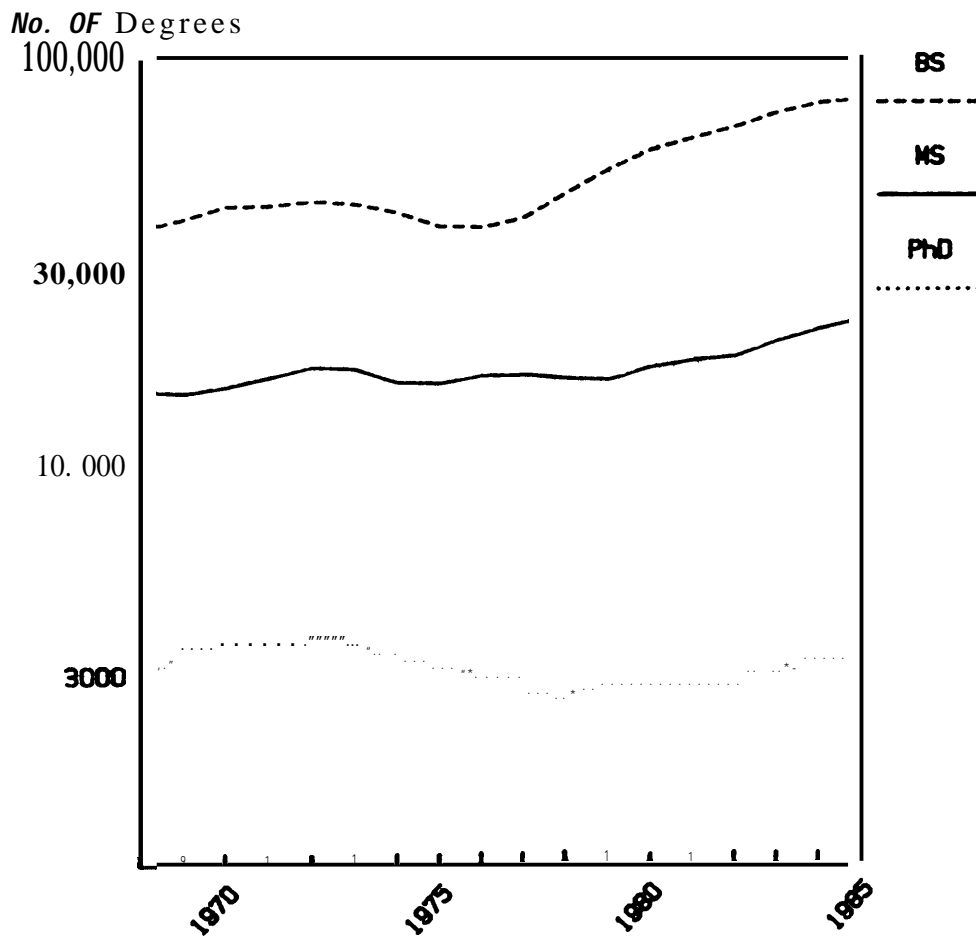
- Engineering technicians are an important part of the engineering labor force and a source of new engineers through mobility and training.

116. National Science Board, Science Indicators: The 1985 Report, NSB 85-1 (Washington, DC: National Science Foundation, 1985), p. 56.

117. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Tables B-1, B-11, B-13, unpublished data.

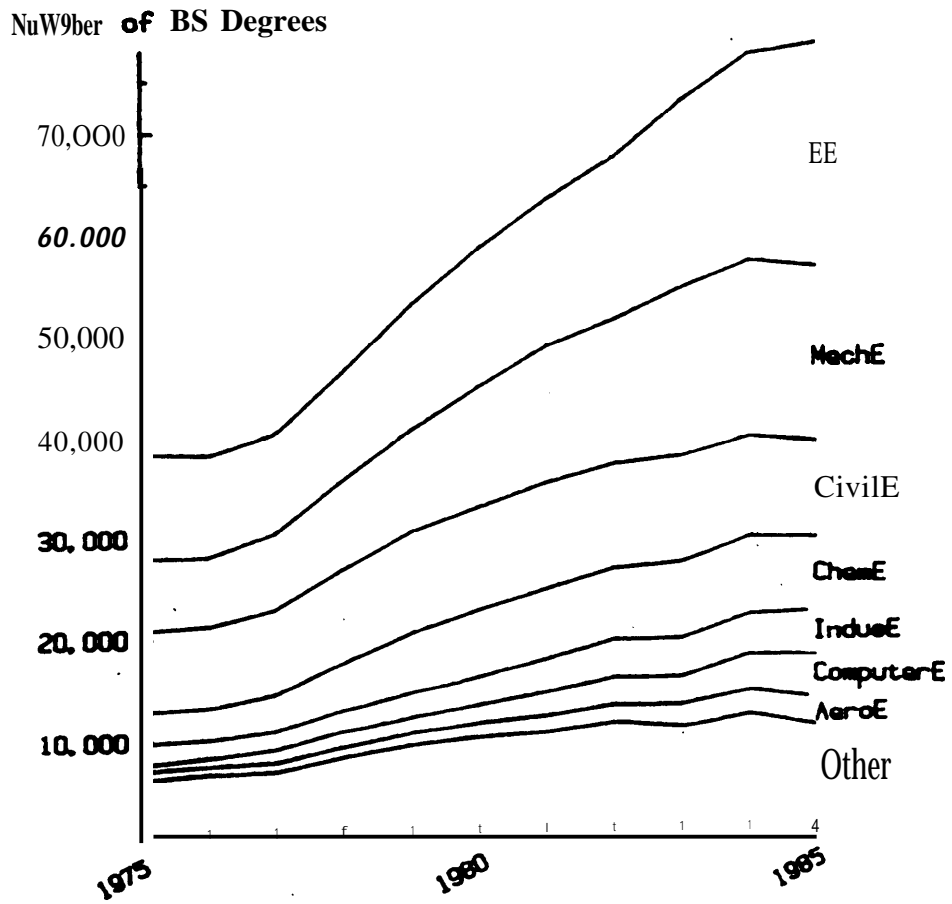
118. National Science Board, *op. cit.*, p. 57.

Total Engineering Degrees. 1968-1985 ES, MS. and PhD

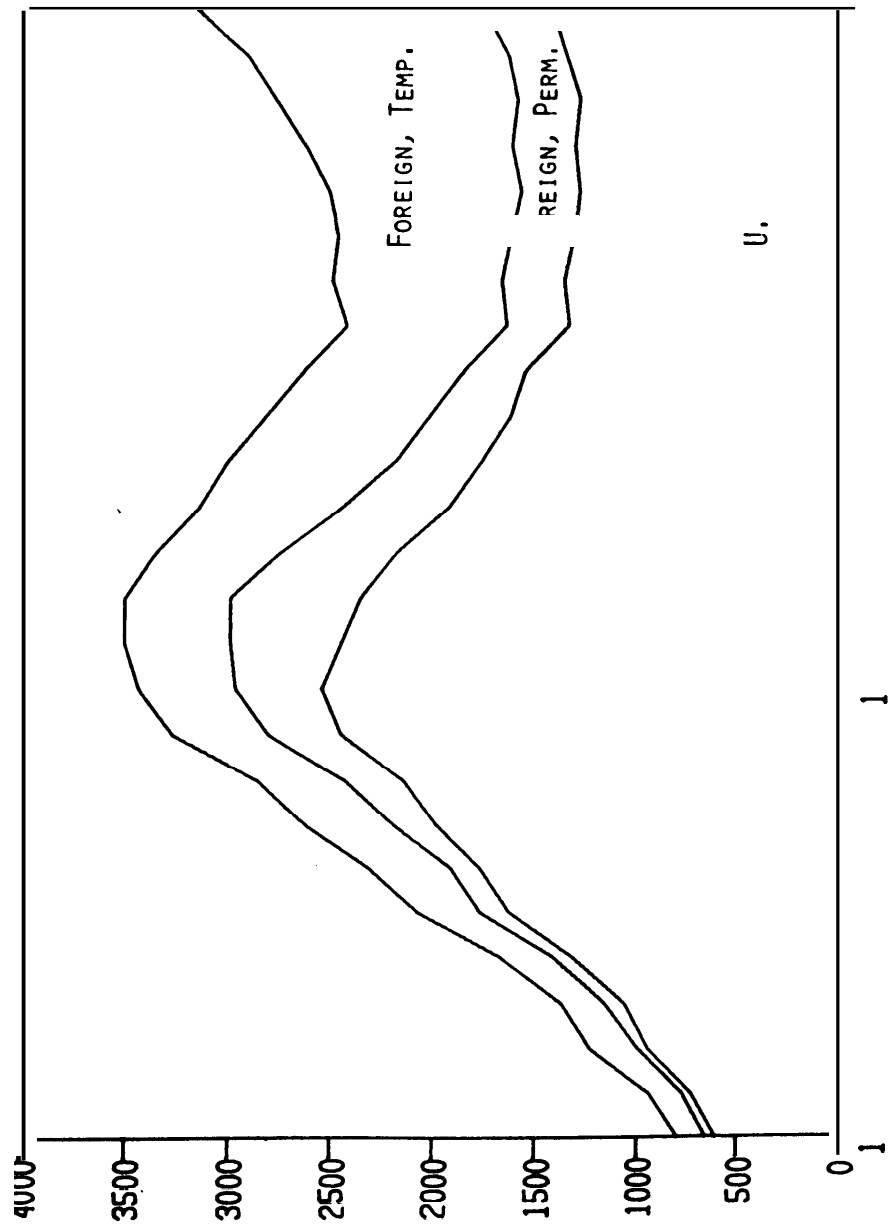


Source: Engineering Manpower Commission

BS Degrees in Engineering 1975-1985



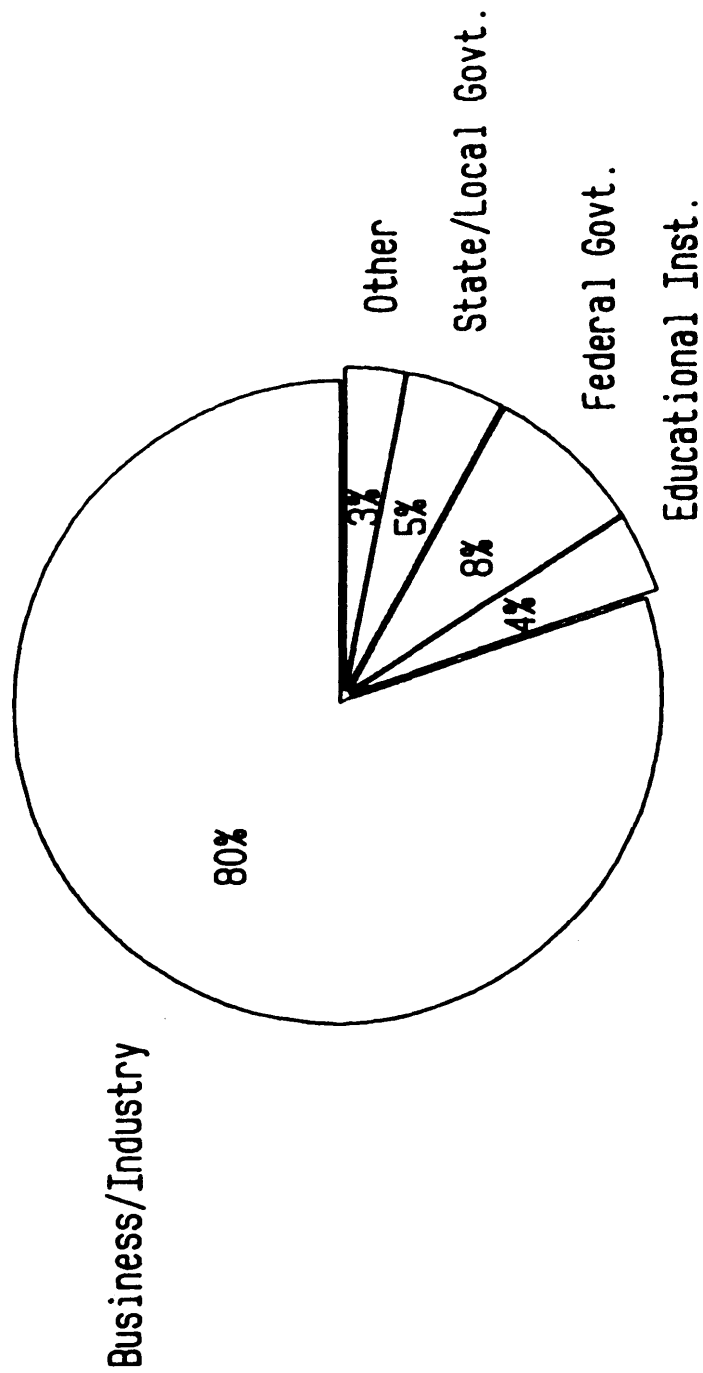
Source: Engineering Manpower Commission



* INCLUDES UNKNOWN CITIZENSHIP

SOURCE: NATIONAL RESEARCH COUNCIL

Where All Engineers' Work, 19



*ALL DEGREES

SOURCE: NA ONAL ENC FOUNDATION

- There are approximately one million engineering technicians.¹¹⁹ A minority are trained in 2-year and 4-year specialized engineering technician and technology programs (about 12,000 4-year bachelor% degrees and 14,000 to 20,000 2-year associate degrees were awarded in engineering technology in 1984).¹²⁰
- Electronics and electrical technicians are by far the largest category, about 40 percent of engineering technicians and technician level degrees.¹²¹

Foreign Nationals

- The influx of foreign students is particularly apparent in engineering. Over 40 percent of recent engineering Ph.D.s have been awarded to foreign students on temporary visas (over 50 percent including those on permanent visas), up from 30 percent in 1975.¹²²
- Forty-two percent of full-time graduate students in Ph.D.-granting institutions are foreign.¹²³ (They are 30 percent of all graduate students, as they are much more likely than the U.S. students to study full-time and to continue on for a Ph.D.). Foreign students have received a steady 7 to 9 percent of bachelor's engineering degrees since the mid-1970s. Their share of master% degrees increased slightly during the 1970s to 25-28 percent, which has held steady since 1980. Foreign

119. Betty M. **Vetter** and Eleanor L. **Babco**, Professional Women and Minorities: A Manpower Data Resource Service, 5th ed. (Washington, DC: Scientific Manpower Commission, August 1984), p. 198, Table 7-31.

120. *Ibid.*, p. 192, Table 7-25. Unpublished data for 1984 furnished by Betty **Vetter**.

121. Estimates of engineering technician population provided by Betty **Vetter**, Scientific Manpower Commission, based on the Bureau of Labor Statistics data and the Engineering Manpower Commission's Engineering and Technology Degrees series. **Vetter** estimates 384,000 electrical/electronic technicians out of 984,000 total in 1985. Department of Education% National Center for Science unpublished data on engineering technology/technician degrees is significantly higher than Engineering Manpower Commission data.

122. National Science Foundation, Science and Engineering Doctorates: 1960-82, *op. cit.*, pp. 30-31, 42-43, Table 2.

123. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, *op. cit.*, p. 28, Table A-9.

engineering students are particularly important at the graduate level due to the paucity of American graduate students.

- The high demand for engineers has made it easier for foreign students to study and work in the United States. In particular, the shortage of academic engineering faculty has made university and college departments particularly dependent on foreign Ph.D.s.
- About half of foreign engineers (at all degree levels) stay on to work in the United States, after graduation. When those with permanent visas are included, the percentage rises to over 60 percent.¹²⁴ Foreign engineering students are much more likely to hold temporary visas than foreign science students; all of the increase in engineering Ph.D. awards has been due to foreign students on temporary visas.
- About 70 percent of the foreign students who receive engineering Ph.D.s are Asian,¹²⁵ and over 90 percent of Asian-American Ph.D. scientists and engineers are foreign born.¹²⁶

Women and Minorities

- Women have shared in the engineering boom but their enrollment and degree-taking is now leveling off after a decade of rapid growth. [In 1985, women received 6 percent of engineering Ph.D.s, 11 percent of master's degrees, and 15 percent of bachelor's degrees.

124. Oak Ridge Associated Universities, Labor and Policy Studies Program, Foreign National Scientists and Engineers in the Labor Force, 1972-1982, op. cit., p. 5.

125. National Science Foundation, Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook, op. cit., p. xiii.

126. National Research Council, Office of Scientific and Engineering Personnel, unpublished data from 1985 survey of doctorate recipients from U.S. universities.

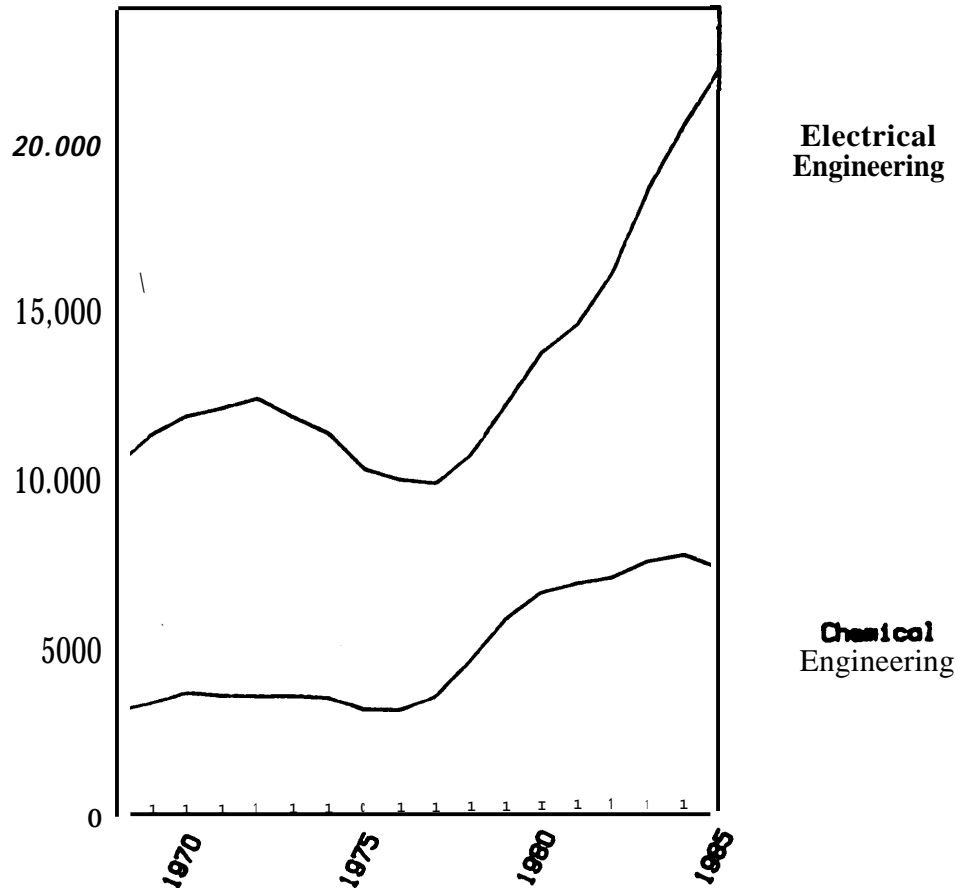
- Women make up 3-6 percent of the engineering labor force. **127 women engineers** tend to concentrate in certain subfields, particularly chemical, petroleum, and industrial engineering, and are less likely to choose electrical and computer engineering. Their greatest increase has been in mechanical engineering.
- The slow inroads of blacks and Hispanics into engineering have stalled. The attrition rate for blacks and Hispanics in engineering is much higher than for whites or Asians; about half of Hispanics and just one-third of blacks among engineering freshmen successfully complete an undergraduate engineering program, compared to an average for all freshmen of 70 percent.
- Blacks are about 2 percent of all employed **engineers**.¹²⁸ Together, blacks, Hispanics, and Native Americans are about 5 percent of engineers. Asian-Americans are an additional 7 percent.
- Minorities in engineering are particularly underrepresented at the Ph.D. level in comparison to the sciences. Between 1958 and 1983, blacks received 0.5 percent of engineering Ph.D.s. Of 1985 bachelor's engineering degrees, less than 3 percent went to blacks, and less than 4 percent to Hispanics and over 5 percent to Asians.
- Asians are doing well in engineering. They received over 5 percent of the bachelor's and over 7 percent of the Ph.D. degrees awarded in engineering in 1985. Most of these degree recipients, however, are foreign-born Asian immigrants.

127. The National Science Foundation estimates 3.3 percent in 1984, the Bureau of Labor Statistics reports 6.7 percent in 1985. National Science Foundation, U.S. Scientists and Engineers: 1984, op. cit., p. 37, Table B-1.

128. National Science Foundation estimates 1.8 percent in 1986, the Bureau of Labor Statistics reports 2.6 percent in 1985. *ibid.*, p. 42, Table B-2.

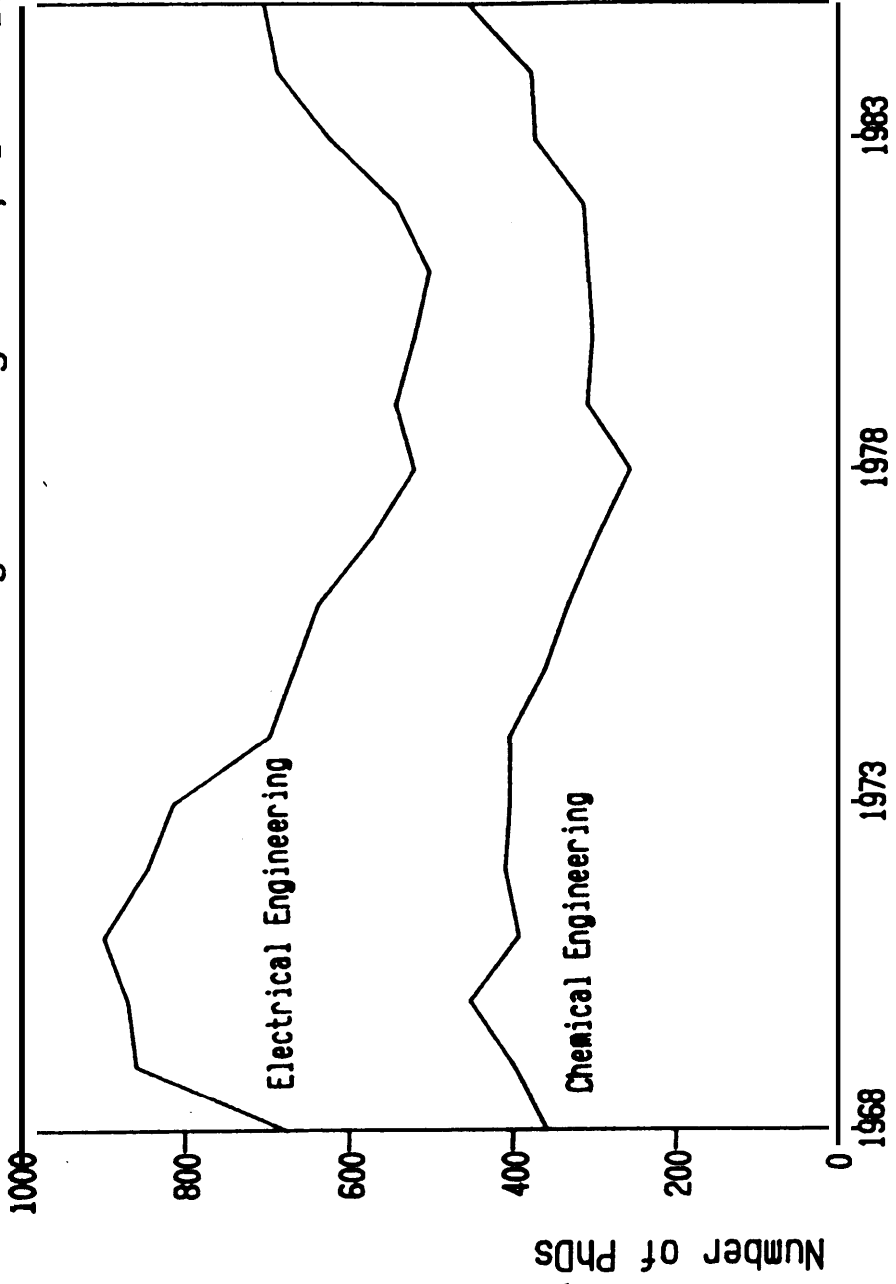
Engineering ES Degrees, 1968-1985

No. of BS Degrees



Source Engineering Commission

Electrical & Chemical Engineering Ph.D. 1968-1985



SOURCE: ENGINEERING MANPOWER COMMISSION

CHEMICAL ENGINEERING

Supply and Demand

- There are 64,000 to 163,000 chemical engineers employed in the United States. Of these, over 90 percent, are employed in S/E positions. Women make up about 7 percent of the chemical engineering S/E work force. Over 90 percent of the S/E chemical engineers work in business and industry, mostly in industries related to chemical production and petroleum refining.¹²⁹ Consequently, the job market fluctuates with the business cycles of the petroleum industry.
- Currently there is an excess of chemical engineers, particularly at the bachelor% level, where unemployment is among the highest for recently graduated engineers. Changes in industry research and development (R&D) priorities have generated the current surplus of petrochemical engineers and shortage of biochemical/bioprocess engineers.
- Undergraduate interest in chemical engineering tracks the current job market, with a 4-year lag in degrees. The 7,300 bachelor% degrees awarded in 1985 is down from 1984, following a steady increase through the 1970s and early 1980s. Master's degrees were awarded to 1,600 in 1985, continuing a slow increase. Ph.D. awards have increased slowly since 1980, to 460 in 1985. Dauffenbach and Fiorito project a small rise in chemical engineering bachelor% degrees by 1995, and faster increases in master's and Ph.D. degrees.¹³⁰
- Chemical engineers (and petroleum engineers) are twice as likely as other engineers to go on for a Ph.D. and are the most likely to do postdoctoral research. This may

129. The Bureau of Labor Statistics reported 64,000 chemical engineers in 1985; the National Science Foundation estimates 163,100 chemical engineers employed in the United States for 1986. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Tables B-1 and B-13, unpublished data.

130. Robert C. Dauffenbach and Jack Fiorito, The Engineering Degree Conferral Process: Analysis, Monitoring, and Projections (Washington, DC: Engineering Manpower Commission, November 1984), p. 58, Table IV-1.

in part be due to the relatively more R&D-intensive, centralized structure of the chemical industry, their major employer.

- There are about 7,000 employed Ph.D. chemical engineers, about 40 percent in R&D. They and petroleum engineers are the highest paid engineers. Most Ph.D.s still go into industry rather than academia— two-thirds are in industry, one-quarter in universities and colleges, 3 percent in nonprofit institutions, and 2.5 percent Federally employed.¹³¹

Women, Minorities, and Foreign Nationals

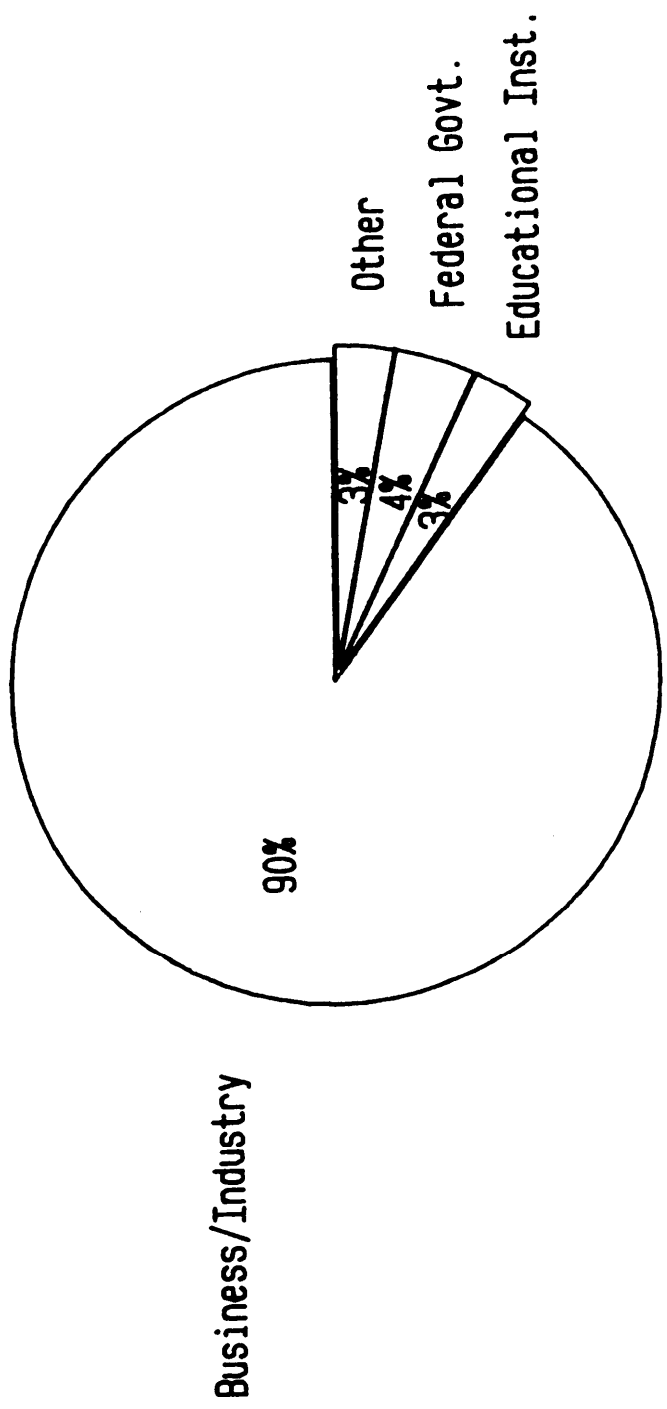
- Chemical engineering has long been one of the most fruitful engineering specialties for women. Women now earn over a quarter of bachelor's chemical engineering degrees, 11 percent of master's degrees, and 6 percent of Ph.D.s.¹³² They are 15 percent of graduate students and about 6 percent of chemical engineers in universities and colleges.
- Minority representation in chemical engineering is typical: among bachelor% recipients, 3 percent are black, 1-2 percent are Hispanic, and **5** percent are Asian.¹³³
- Chemical engineering attracts relatively few foreign students; they earn about 5 percent of bachelor's chemical engineering degrees, a proportion that exceeded 8 percent in 1976.

131. National Science Foundation, Characteristics of Doctoral Scientists and Engineers in the United States, NSF85-303 (Washington, DC: 1985), p. 22? Table B-5.

132. Engineering Manpower Commission, Engineering and Technology Degrees (Washington, DC: American Association of Engineering Societies, published annually).

133. Ibid.

Where Chemical Engineers Work, 1986



Business/Industry

- Chemical engineering is the only engineering specialty where foreign nationals have steadily decreased as a proportion of full-time graduate enrollments (since 1977).¹³⁴ However, the most recent National Science **Foundation estimates show** an increase in the proportion of foreign full-time graduate students to 40 percent.

134. National Science Foundation, Academic Science/Engineering: Graduate Enrollment and Support, Fall 1983, op. cit., pp. 104, 130-31, Tables C-6, C-27, C-28.

ELECTRICAL ENGINEERING

Supply and Demand

- Electrical and electronic engineering is the largest engineering specialty. In 1986, there are 580,000 electrical and electronic engineers employed in the United States. According to the National Science Foundation, of these, 95 percent are working in S/E positions with over 80 percent employed in business and industry, primarily the electronics and computer industries. Women make up 2 percent of the electrical and electronic engineering work force. About 3 percent of all employed electrical and electronic engineers hold Ph.D. degrees.¹³⁵
- Slightly more than one-quarter of all engineering bachelor's degrees and slightly less than one-quarter of all engineering Ph.D.s are in electrical engineering.¹³⁶
- High industrial demand and high salaries spurred a doubling of bachelor's awards in electrical engineering between 1975 and 1985, from 10,000 to 22,000. Master's awards have slowly increased since 1979 to 5,500. Following the engineering-wide decline in Ph.D. awards through the 1970s, electrical engineering Ph.D. awards did not begin to increase until 1981, in great part because of the high demand for bachelor's electrical engineers.
- Dauffenbach and Fiorito project a 65 percent increase in bachelor's awards and a 20 percent increase in Ph.D.s by 1995 due to continued expansion of computer and electronics applications in all industries.¹³⁷
- Electrical engineering is a bachelor's level field. Of the over one-half million employed electrical engineers, less than 5 percent have a Ph.D. Those who do earn

135. National Science Foundation, Science Resources Studies Division, preliminary 1986 estimates, Tables B-1, B-11, and B-13, unpublished data.

136. Engineering Manpower Commission, Engineering and Technology Degrees, op. cit.

137. Robert C. Dauffenbach and Jack Fiorito, The Engineering Degree Conferral Process: Analysis, Monitoring, and Projections, op. cit., p. 58, Table IV-1.

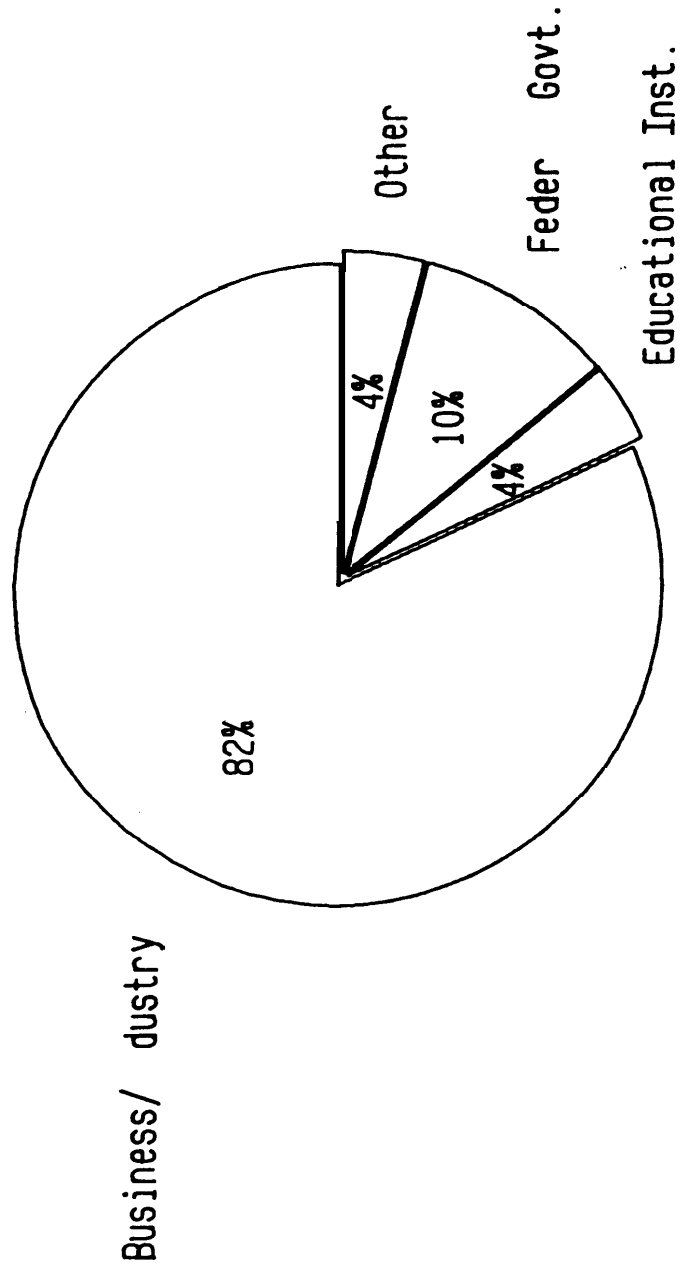
a Ph.D. are more likely to go into academic teaching than are chemical engineers. Most Ph.D.s, however, still go into industry.¹³⁸

Foreign Nationals, Minorities, and Women

- The vigorous worldwide computer and electronics market has attracted many foreign students to enroll in U.S. electrical engineering programs. Foreign students have earned 8 to 9 percent of bachelor's electrical engineering degrees since 1980 and nearly half of Ph.D.s. Electrical and computer engineering host the fastest growing number of foreign students.
- Asian-Americans have been particularly successful in electrical engineering, while other minorities lag behind. Blacks and Hispanics each earn a constant 3 percent of bachelor's degrees, while Asians have increased their share to over 8 percent of bachelor's awards. Among graduate students, Asians outnumber both blacks and Hispanics by four to one.
- Women have slowly but surely made their way into electrical engineering. They earn about 10 percent of the bachelor's degrees, but account for only 2 percent of the employment in electrical engineering.

138. National Science Foundation. Characteristics of Doctoral Scientists and Engineers in the United States 1983, op. cit., p. 22, Table B-5.

Where Electrical Engineers* Work, 1986



*ALL

SOURCE: NATIONAL SCIENCE FOUNDATION