The Demand and Supply of Engineers and Engineering Technicians

A Study for the Expert Group on Future Skills Needs
by
McIver Consulting

Final Report
May 2003

Foreword by Dr. Danny O'Hare, Chairman, Expert Group on Future Skills Needs

This report is submitted by the Expert Group on Future Skills Needs to Mary Harney, T.D., Tanáiste, and Minister for Enterprise, Trade ane Employment, and Noel Dempsey, T.D., Minister for Education and Science. The report was prepared as part of the ongoing work of the Expert Group in looking at the future skills needs of the Irish economy.

Ireland's economic development since the 1980s has been built in large part on its supply of engineering graduates. The Expert Group on Future Skills Needs fully recongises the importance of engineers and engineering to the Irish economy and believes the provision of engineering skills is critical to the competitiveness of the Irish economy. However, the Group has also publicly expressed its concerns regarding the falling numbers of individuals taking engineering courses at third level. Lack of awareness among second level students of the exciting career prospects and opportunities in the engineering profession has undoubtedly played a role in the decline. The STEPS Programme organised by the Insitution of Engineers of Ireland, together with the Expert Group's National Skills Awareness Campaign have made significant efforts to try to address this imbalance.

The aim of the current study was to identify the existing and anticipated mismatches between supply and demand for the engineering profession across all sectors of the economy. The report highlights the contribution of engineers to the economy in all sectors, from ICT to construction, pharmachem and medical devices. It quantifies gaps in the supply of engineers and engineering technicians across all engineering disciplines in these sectors, and identifies some important reasons for the short-fall in numbers within secondary level taking up engineering-related courses. The report makes important recommendations for government, state agencies, educational institutions, employers and the engineering profession to increase the take-up of engineering as a career by second level students and to increase the output of engineers and engineering technicians by the third level system.

On behalf of the Expert Group on Future Skill Needs, I would like to thank the Steering Group who guided the work and Catherine Kavanagh of Forfás who chaired the Steering Group and without whose dedicated management of the project this publication would not have been possible. The findings of this study are important and I would encourage the speedy implementation of the recommendations it makes to ensure an adequate supply of engineering skills in the future.

Daniel O'Hare

Dr Daniel O'Hare
Chairman

Expert Group on Future Skills Needs

Foreword by Brian Kearney, President IEI, 2002-2003

The strength of the Irish economy is based on visionary and what have proved to be very sound industrial development and allied education policies adopted by Government through the eighties.

These policies were aimed at making Ireland an attractive location for high technology international companies to set up and remain while also encouraging the establishment of a competitive indigenous technological sector. The success of these policies in growing the Celtic Tiger is in no small way a result of the availability of a pool of highly skilled engineering and technological personnel through the eighties and nineties. This pool of engineering expertise has also allowed the significant increase in infrastructure development required under the National Development Plan to be progressed.

However, we cannot afford to be complacent. The Annual Competitiveness Report 2002 paints a disturbing picture of Ireland's deteriorating performance in areas which involve investment in engineering - hard and soft infrastructure. The 2002 Report of the Task Force on the Physical Sciences paints an equally disturbing picture of a decline in interest in the physical science subjects at second level and in careers in science, engineering and technology.

Ireland's industrial and economic performance into the future and our ability to redress the current infrastructure deficit and to meet the challenges of the National Spatial Strategy, are dependent on the availability over the coming decades of an adequate supply of appropriately qualified engineering professionals. The Institution of Engineers of Ireland therefore welcomes the Report by the Expert Group on Future Skills Needs on the Demand and Supply of Engineers and Engineering Technicians in the Irish Economy. It will be an invaluable reference for those charged with formulating policy in the education sector, for third level institutions and for human resource personnel in the private sector. I congratulate the Expert Group on Future Skills Needs on the production of such a comprehensive and much needed Report and strongly urge that its recommendations be implemented in full.

Brian Kearney
Chartered Engineer
President 2002-2003

The Institution of Engineers of Ireland

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E.1 Introduction

The Expert Group on Future Skills Needs commissioned this report to examine how the future supply of engineers and engineering technicians in Ireland will match the requirements of industry and public bodies. The report also makes recommendations on how to bridge any gaps that are likely to be significant.

The conclusions are based on the following research activities:

- A survey of engineering employers. This informed the demand projections and provided information on continuing training activities;
- Visits to all Irish third level institutions providing courses in engineering to undertake interviews with engineering academic staff, and group interviews with engineering students;
- Interviews with a range of industry organisations and the industrial development agencies;
- A collation of historical student and graduate statistics, sourced at course level from the Higher Education Authority (HEA), the Department of Education & Science, the Higher Education and Training Awards Council (HETAC), and supplemented with current data obtained by surveying colleges;
- An analysis of anonymised data from the First Destination of Award Recipients databases held by the HEA and HETAC; and
- Review of literature, and other relevant sources of data.

In looking to the future, the report attempts to envision how Irish industry may develop, focusing on industries that appear to have the greatest potential for growth, and which are significant employers of engineers and engineering technicians. The demand projections in the report indicate roughly how many engineers and engineering technicians will be required if the vision is realised.

Two main issues emerge from the analysis:

- A fall in numbers entering electronic engineering has the potential to limit the growth of a range of ICT sectors once markets for ICT products and services recover from the current global economic slowdown; and
- There is a threat of a general decline in numbers graduating in engineering, which may limit the potential of a much wider range of sectors.

In response, the report recommendations focus on boosting the numbers graduating in engineering from Irish education institutions.

E.2 Demand for Graduates

The report makes projections of demand for engineers and engineering technicians for each of the following industry sectors, disaggregated by discipline:

- Software and IT Services;
- Electronic Systems and Hardware;
- Integrated Circuit Design;

- Telecommunications Services;
- Construction and Engineering Consultancy;
- Local Authorities;
- Medical Devices; and
- Pharmachem.

Between them, these sectors employ more than 80% of engineers and engineering technicians who graduated in 2000. The report also makes demand projections for the rest of the economy.

The main issues reflected in the projections are the following.

- The ICT sector has experienced its worst ever downturn. This has caused significant loss of employment and may cause significantly more losses before industry growth resumes. Projections are made on the basis that the upturn will begin before the end of 2003, with a positive impact on employment in 2004, and strong growth thereafter. The projections show demand for new graduate engineers and engineering technicians from the ICT sector being depressed in 2003, but recovering in 2004 and rising thereafter. The ICT sector employs graduates from all engineering disciplines, but is particularly dependent on graduates in electronic engineering.

- It is assumed that the construction sector has come to the end of a period of very rapid growth, which was paralleled by a rapid rise in demand for engineers and engineering technicians, predominantly for civil engineers. It is projected that demand for civil engineers and technicians from the construction and engineering consultancy sectors will stabilise.

- It is anticipated the pharmachem and medical devices sectors will continue to grow strongly with a progressively greater emphasis on research and development work in Ireland. A significant part of this growth in both cases will be connected to the application of biotechnology. Continued growth will drive significant demand for chemical engineers in the pharmachem and engineering consultancy sectors, and for biomedical engineers[1] in the medical devices sector.

Table E.1 summarises the "total economy" projections, which represent the sum of the sectoral projections. As two projections (Projections 1 & 2) are presented for the software & IT services sector, two separate totals are presented for each level of qualification.

The steep rise in projected demand for engineering graduates early in the period reflects a recovery in demand arising from a recovery in global ICT markets. The disciplines for which most demand is projected are civil engineering and electronic engineering, both at degree level and at diploma and certificate level. The demand for civil engineering graduates is driven mainly by construction activity, while the demand for electronic engineering graduates is driven by projections of a resumption of growth in ICT industries.

The degree level projections do not distinguish between demand for primary degree graduates and that for higher degree graduates. Other studies by the Expert Group on Future Skills Needs have projected that there will be a major need for graduates with research degrees to staff many of the research and development positions that are expected to emerge. Also, the view of the future projected is one in which there will be

[1] Including materials scientists and mechanical engineers with a biomedical specialisation.

very much more product development work undertaken in Ireland. Across all sectors this will lead to a greater need for graduates with research degrees.

Table E.1 Total Projections of Engineering Graduate Demand for Whole Economy

	Projection 1		Projection 2	
	Degree	Diploma & Certificate	Degree	Diploma & Certificate
2003	866	1,190	866	1,190
2004	1,226	1,338	1,179	1,329
2005	1,320	1,365	1,214	1,345
2006	1,338	1,326	1,219	1,304
2007	1,374	1,296	1,243	1,271
2008	1,415	1,278	1,268	1,250
2009	1,468	1,312	1,304	1,281
2010	1,503	1,324	1,322	1,289
2011	1,530	1,318	1,333	1,279
2012	1,575	1,341	1,357	1,299

E.3 Supply of Graduates

The number of students graduating in engineering has increased markedly since the 1980s, although general growth in graduate output in Ireland means that the share of graduates accounted for by engineering has fallen since around 1986.

Not all engineering graduates become available for employment by Irish industry. Many, particularly at certificate and diploma level, proceed to obtain a higher qualification, and thus do not enter the labour market at the level at which they graduate initially. Significant numbers also emigrate at degree level. However, the percentage of degree level engineering graduates remaining in Ireland has increased substantially over time.

The number of students graduating is likely to increase over the period to 2004, and there is likely to be a modest fall in degree level output in 2005. Over this period there will be a shift in the mix away from electronic engineering, with continued growth in civil engineering.

In the long-term, the supply of engineering graduates is in large part a function of the number and quality of applicants for engineering courses. As relatively few mature students applying for admission to third level have a strong mathematical and scientific/technical background, this means that the supply of degree level graduates is mainly a function of the number and mix of school leavers applying to study engineering.

Both the number of college applications and the number of students in the school leaving age cohort peaked in 1998. Both have already fallen since, and are expected to fall further, with school leaving numbers falling to approximately 60,000 in 2006 and approximately 50,000 in 2012. This would reduce the number of students applying for engineering courses by an equivalent amount. This is equivalent to a fall in degree output from 1,720 projected for 2002 to 1,441 in 2010 and 1,208 in 2016[2].

Based on interviews with engineering students and engineering academics undertaken for the current study, it is apparent that the other major factors affecting the level of interest in studying engineering include:

- Perceptions of opportunities for engineering graduates;

[2]The typical duration of a primary engineering degree course is four years (2010 and 2016 are four years after 2006 and 2012 respectively).

- Subject choice at Leaving Certificate and Junior Certificate level; and

- Perceptions of engineering among school students.

E.5 Gap Analysis

The gap analysis undertaken is based on two scenarios that provide different indications of the future development of the supply of graduates in engineering.

- **Scenario 1** is based on the assumption that recruitment into engineering courses will fall in proportion to the falling size of the school leaving age cohort, and that this will have a proportionate impact on the number of graduates these courses will produce.

- **Scenario 2** takes Scenario 1 as its starting point, and further assumes that the fall in applications for engineering courses experienced in 2002 is maintained, and has a persistent impact on the number of graduates produced.

Table E.2 summarises the overall balance between supply and demand under each of the two scenarios[3]. It shows the balance between supply and demand shifting from surplus to shortage conditions under each of the supply scenarios[4].

Table E.2 Overall Balance Between Supply and Demand Under Two Supply Scenarios

	Degree		Dip & Cert	
	Supply Scenario 1	Supply Scenario 2	Supply Scenario 1	Supply Scenario 2
2003	767	357	767	357
2004	411	172	411	11
2005	292	94	166	-62
2006	232	102	109	-50
2007	171	127	50	-25
2008	153	132	31	-18
2009	34	18	-83	-124
2010	-116	-79	-224	-212
2011	-210	-94	-313	-225
2012	-317	-97	-416	-230

It is important to exercise some caution in interpreting the results. Even if the views on the future encapsulated in this report turn out to be fairly accurate, variations in demand, changes in course provision, and changes in the disciplines attracting the most applications, could overturn an overall over-supply or under-supply of some hundreds of graduates.

Also, an indication of an excess of supply over demand does not in itself suggest that there is a problem. Where the numbers likely to do this are not overwhelming, an oversupply of graduates should be seen in a positive light.

When individual disciplines within engineering are considered, the following are the most important issues that arise.

- At both degree and diploma/certificate levels, the supply of electronic engineering and telecommunications engineering graduates is projected to

[3]For simplicity, just one of the software & IT services projections is used in this comparison, that is, Projection 1.
[4]The aggregate analysis excludes computer engineering graduates. The rationale for omitting computer engineering graduates from the total figures is explained more fully in Chapter 3

exceed demand in the short-term, but there is potential for a severe shortage in the longer-term. As the availability of electronic engineers is a prerequisite for many of the industry developments envisioned, the degree level shortage could have significant negative industrial development implications. This shortage at both levels has the potential to be worse if interest in electronic engineering among college applicants does not recover.

- There is potential for a shortage of graduates with diplomas and certificates in civil engineering[5].

- There is a general issue across all disciplines and levels that the balance between supply and demand for graduates is projected to tighten significantly over the period to 2012.

- In very broad terms over the period addressed by the projections, and aside from a significant over-supply being likely in some disciplines in the short-term, there is no very major discipline specific supply imbalance projected at degree level in other engineering disciplines.

In summary, the main areas where gaps in supply are projected are in electronic engineering and degree level telecommunications engineering. In these areas, the main constraint is to do with the number and quality of college applicants wishing to apply for courses. The provision of further places will only become a significant policy issue if this can be resolved.

E.6 Summary of Recommendations

Recommendation 1: Expanding and Reviewing STEPS

It is recommended that the extent of existing STEPS activities should be expanded so as to reach a significantly higher proportion of second level students. This will require a significantly greater commitment of funding from industry and from the Department of Education & Science. It will also require a greater commitment of time and effort from employers of engineers, from engineers and engineering academics, and from the IEI.

Recommendation 2: Reviewing STEPS

It is recommended that IEI should undertake a review of the operation of STEPS. Implementation of the other recommendations on STEPS presented in the current report should not be delayed for this review.

Recommendation 3: Taster Courses

It is recommended that STEPS should become involved in engineering taster courses, through:

- facilitating the sharing of expertise and experience between colleges;

- providing support materials; and

- developing, in co-operation with the colleges, an overall planning framework that ensures good coverage of the key target groups.

Recommendation 4: Research into Engineering Careers

It is recommended that the IEI in association with Forfás should initiate an analysis of actual long-term career outcomes of people with third level engineering qualifications. This will have potential use in future promotional activities.

[5] For purposes of the current study, civil engineering includes structural engineering, construction studies and construction management.

Recommendation 5: Marketing Resource for Third Level Colleges

It is recommended that the HEA and the Department of Education & Science should consider financing a marketing resource to support the engineering, science and computing faculties and schools in each third level college.

Recommendation 6: Guidance Counsellors

It is recommended that the Department of Education & Science should develop and provide a labour market in-service training programme for guidance counsellors, placing emphasis on careers in engineering, science and technology and the industries that employ graduates in these disciplines. It should develop and revise regularly a suite of materials on the labour market to support guidance work.

Recommendation 7: Review of Mathematics

It is recommended that the review of mathematics recommended by the Task Force on the Physical Sciences should be asked to address increasing the number of students taking Higher Level Mathematics.

The review should take account of the evidence on marking and of the recommendation of the Task Force on the Physical Sciences that problems of this nature should be resolved.

The group should consider the possibility of offering bonus CAO points for mathematics for all college courses, both to give students at all levels an incentive to treat it as one of their core six subjects, and to compensate them for the perceived heavy workload associated with taking the subject seriously.

The review should also address the factors at primary level and at junior cycle second level that may limit the take-up of Higher Level Mathematics at Junior Cycle, thus limiting the size of the pool from which students taking Higher Level Mathematics to Leaving Certificate level can be drawn.

Recommendation 8: Common Entry Options for College Entry

It is recommended that colleges should move to increase the percentage of engineering degree students recruited through common entry mechanisms. The HEA should monitor trends in entry through these mechanisms.

Recommendation 9: Labour Market Information for Engineering Academics

It is envisaged that the Expert Group on Future Skills Needs and Forfás will communicate a thorough and balanced analysis of the labour market position and outlook to key engineering academics.

Recommendation 10: Research Resources and Facilities

The HEA should consult with colleges about the space and other resources they need for postgraduate engineering research, with a view to providing a separate fund for investment in additional space, and upgraded space, where sufficient suitable space cannot be sourced within the college.

Recommendation 11: Funding for Postgraduate Research

It is recommended that the Government and relevant funding bodies should ensure that sufficient funding for research by engineering postgraduates is made available so as to avoid making funding an important constraint on the number of well qualified people able to take up postgraduate research in engineering. Funding bodies should review the operation of funding cycles so as to ensure that it is possible for engineers to take up postgraduate studies as they become available for study, rather than necessarily waiting for the start of the next academic year. The HEA should monitor progress on this recommendation.

Recommendation 12: Approaches to Learning in Engineering

It is recommended that the Engineering Deans and Heads of School in third level colleges should form an ad-hoc taskforce to examine the potential benefits from, and obstacles to, moving towards a more project-based and problem-based approach to learning. A report should be prepared based on this examination for consideration by the Expert Group on Future Skills Needs, the HEA and the Department of Education & Science.

Recommendation 13: Pre-Engineering Courses

It is recommended that, where sufficient demand exists from people with suitable levels of ability and commitment, institutions including further education colleges[6] and third level colleges should run pre-engineering courses designed to bring mature students to a level in mathematics and the physical sciences equivalent to at least a higher level C3. Where such courses already exist, they should be continued. Forfás should monitor the provision of such courses.

Recommendation 14: National Programmes

It is recommended that the Institutes of Technology should continue the Industry Trainee Programme and Accelerated Technician Programme where there is sufficient demand from trainees and industry.

Recommendation 15: Certification of People Up-skilled in Companies

It is recommended that engineering departments of third level colleges, particularly of Institutes of Technology, should work with HETAC, industry and the IEI to develop more active systems of accreditation of prior and experiential learning, and also to provide tailored upskilling opportunities to bridge existing learning and the requirements of higher levels of qualification.

Recommendation 16: Promoting Immigration by Engineers

It is recommended that the Government should take into account in future immigration policies the likelihood that there will be a need for immigration by engineers from within the EU and from beyond the EU. It should also allow flexibility to introduce targeted skills initiatives.

Recommendation 17: Drawing Students from Overseas

The Expert Group on Future Skills Needs recommends that interested bodies should take positive action towards attracting engineering students from overseas, and that they should use the forthcoming HEA study of the issue to inform their responses. Forfás and the HEA should monitor progress in this area.

Recommendation 18: Systems of Statistical Classification

The Expert Group on Future Skills Needs recommends that Forfás should initiate a review of industry data sources. This should include its own data and that from other agencies including FAS, HEA, Enterprise Ireland and IDA Ireland, and at CSO data sources, in the context of the requirements of skills policy research, formulation, implementation and review. The review should make recommendations on industry classifications and survey coverage applicable across all relevant agencies.

[6] Colleges that were termed "PLC colleges" in the past are now generally termed "further education colleges".

1. Introduction, Context and Methodology

1.1 Introduction

Forfás, acting on behalf of the Expert Group on Future Skills Needs commissioned McIver Consulting to undertake an examination of the future supply of engineers and engineering technicians. The findings and recommendations have implications for the education, business and government sectors to ensure an adequate supply of this key profession in the future.

The purpose of this chapter is to describe the context for the study. It begins by reviewing the role of engineers and engineering technicians in the economy. It continues by examining Irish industrial development and its beneficial consequences, and highlights the central role that engineering-intensive industries have played. It shows how these industries have depended on being able to recruit large and increasing numbers of graduates in engineering disciplines.

The analysis shows, however, that engineering has not kept pace with higher education generally in terms of the number of graduates produced. Engineering's share of degree graduates has fallen from 15.2% in 1986 to just 10.2% in 2000. The share of diploma and certificate graduates accounted for by engineering has fallen from 31.7% in 1991 to 25.1% in 2000.

The chapter goes on to examine the future of Irish industry, and shows that the vision of the future implicit in the strategies of the industrial development agencies is one in which engineering-intensive industries will continue to play a central role. This being the case, the supply of graduates in engineering will be an important determinant of Ireland's future economic success.

However, the supply of graduates in engineering into the future faces a number of challenges. These include the ongoing decline in the number of people in the school leaving age cohort, and a loss of popularity for some key engineering disciplines among college applicants.

The chapter proceeds to investigate the international context. First it compares Ireland's output of engineering graduates with that of a range of other countries. Then it examines how countries overseas have responded to similar threats to the supply of engineers and other technological professionals. Finally the chapter analyses the potential to source engineers and engineering technicians from overseas. The chapter concludes with an overview of the methodologies used for the study.

1.2 Role of Engineers and Engineering Technicians

Engineers and engineering technicians play a crucially important role in many sectors of Irish industry, and also in a range of areas of public service provision.

Key roles undertaken by engineers include:

- Designing, developing and producing new products, software etc., and improving existing products, software etc.;
- Designing, managing and improving production processes;

- Planning, designing and implementing infrastructure development;
- Designing and managing construction projects; and
- Advising on technical issues across the public and private sectors.

These are roles that drive improvements in productivity, innovation and competitiveness. Engineers also play a role in health & safety and environmental management, and setting and ensuring compliance with public regulations.

Many of Ireland's companies, big and small, have engineers in senior leadership roles. Major organisations with engineers as managing directors include Intel, Hewlett Packard, Boston Scientific, Iona Technology, Xilinx, Bausch & Lomb, ESB, CRH and Ascon, among others.

Typical roles undertaken by engineering technicians include:

- supporting engineers in any of the above roles, often through hands-on work such as fabricating prototypes, preparing drawings, using computer aided design tools, testing products, or operating quality assurance systems; and
- working in engineering roles, although usually at a significantly lower level than an engineer with an equivalent duration of experience.

The roles described here overlap with those of some other professions. In some industries, scientists have key roles in developing and improving products, and in designing, managing and improving production processes. In industries such as pharmaceuticals and food, most of the technicians undertaking support work are science technicians, rather than engineering technicians.

In the area of IT skills, there is no well-established boundary between engineer software developers and non-engineer software developers. Even where job titles suggest a distinction, this tends to be a matter of local terminology, rather than anything systematic. The IEI now accredits some computing courses, but it remains to be seen whether this will have a meaningful impact on actual occupational structures in industry.

In order to undertake this study, there was a need to establish a clear basis for determining whether or not a third level course should be considered to be within the scope of the study. The following points address the main areas where the choice was not clear-cut.

- In the broad IT area, courses with titles such as Electronic Engineering, Telecommunications Engineering or Computer Engineering are treated as falling within the scope of the study. Courses with titles such as Software Engineering, Computer Science, Computing or Computer Applications are treated as falling outside the scope, as it would not be feasible to distinguish between demand for graduates of these and other software development related courses. Previous studies undertaken by the Expert Group on Future Skills Needs have drawn the distinction between engineering at approximately the same point[1].
- Graduates of Science departments in the Institutes of Technology are generally treated as being outside the scope of the study. Thus, while there are Chemical Engineers within the scope of the study, there are no Chemical Engineering technicians. Graduates in Instrumentation Physics, who often enter employment as Instrumentation Technicians and Instrumentation Engineers are also excluded from the scope of the study.

1 Computer Engineering has sometimes previously been treated as falling on the Computing side of the boundary. However, as Computer Engineering courses tend to have close organisational and content affinities with Electronic Engineering, it was decided to include them in the current study. The graduate numbers involved are not large, and the close relationship between demand for Computer Engineering graduates at that for other Computing graduates is addressed in the analysis.

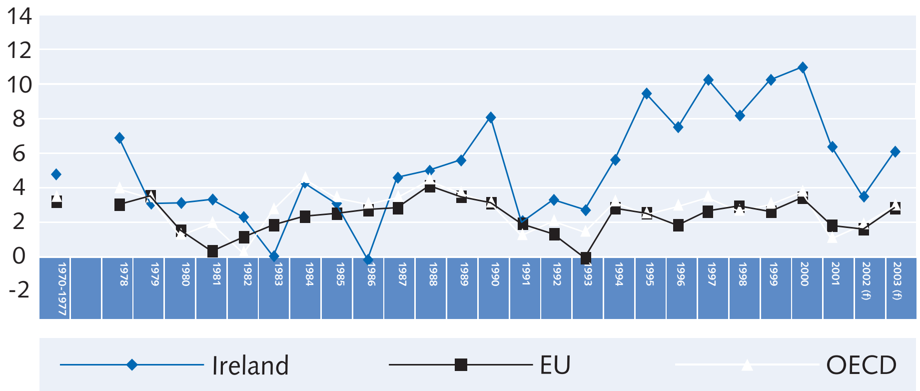
• No distinction is made between degree courses accredited by the IEI and those unaccredited. The main areas where unaccredited courses occur within the scope of the study are in manufacturing/industrial engineering, and in some construction-related areas that are classified with civil engineering for the purposes of this study.

1.3 Irish Industrial Development and its Consequences

Much of the success that the Irish economy has experienced in recent years has its origins in earlier decades. A pattern of inward investment in pharmaceuticals was established by the 1960s. The roots of the software sector lie in the 1970s. Inward investment in electronics hardware was also established by the 1970s, but accelerated after the landmark establishment of Irish operations by Digital Equipment Corporation in 1982.

From the late 1980s, these developments and others brought the Irish economy's rate of growth significantly above the average for other developed countries, a pattern that has continued since.

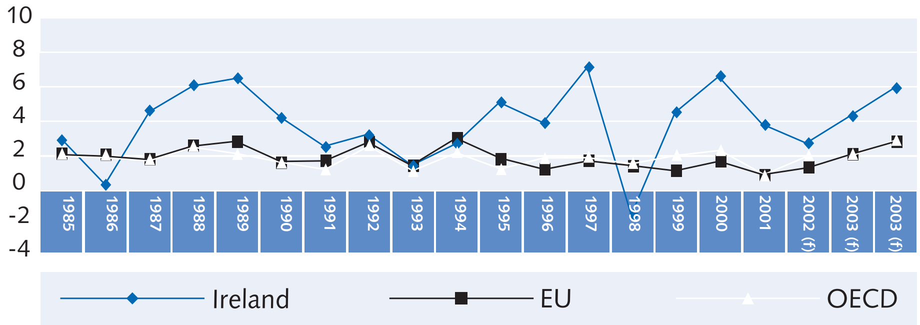
Figure 1.1 Growth in Real GDP



Source: Data from OECD Economic Outlook, various editions, including June 2002 edition.

This high rate of economic growth has reflected a rate of increase in labour productivity that far exceeds the average for other developed economies.

Figure 1.2 Growth in Labour Productivity



Source: Data from OECD Economic Outlook, various editions, including June 2002 edition.

This has increased Irish output per capita from a level well below the average for developed countries to a level that is now well above the average. It has increased Irish household consumption per capita to a level similar to that in other developed countries, which demonstrates that a substantial part of the increase in productivity has been captured by workers in increased spending power. It has lowered the unemployment rate in Ireland to well below the EU and OECD average.

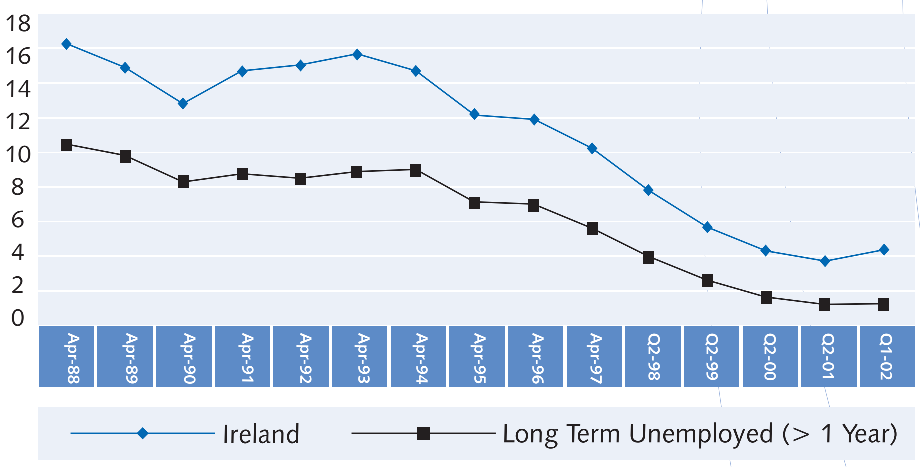
Table 1.3 Comparative Data on Performance of Irish Economy

	GDP per Capita in 1995 US$, Based on Purchasing Power Parities			Household Final Consumption per Capita in 1995 US$, Based on Purchasing Power Parities			Unemployment Rate (%)		
	IRL	EU 15	OECD	IRL	EU 15	OECD	IRL	EU 15	OECD
1970	7,772	11,609	12,000	5,416	6,398	7,153			
1980	10,706	14,958	15,216	7,038	8,503	9,218	7.3	5.9	5.7
1985	11,662	16,036	16,586	6,875	8,938	10,015	16.5	9.8	7.4
1990	14,824	18,461	18,908	8,260	10,521	11,433	12.8	8.1	5.7
1995	18,157	19,454	19,987	9,352	11,018	12,142	12.2	10.7	7.3
2000	27,672	21,852	22,662	13,232	12,428	13,811	4.3	8.5	6.1
2001							3.9	8.0	6.4

Source: National Accounts of OECD Countries: Main Aggregates, 2002, OECD; Unemployment Rate Data (including forecasts) from OECD Economic Outlook, various editions, including June 2002 edition.

It has directly benefited many of the most vulnerable groups in Irish society by reducing the long term unemployment rate to less than one eighth of what it was, from 10.4% in 1988 to 1.2% in Q2 2002.

Figure 1.4 Irish Unemployment Rate (%)



Source: Quarterly National Household Survey (QHNS), Q1 2002, CSO.

1.4 The Engineering-Intensive Industries that have Contributed

1.4.1 History of Industry Growth and of Recruitment of Engineering Graduates

The fall in the Irish unemployment rate has reflected a large rise in employment. Having stabilised at around 1.1m by the mid-1980s, Irish employment rose to 1.7m in 2001, despite the continuation of a long term decline in employment in agriculture.

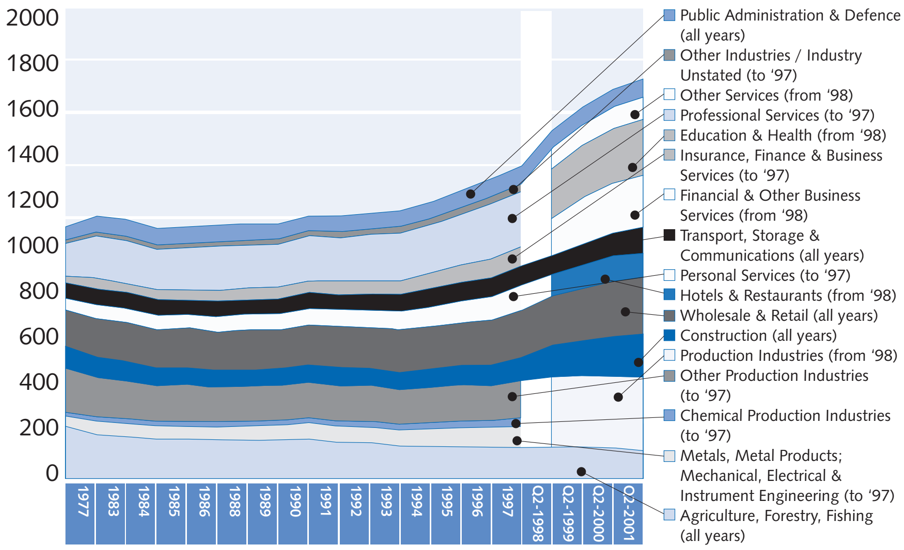
Figure 1.5 summarises sectoral employment statistics drawn from the Labour Force Survey and the Quarterly National Household Survey. These surveys present less sectoral detail than other CSO surveys, but have the benefit that they cover the whole economy.

An examination of these statistics shows that the key internationally-traded sectors involved, in terms of the classifications used by the CSO, were:

- Metals, Metal Products; Mechanical, Electrical and Instrument Engineering;
- Chemical, Rubber and Plastic Products; and
- (Insurance,) Finance and Business Services.

Much of the rest of the increase in employment came from domestically-traded sectors that expanded to service the needs of these sectors, or to service the needs of consumers whose income derived ultimately from these sectors. **Key among these is the construction sector, where employment rose to 81,500 in 1995, and then more than doubled to 180,200 in 2001.**

Figure 1.5 Employment by Industry in Ireland (000s), 1977 and 1983 to 2001

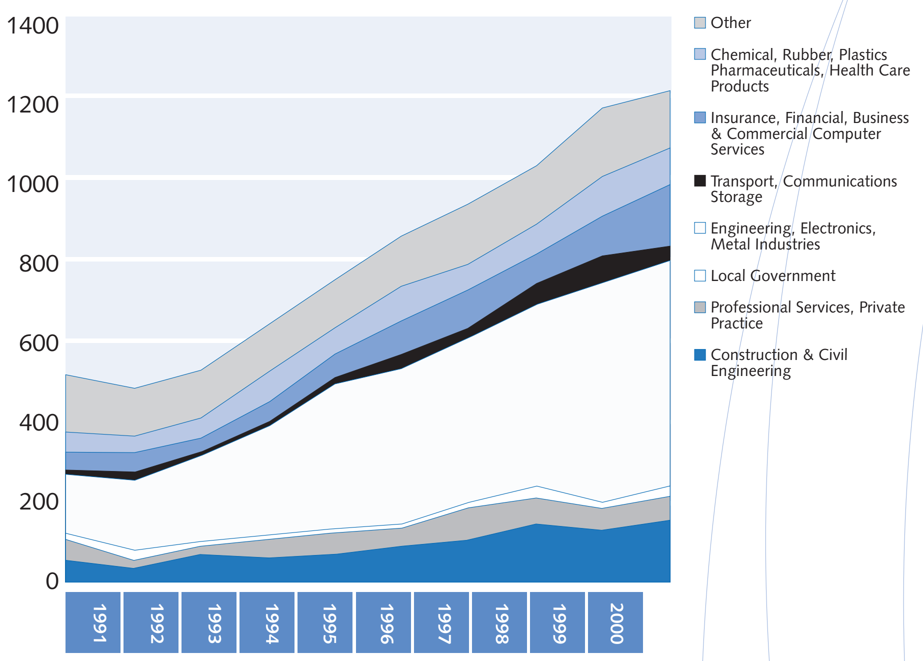


Source: Data from 1977 to 1997 drawn from annual Labour Force Survey, CSO. Data from 1998 to 2001 drawn from QHNS, CSO. The detailed industry classifications published in the QNHS were changed from those published in the LFS, its predecessor. Some industry definitions were changed very little, and these areas of continuity are shown as being continuous in the chart.

There is a close correlation between the sectors where employment growth has occurred and the sectors which mainly recruit engineers, as can be seen from Figure 1.6, which shows how recruitment of new engineering graduates by sector[2] has developed over the last ten years. The substantial increase in employment in these sectors has been reflected by very substantial recruitment of engineering graduates.

2 The sectoral definitions in First Destination statistics published by the HEA are broadly similar to, but not identical to, those used by the CSO. A key difference is that the medical devices sector is included in "Chemicals, Rubber, Plastics, Health Care Products" by the HEA, but forms a part of "Metals, Metal Products; Mechanical, Electrical and Instrument Engineering" in the HEA statistics.

Figure 1.6 Recruitment of New Primary Degree Engineering Graduates by Irish Employers Classified by HEA Industry Sector, 1991 to 2000



Source: Grossed up from data from First Destination of Award Recipients in Higher Education, editions from 1991 to 2000, HEA.

The increase in recruitment has mainly been concentrated at primary degree level. Recruitment of primary degree engineering graduates by Irish industry more than doubled between 1991 and 2000. Over the same period, recruitment of holders of diplomas and certificates in engineering rose by just over half. Recruitment of higher degree engineering graduates by Irish industry has been more volatile reflecting in part a fall-off in higher degree numbers after 1995[3].

1.4.2 Industry Definitions

While the industry classification systems behind the CSO industry data and the HEA graduate data are very similar, these systems of classification provide insufficient detail in key growth areas for the purposes of this report. The following, (cross-referenced to HEA classifications in italics) were the key growth areas that recruited engineers and engineering technicians:

- Software and IT Services (part of Insurance, Finance and Business Services and of Metals, Metal Products; Mechanical, Electrical and Instrument Engineering);
- Electronics Hardware & Systems (part of Metals, Metal Products; Mechanical, Electrical and Instrument Engineering);
- Integrated Circuit Design[4] (part of Metals, Metal Products; Mechanical, Electrical and Instrument Engineering);
- Medical Devices (part of Metals, Metal Products; Mechanical, Electrical and Instrument Engineering);
- Pharmaceuticals (part of Chemical, Rubber and Plastic Products);
- Construction; and
- Engineering Consultancy (part of Other Services / Professional Services).

3 See statistical appendix for more detailed information on recruitment of graduates with higher degrees, and with diplomas and certificates.
4 There are different ways in which the boundaries between the main information technology industries above can be drawn. For the purposes of this report, we follow the National Informatics Directorate definition of the software sector, which encompasses pure software companies, other pure software development facilities, even if they form a part of Electronic Hardware and Systems companies, and IT services companies. Integrated Circuit Design is also addressed separately from Electronic Hardware and Systems because it has grown rapidly in recent years, because it is targeted for future growth by the industrial development agencies, and because it mostly does not involve manufacturing in Ireland.

More detailed information about the history of employment in most of these sectors is presented in Chapter 3. Recruitment of degree level engineering graduates is also presented at a more detailed level, based on an analysis of the actual employers recorded in the HEA's First Destination database carried out for this study on graduates of 2000[5].

1.5 Engineering Graduate Output

1.5.1 Levels of Qualification

The levels of qualification at which projections are made are as follows:

- Degree (primary degrees, higher degrees and postgraduate diplomas); and
- Diploma or certificate (undergraduate qualifications).

A certificate in engineering typically takes two years of study. A diploma typically takes three years. This may be through a three year "ab-initio" programme, or through taking a one year "add-on" programme after a certificate programme.

A primary degree in engineering takes four years if pursued ab-initio. If pursued as an add-on to a diploma, it takes a further two years if it leads to a Bachelor of engineering (B.E. or B.Eng.) accredited by the IEI[6], or one year otherwise. A graduate diploma takes one year of study. Graduate diplomas in engineering may be taken by engineering graduates. Some also take significant numbers of Science graduates. A taught masters degree in engineering takes one or two years of study with full time courses usually taking one year, and part time courses usually taking two years. The duration of study towards research degrees varies.

1.5.2 History of Engineering Graduate Output

In the latter half of the 1970s, the establishment of two new National Institutes of Higher Education[7], and an initiative to increase the number of graduates available to the electronics sector, combined to increase the intake into primary degree programmes in engineering. Primary degree output rose steeply, before leveling off after 1986. Steady growth in primary degree output resumed after 1990, continuing through the 1990s.

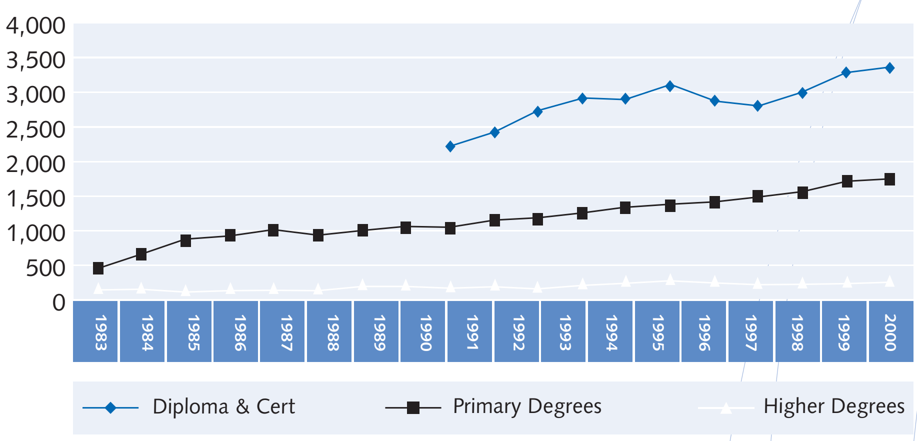
Higher degree output has been more volatile, responding both to increases in the number of students receiving primary degrees, and to labour market conditions. In times of strong demand, such as the latter half of the 1990s, the proportion of primary degree graduates continuing their studies has fallen. Most of the Institutes of Technology were formed in the early to mid 1970s, initially producing small numbers of graduates with certificates in engineering, and eventually adding diploma level courses. Diploma and certificate engineering graduate numbers from these, and from the existing Dublin colleges that later merged to form Dublin Institute of Technology, increased over time, falling back after peaking in 1995, before increasing again in the period up to 2000.

5 Limitations in the data recorded meant that it was not possible to repeat this exercise for diploma and certificate graduates.

6 The IEI is established by Charter. It is empowered under its Charter to admit to membership, classify and confer titles on its members to indicate their professional standing and classification or grade. In doing so it has regard to current international practice and the various international agreements it has entered into in promotingthe standing and standards of Irish engineering expertise. These agreements provide benchmarks against international standards for Irish Engineering qualifications, and provide a basis for recognition of Irish Engineering qualifications overseas.
Accredited degree programmes, which allow full membership of the Institute, are recognised internationally through the Washington Accord. Accreditation also makes a course eligible for inclusion in the list of programmes whose graduates are eligible for the Eur Eng title of FEANI - Fédération Européenne d'Associations Nationales d'Ingénieurs. Most accredited degrees covered by this study lead to the award of a Bachelor of Engineering degree. The main exceptions are at Trinity College Dublin, which awards B.A.I. degrees. Some degrees in Software Engineering (and closely related areas) accredited by the IEI, which fall outside the scope of this study, also have different award titles. The IEI also approves Engineering Diplomas and certain degrees in Technology and Science as meeting its academic requirements for Associate Membership (AMIEI). These diplomas and degrees are internationally recognised through the Sydney Accord. The most typical title for an approved, but non-accredited, degree is that of BTech. The Institution approves Engineering Certificate programmes as meeting its academic requirements for Technician Membership. These certificates are recognised in the UK through the Dublin Accord.

7 These are now the University of Limerick and Dublin City University.

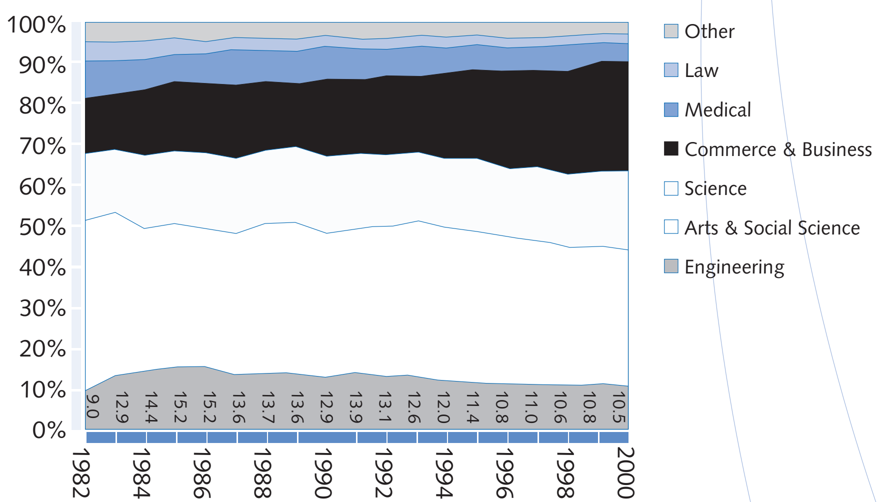
Table 1.7 Numbers of Engineering Graduate to 2000[8]



Source: Data from First Destination of Award Recipients in Higher Education , HEA, 1982-2000. (Earlier editions disaggregate Diploma and Certificate graduate numbers by discipline.)

Increases in the number of engineering graduates over time should be seen in the context of a general rapid expansion in higher education in Ireland. In the period up to 1996, the share of all primary degree graduates accounted for by engineering increased, from 9.6% in 1982 to 15.2% in 1986. Since then, engineering's share has fallen slowly, reaching 10.5% in 2000.

Figure 1.8 Disciplinary Mix of Primary Degree Graduates, 1982 to 2000



Source: Drawn from First Destination of Award Recipients in Higher Education , HEA, 1982 -2000.

Engineering's share of all diploma and certificate graduates is lower than it was in the 1980s and early 1990s, but has been fairly stable since 1996.

1.6 Future of Irish Industry

In order to take a useful view as to future requirements for engineers and engineering technicians in Ireland, it is necessary to develop a vision of Irish industry in five and ten years time.

The industrial development agencies have a view of where the key opportunities lie[9]. Areas highlighted are as follows.

- Information and Communications Technologies: The ICT industries have served

8 Note that many of those receiving diplomas have previously received certificates. Thus the net output of graduates with diplomas and certificates is less than that shown here.

9 "Two fundamental technologies, biotechnology and information technology, are likely to be at the heart of future growth", IDA Ireland Annual Report 2001. The Annual Report focuses on four sectors. The "ICT sector" and the "internationally-traded services" (mainly software) sector are both closely linked to ICTs. The "pharmaceuticals and biotechnology" sector, and the "healthcare" (mainly medical devices) sector are increasingly linked to biotechnology. **Enterprise Ireland** has published strategies for ICT (2000) and Biotechnology (2001). The sectoral breakdown of its Annual Report for 2001 is dominated by ICT industries, and by Food (which is not a major employer of Engineers). Pharmaceuticals and healthcare also feature. The significance of ICT sectors for the future is reflected, for example, in the 89.9% of total funding under the Seed and Venture Capital Measure (managed by EI) accounted for by Software and Communications in 2001. The brief of Science Foundation Ireland is to focus on ICTs and Biotechnology.

Ireland well as a basis for industrial development at least since the early 1980s. They are receiving backing from the State in the form of substantial funding for research through Science Foundation Ireland and the Higher Education Authority. The industrial development agencies see them continuing to provide many of the key opportunities in the future[10].

Biotechnology: Biotechnology is a major focus of State spending on research, and of promotion by the industrial development agencies[11].

These future industry areas are rooted in the industries in which Ireland has demonstrated comparative advantage in the past, but will represent an ongoing shift towards higher value adding activities. In many cases, the industries will be more engineering-intensive than in the past, with a higher proportion of engineers in the occupational mix. With a shift in focus from manufacturing towards product development and other knowledge-intensive activities, they will also place different demands on engineers, and it is likely that the mix of demand will shift away from manufacturing-industrial engineering towards design-oriented disciplines.

In addition to these key traded industry areas, it is expected that infrastructure development will continue to be a priority over the period addressed by the study. The completion of the National Development Plan and the implementation of the National Spatial Strategy will drive a high level of continuing activity in road, waste, water, public transport, the environment and electricity, and will thus be a major source of employment for engineers and engineering technicians in the future.

10 Key areas include the following.
- Indigenous Software Companies: It is anticipated that a high rate of new business formation and rapid growth of indigenous software companies will resume once the current downturn in IT market demand comes to an end.
- Overseas-owned Software Units: A number of areas within software, including operating system software, are among the main industry areas targeted for development of inward investment by IDA Ireland.
- Electronic Systems: Electronics operations in Ireland are moving away from low-end manufacturing to parts of the electronics value chain where more value can be added, such as new product development, and developing the software for electronic systems, and into higher value added manufacturing activities.
- Integrated Circuit Design: This is seen as being a major area of opportunity for inward investment, the long term growth of which in Ireland will probably be limited by the supply of graduates in relevant areas of Engineering. While indigenous companies in the area are currently experiencing market difficulties, it is also seen as offering such companies good opportunities over the medium to long term.
- Digital Media: This is seen as an area of opportunity, but it is not yet clear in what areas Ireland may be able to build a sufficient competitive advantage to develop a strong industry. Thus, it is not yet clear whether the industry will have a significant requirement for Engineers or Engineering Technicians. Most existing digital media companies are not significant employers of Engineering graduates other than in Software Engineering.

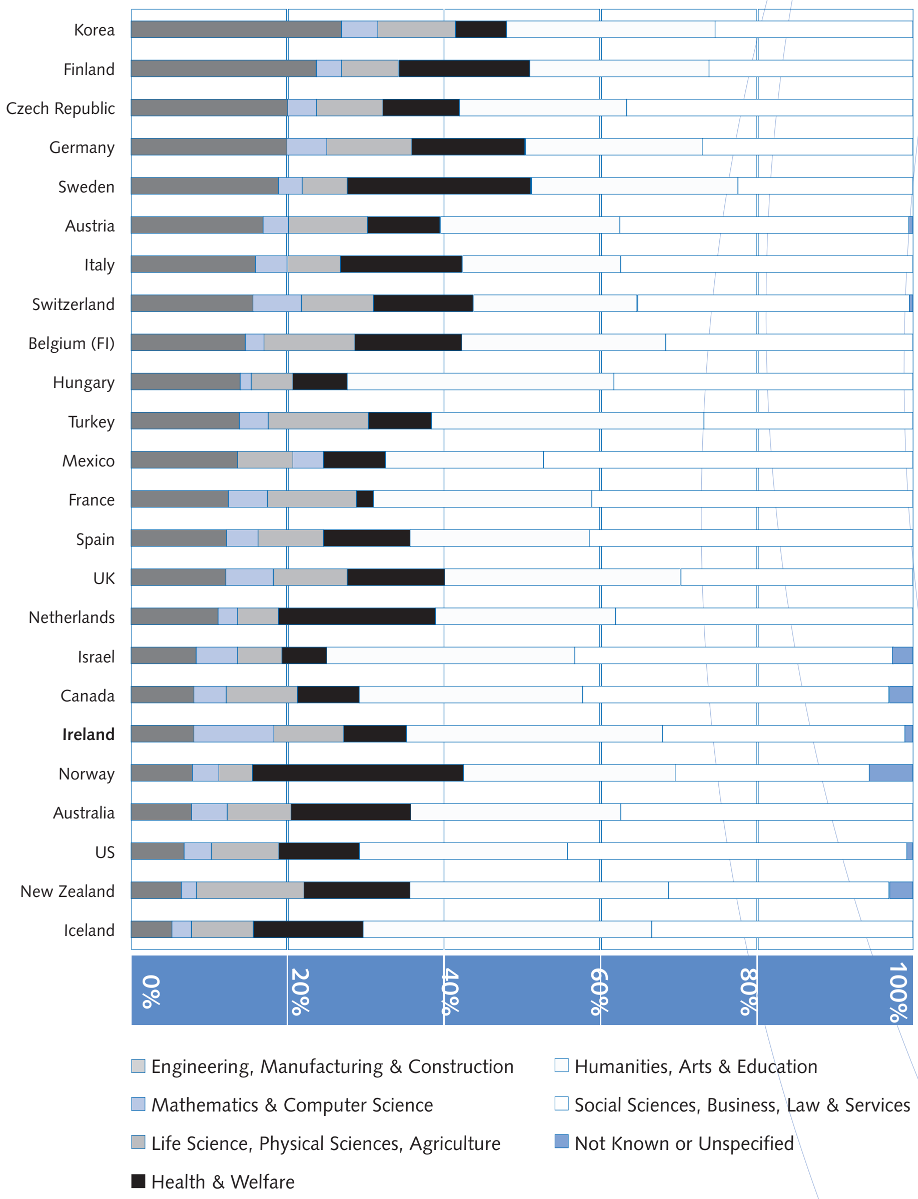
11 The main areas of Biotechnology that are very likely to require significant numbers of Engineers in Ireland are:
Biopharmaceutical manufacturing: There is already significant inward investment in this area underway, and it is seen as an area where there are good prospects for future growth, building on existing pharmaceutical industry strengths.

1.7 International Context

1.7.1 Comparison of Engineering Graduate Output

Figure 1.9 shows that the proportion of Irish degree level graduates who have studied engineering is low by international standards, although similar to that in the US. As the economy is particularly dependent on engineering-intensive industries, the resulting supply of graduates will be an issue.

Figure 1.9 Graduates by Field of Study from Tertiary Type A (mostly equivalent to degrees) and Research Programmes in 1999



Source: Education at a Glance 2001, OECD.

Figure 1.10 shows that, as at degree level, Ireland is a world leader in producing computing graduates at the equivalent of diploma and certificate level, but its output of engineering graduates is more modest by comparison with many other OECD members.

- Biotechnology applied to Medical Devices: Medical devices companies in Ireland have moved strongly into research and product development, and this is seen as an area where biotechnology can be applied in ways that build on Ireland's existing strengths in medical device manufacturing.

It is plausible that other areas could emerge. Areas of Biotechnology such as automated screening and chip-based testing equipment are highly Engineering-intensive but may not become established in Ireland. For the purposes of the current study, bioinfomatics is assumed to be a subsector of software & information technology services.

Figure 1.10 Graduates by Field of Study from Tertiary Type B (mostly equivalent to certificates and diplomas) in 1999

Source: Education at a Glance 2001, OECD.

1.7.2 International Measures on Supply of Engineers

A review of measures taken in response to perceived shortages, and perceived threats of shortages of engineers in other countries has highlighted the following key points.

- A number of other developed countries attempted to boost the numbers graduating from engineering[12]. The key points of leverage that they seek to use to achieve this are:

  - Promoting the study of mathematics, physical sciences and related subjects at second level, to boost the supply of people with the educational background required to study engineering, and to promote interest in studying engineering, science and technology at third level; and

  - Undertaking a variety of initiatives to inform second level students about engineering, and to promote interest in studying it at third level.

12 Examples include Germany and Australia.

- Engineers are frequently targeted by countries with immigration and work-visa policies designed to admit people with economically-useful skills. However, it is worth noting that analyses of the US H1-B work visa programme for professionals have shown that in practice it admits relatively few people who would meet a narrow definition of the term "engineer", but admits large numbers of graduates in computing.

- Any claims of shortages and potential shortages of engineers and related professionals must be treated with some caution. For example, US studies have found that there was no general shortage of IT staff in the US in the latter half of the 1990s[13,14]. Normal market forces appear to be capable of producing an effective response to an impending shortage of technically-qualified staff, whether by encouraging the transfer of experienced people with cognate skills from other industries, by increasing the retention of the substantial numbers of engineers whose normal career development in many industries would otherwise lead them into non-engineering work, or by increasing the number of people taking up accelerated entry routes (more applicable to computing than to most engineering disciplines). Over the longer term, graduate numbers tend to respond to market signals.

Because of this, it is necessary to have some regard for market signals and their impact when designing interventions. One of the main criticisms of the H1-B programme mentioned above is that it may have depressed pay, thus discouraging Americans from entering engineering and computing courses. Discussions with civil engineering students in Irish institutions suggest that the cause of a shortage of civil engineers in the UK reported by the Institute of Civil Engineers may possibly lie in pay levels that are uncompetitive with those for other career options.

1.7.3 Threat of Emigration to Supply of Engineers

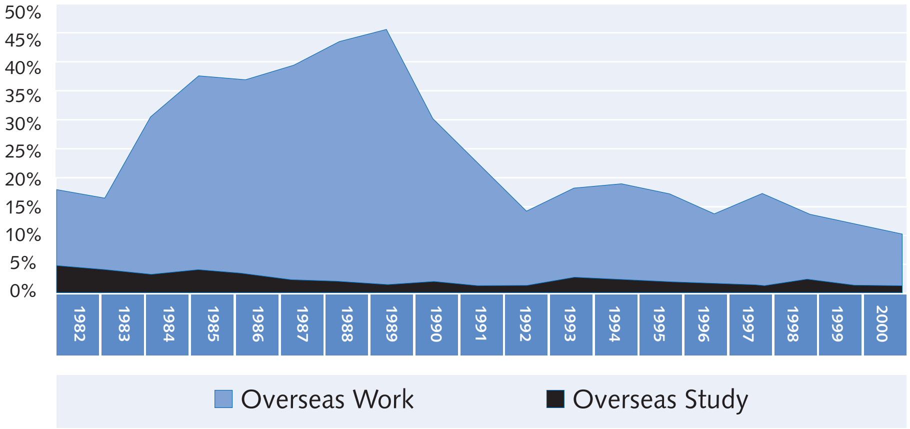
During the mid- to late 1980s, substantial numbers of Irish engineering graduates moved overseas to work, and in some years the number of new degree graduates finding employment overseas exceeded the number finding employment in Ireland. This high rate of emigration followed an expansion in the number of places on engineering courses that appears to have raised numbers graduating to a level that exceeded immediate demand in the economy by a significant margin. However, the high level of emigration was not just an outcome of a lack of opportunity in Ireland. It also reflected the fact that relatively few of the jobs available were in engineering development work, and that most graduates who wished to pursue a career in this area thus had to go overseas to find the type of work they wanted.

In this context, it is relevant to note that many of these graduates subsequently returned to Ireland, and indeed that the availability of large numbers of engineers with substantial international technology industry experience, actively interested in moving to Ireland, was a major selling point for IDA Ireland during the 1990s. Moreover, some of the most significant indigenous technology companies have been founded by engineers who graduated during the 1980s, in several cases after a time spent working overseas.

Since the start of the 1990s, the rate of emigration among degree graduates has fallen to around 10%, reflecting both very much stronger demand in the Irish economy, and the emergence of significant volumes of engineering jobs in design and development arising from the ongoing shift of industry into higher value-adding activities. This has been in the face of strong demand for degree graduates from overseas, with strong IT sector demand driving high levels of demand for graduates in electronic engineering in European electronic hardware and systems companies, and with a persistent shortage of civil engineers in the UK.

13 See Information Technology Outlook 2002, OECD.
14 There was such a shortage in Ireland. The tests (primarily to do with the rate of increase in pay) that fail to demonstrate a shortage when applied to US evidence for the late 1990s clearly demonstrate a shortage when applied to Irish evidence for the same period.

Figure 1.11 % of Primary Degree Engineering Graduates Going to Study or Work Outside Ireland



Source: First Destination of Award Recipients, various years, HEA

Thus, the evidence is that, under conditions of strong demand in Ireland, most engineering degree graduates will now remain in Ireland, even if there is strong overseas demand for their skills.

At diploma and certificate level, the propensity to emigrate has historically been lower than for degree level graduates, although it has been boosted in the past by graduates at both diploma and certificate level joining UK courses to upgrade their qualifications. The development of more add-on diploma and degree programmes in engineering in Ireland has tended to hold more of these graduates within the country in recent years[15].

1.7.4 Supply of Engineers from Overseas

The experience of recent years is that it has been feasible to recruit significant numbers of engineers from elsewhere in Europe to work in Ireland. A shortage of civil engineers that arose from rapid growth in the construction and engineering consultancy industries over the latter half of the 1990s was offset to a significant extent by the migration of significant numbers of civil engineers from the UK. A requirement for electronic engineers to work in integrated circuit design that, around 1999, far exceeded the annual output of graduates in this discipline from Irish colleges, was supplied through a combination of local recruitment and substantial inward migration from a number of different European countries, as well as by the establishment of a number of design centres in overseas locations.

FAS/ESRI Manpower Forecasting Studies Report No. 9[16] examined the likely contribution of immigration to the supply of labour on an economy-wide basis across all occupations. Its forecast for Professional Occupations (of which engineers form a part), and Associate Professional Occupations (of which engineering technicians form a part) is set out in the Statistical Appendix. It demonstrates that immigration has been a significant factor in manpower supply in the past for these occupational areas, and is expected to continue to be so in future.

The likelihood is that it will continue to be possible to recruit engineers in significant numbers from overseas, where this is necessary. Engineers form a much greater part of the graduate mix in many other European countries. Companies in Ireland have, in recent years, recruited significant numbers of electronic engineers from several European countries, both within the EU and in Eastern Europe, under conditions where there was perceived to be an international shortage. Likewise, much of the shortfall in the supply of civil engineers in Ireland in recent years has been bridged by engineers from the UK, under conditions where the UK was perceived to have a shortage of civil engineers. Thus, it is anticipated that it will continue to be possible to attract engineers from overseas when the need in Ireland is sufficiently great.

15 See Statistical Appendix.
16 Estimating Labour Force Flows, Job Openings and Human Resource Requirements, 1990-2005, Sexton et al, April 2001, FAS & ESRI.

However, even if it is feasible to attract engineers from overseas, they will not necessarily form as usable a source of supply as domestically-qualified graduates. Key constraints include:

- possible language and cultural barriers;
- greater difficulty and expense of recruiting away from Ireland;
- relocation costs, whether borne by the engineer or the recruiting company;
- the likelihood that a significant proportion of those recruited will eventually leave the country, depriving Ireland of accumulated experience and expertise, but, on the other hand, possibly improving Ireland's connectedness with global technology industries; and
- country-specific knowledge (in the construction industry there are significant differences in practices between Ireland and the UK {which have generally similar practices} and other European countries).

Some companies, both overseas-owned and indigenous, may find that the other advantages of locating an operation in Ireland are insufficient to prevent them from establishing new operations in countries that have supplies of engineers available, rather than seeking to relocate them to work in Ireland.

A possible alternative or complementary approach to sourcing overseas nationals to work as engineers in Ireland, which overcomes many of the constraints just described is to attract overseas students to take up college places in engineering that cannot attract sufficient indigenous students. This approach is used in the US to ensure a strong supply of graduates with research qualifications in technological and scientific disciplines. It is also used in the UK to boost the number and quality of students taking technological and scientific degrees, while raising funds for colleges through charging fees.

Discussions in the course of interviews with Irish engineering academics indicate that the possibility of attracting students from overseas is already under consideration by a number of engineering faculties. However, most are reluctant to proceed quickly for fear of being seen to be failing in what they see as being their primary duty to provide educational opportunities for Irish (and other EU) students.

International experience suggests that the main areas from which students can be attracted to engineering courses in Europe or North America on a commercial basis are in the Far East, and that the single biggest source of paying students is China. Academics considering the possibility of attracting more students from elsewhere in Europe had mixed views as to what would be required. Some felt that Ireland's reputation as an English-speaking country with solid engineering education, a strong technology sector and an attractive lifestyle would attract significantly more students in the event that a marketing effort was made. Some others thought that, it might be necessary to offer incentives in order to attract sufficient additional students, as there is no persistent shortage of places in engineering schools in the EU or in the main candidate countries.

1.8 Careers of Engineers

It is a common feature of engineering graduates that many who begin their careers in engineering move into other types of work. In some cases, they do this within a well-established industry career structure in which there is a natural progression from engineering into management, administrative or other professional roles. Often their engineering qualification is required for access to those roles, even if it is not used directly. In other cases, many move into non-engineering roles that do not require engineering qualifications, either immediately after graduating, or after some time working in an engineering role.

1.9 Methodology

1.9.1 Data Sources

A wide variety of data sources were used. The main sources relating to industry employment include:

- Census of Industrial Production (CSO);
- Survey of Industrial Employment (CSO);
- Labour Force Survey / Quarterly National Household Survey (CSO); and
- Surveys by National Software Directorate (now the National Informatics Directorate).

The main source of data on recruitment of graduates is the HEA's annual First Destination of Award Recipients in Higher Education Survey. Much of the data on graduate recruitment comes from grossing up the published survey results.

In addition to the published analyses, a more detailed analysis was undertaken of anonymised data on engineering graduates of 2000, supplied by the HEA and HETAC. Each engineering course was classified into one of the following areas, or was excluded as being outside the scope of the study.

The following are the disciplines used in the study.

- Biomedical Engineering - These courses combine content that usually forms a part of a Mechanical Engineering course or a Materials Science course with content on human biology, and on the use of materials suitable for use in medical devices. They are designed primarily to service the skills needs of the medical devices sector.

- Building Services Engineering - Building Services Engineering addresses systems (such as air conditioning or building management systems) that form a part of buildings.

- Chemical / Process Engineering - These degrees focus on production processes for process industries, in Ireland, primarily on production of pharmaceuticals and fine chemicals, with some focus also on food processing.

- Civil Engineering - Courses in Civil Engineering, Structural Engineering and Construction Management have been included under this classification. Courses in Quantity Surveying, Building Surveying, Construction Economics and Architecture, which are frequently classified in Irish education statistics as being within Engineering (Architecture is only treated this way at diploma and certificate level) have been excluded as being outside the scope of the research.
- Computer Engineering - These courses combine features of an Electronic Engineering course with those of a Computing course. Courses whose description includes both electronics and computers have been classified as Electronic Engineering. Courses described as Software Engineering have been

excluded from consideration as they form a part of the mainstream of Computing courses.

- Electronic Engineering - Courses in Electronic Engineering, courses which combine Electronic and Electrical Engineering and courses on the boundary between Electronic Engineering and Computer Engineering have been classified as Electronic Engineering for the purposes of this study. We exclude courses in the manufacture of electronic products, which have been classified as Production / Manufacturing Engineering.

- Electrical Engineering - In the Irish context, Electrical Engineering differs from Electronic Engineering in that it addresses circuits that carry significant amounts of electrical power.

- Mechanical Engineering - Mechanical Engineering courses combine a greater or lesser amount of mechanical design, with some electronic design, and with a greater or lesser amount of Production Engineering. The discipline abuts many of the other disciplines described here, and Mechanical Engineering graduates often find themselves working in these other disciplines, which include Biomedical Engineering, Building Services Engineering, Mechatronic Engineering and Production / Manufacturing Engineering.

- Mechatronic Engineering Mechatronic Engineering courses combine Mechanical Engineering and Electronic Engineering content in approximately equal proportions.

- Other Engineering This classification combines diverse courses in areas such as Aeronautical Engineering, Agricultural Engineering or Polymer Engineering.

- Manufacturing / Industrial Engineering This classification has been used to draw together production-oriented courses with a very wide range of titles, including Production Engineering, Manufacturing Engineering, Industrial Engineering, Management Engineering, Automation, Electronics Manufacturing and Quality Engineering among others.

- Telecommunications Engineering is effectively a branch of Electronic Engineering with a heavy focus on Telecommunications systems.

For most degree level engineering graduates, information was available in the First Destination database as to the actual company that the graduate had joined. This made it possible to reclassify the destinations of these graduates according to a much more detailed classification system, devised specifically for the current study, and to prepare statistics (and grossed up destination estimates) based on this classification system.

The following are the main data sources used to produce statistics on student and graduate numbers.

- Historical data was drawn mainly from the HEA (students and graduates), HETAC (graduates) and the Department of Education & Science (students). Where possible, this was tabulated with the number of students in each year of each course for academic years 1998/9, 1999/0 and 2000/1, and with graduate numbers for 1999 and 2000.

- Current data was drawn from a survey of colleges undertaken for the current study, which asked for student numbers in academic year 2001/2, and graduate numbers in 2001. This was tabulated with the historical data.

Statistics on college applications are drawn from the following three sources.

- Historical Central Applications Office data, as published in the CAO annual report, which includes Engineering and Computing within the same Engineering/Technology classification.

- Central Applications Office data for 2001 and 2002 analysed by a different classification system that has separate Engineering, Construction and Computing classifications.

- A sample of applications data for 2001 and 2002 collected at the level of the individual course in the survey of colleges undertaken for the current study. The question asked colleges to return data on the total number of applications of all preferences that the course had received.

1.9.2 Demand Projections

For purposes of producing demand projections, the study divides the economy into a number of industry sectors, along with a residual "rest-of-economy" sector. The sectors covered are as set out below.

Information & Communications Technology Sectors

- Software and IT Services;
- Electronic Hardware & Systems;
- Integrated Circuit Design; and
- Telecommunications Services.

Construction-Related Sectors

- Construction;
- Engineering Consultancy; and
- Local Authorities.

Other Key Industries

- Medical Devices; and
- Pharmaceuticals & Chemicals.

Rest of Economy

The biotechnology opportunities described earlier are mainly reflected in the Medical Devices and Pharmaceuticals & Chemicals industries. Opportunities in bioinformatics are reflected in Software and IT Services. Any other biotechnology opportunities are assumed to be reflected in the Rest of Economy sector.

The detail of the methodology applied to projecting demand varies between the sectors, and is described in the section of the report that addresses each one. In each case, the methodology has been devised to reflect both the data that is available in relation to the sector and what is known about the drivers of demand for engineers and engineering technicians in that sector.

Where historical data is available, **the first step in the methodology for each sector** is to produce a projection of future employment up to 2012, based on a combination of past trends, what is known about the current circumstances in the industry, and a view as to the total employment in the sector that might result from the potential that appears to exist for the Irish economy, given the current state of knowledge of that potential.

The **second step** in the methodology for each sector is to produce a quantitative view as to the demand for new engineering graduates at degree and at diploma/certificate level that is likely to be associated with that future level of employment.

There are variations between sectors in how this relationship is calculated, reflecting the facts that:

- the nature of the relationship between trends in employment and demand for graduates varies significantly between sectors;
- the range of historical data available also varies significantly; and
- the relevance of historical relationships varies between sectors.

Four main approaches are used as follows.

1. In cases where industry growth has historically been the main driver of demand, and where this is expected to continue to be the case into the future, the projection of demand for a year is made up of two components. These are demand arising from growth, and demand arising from replacement of a percentage of those already working in the sector. Demand arising from growth is calculated on the basis of the percentage of that growth expected to be accounted for by engineers and by engineering technicians. Demand arising from replacement is based on the assumption that a net 2%[17,18], of the population of engineers will be lost to the industry in each year, and that it will be necessary to replace these.

2. In construction and engineering consultancy, regression analyses of historical data have shown that recruitment of new graduate engineers and engineering technicians is relatively insensitive to industry employment growth in any given year, but is sensitive to total sectoral employment. In these cases, it appears that a substantial part of the total recruitment into the industry arises from a combination of the need to fill junior posts, and from a progressive increase in the proportion of total sectoral employment accounted for by engineers and (sometimes) engineering technicians. In this case the projection is based on a

17 In some cases, this is adjusted to 5% for the assumed duration of the current ICT sector downturn, reflecting the likelihood that the outflow from the sector will be elevated while labour market conditions are difficult.

18 In the industries where this approach is applied, the age profile of population of Engineers is relatively young, and the available evidence suggests that (at least under buoyant labour market conditions), the rate of outflow from the industry by young Engineers is not high. A rate of outflow of 2% per annum has been assumed in earlier Expert Group analyses of the software & IT services sector. The steady-state rate of loss would be substantially higher than 2%, and might possibly exceed 5%.

relationship between recruitment, industry employment andindustry employment growth established by regression analyses[19,20].

3. For some sectors, the vision of sectoral development behind the projection requires a significant change in the number of graduate engineers and engineering technicians recruited that does not continue a trend visible in the historical data. In these cases, the logic for the demand projection is just stated.

4. In some cases (local authorities and telecommunications services), there is no overall sectoral employment data available, but there is relevant historical data on recruitment of new graduates into the sector. In these cases, which do not account for a very substantial volume of demand, a description is given of the future industry developments envisaged, and a view is stated as to the recruitment implications of these developments.

In each case, data from the survey of employers of engineers has been used to inform and check the validity of the industry level employment projections.

The **third step** in the methodology for each sector is to divide the employment projections by engineering discipline. Generally, the disciplinary mix projection for an industry is based on the mix of engineering graduates of 2000 recruited by that industry[21]. In some cases, adjustments have been made to reflect industry changes underway. For example, the move to higher value added activities in the electronic hardware and systems sector, and in the medical devices sector, has led to adjustments being made that reduce the proportion of manufacturing/industrial engineers assumed to be required, and increase the proportion of engineers assumed to be required in disciplines relevant to product development.

Data drawn from the survey of engineering employers has been used to check that the projections of the mix of Engineering disciplines required are reasonable.

The discipline-level projections of demand for all of the industries addressed are added to produce a "whole economy" demand projection for each discipline.

Because of the approach used, caution should be exercised in drawing conclusions from the projections at the level of the individual discipline and industry.

1.9.3 Supply Projections for Near Future

The supply projections begin from current and historical data on student and graduate numbers collected at the level of the individual course. For each course, an estimate was made of the number of graduates that will emerge in each of the years when students already in college are expected to graduate in the normal course of events. Thus, for example, an ab-initio degree course will have had four classes in academic year 2001/2, expected to graduate in 2002 (year 4), 2003 (year 3), 2004 (year 2) and 2005 (year 1). Where sufficient historical data was available, the estimate for each year was based on the historical relationship between student and graduate numbers for that course.
Where these data were not available, it was assumed that the number of degree students graduating in the appropriate year would be 80% of first year numbers. For second year numbers, it would be 90%. For third year numbers, it would be 95%, and for fourth year numbers it would be 100%. It was assumed that late graduations would remain sufficiently close to constant so that they could be ignored as a factor in the analysis.

For certificate and diploma courses, historical data was more complete, but where gaps existed estimates of graduate numbers were made on the basis of evidence from similar courses.Each course was classified into one of the disciplinary areas referred to earlier,

19 In each case, a range of different regression datasets has been explored, and the relationship chosen for the model has been based on a representative dataset. Years (1999 & 2000) where there was a severe shortage of graduates available to the industry have been excluded from the regression dataset, as actual recruitment is likely to have been significantly less than demand in these years.

20 The rate of outflow of Engineers from these industries implicit in this analysis is substantially higher than 2%.

21 For most industries, the requirement in 2000 was dominated by one or two disciplines closely connected with the industry, with a small number being recruited from each of a small number of other disciplines. In each case, the general shape of the disciplinary mix recruited in 2000 appears intuitively reasonable, given the characteristics of the industry sector. Thus, this data appears to provide a reasonable basis for projections, provided that the fine detail is treated with some caution.

and the projections within each disciplinary area and level of qualification were aggregated.

For each disciplinary area and level of qualification, an assessment was made of the percentage of graduates likely to be available to Irish employers, which was informed by the First Destination of Award Recipients analysis. These assessments were used to convert the projections of graduate numbers into projections of the supply of graduates from Irish colleges.

The supply projections do not take direct account of immigration as a source of supply. However, as the demand projections are mainly rooted in past recruitment of graduates from Irish colleges, there is implicitly some additional demand that has historically been filled by immigration, and which is assumed to continue to be filled in this manner in future.

The projections suggest that immigration beyond this implicit level may be required. In the analysis, this is treated as a contributor towards bridging the gap between Irish supply and demand, rather than a core part of the supply. Thus, it is addressed in Chapter 5 which focuses on bridging the gap between supply and demand.

1.9.4 Supply Scenarios

Two scenarios describing the future supply of graduates in Engineering are set out.

- **Scenario 1:** The first scenario is based on the assumption that the output at each qualification level and in each disciplinary area will fall in direct proportion to the decrease in the size of the most relevant age cohort, beginning from a base of the number of graduates predicted for the year in which the first years of 2001/2 are expected to graduate. This scenario posits that each engineering discipline holds its share of school leavers relative to all other third level disciplines, but does not benefit significantly from the increases expected in the number of mature students attracted to third level.

- **Scenario 2:** The second scenario takes the first scenario as a base case. It further posits that the reductions in the number of college applications seen in a number of engineering disciplines in 2002 will lead to eventual reductions in graduate numbers, through a combination of reductions in the numbers accepted into courses and raised non-completion-rates. It suggests that these reductions will be cumulative with reductions arising from the falling size of the age cohort, and that they will be permanent.

1.9.5 Research Activities

The main research activities carried out for the study were:

- A survey of engineering employers. This informed the demand projections and provided information on continuing training activities;

- Visits to all Irish third level institutions providing courses in engineering to undertake interviews with engineering academic staff, and group interviews with engineering students;

- Interviews with a range of industry organisations and the industrial development agencies;

- A collation of historical student and graduate statistics, sourced at course level from the Higher Education Authority (HEA), the Department of Education & Science, the Higher Education and Training Awards Council (HETAC), and supplemented with current data obtained by surveying colleges;

- An analysis of anonymised data from the First Destination of Award Recipients databases held by the HEA and HETAC; and

- Review of literature, and other relevant sources of data.

2. Literature Review

2.1 Introduction

The purpose of this chapter is to review the findings of past reports by the Expert Group on Future Skills Needs in relation to engineering, and briefly outline relevant issues in the Report of the Task Force on the Physical Sciences. It also reviews a number of overseas skills studies relating to engineering, and some documentation relevant to skills from overseas engineering institutes.

The review shows that concerns about the supply of engineers are not unique to Ireland, and that many of the issues identified as being important in Ireland, such as subject choice in school and the need to promote engineering as a career, are also highlighted widely by studies in other countries.

2.2 Previous Reports of the Expert Group on Future Skills Needs

Each of the three main reports to date of the Expert Group on Future Skills Needs has addressed the supply and demand for engineers and engineering technicians in Ireland. In each case, the reports have addressed demand for engineers and engineering technicians in the context of the IT industry.

2.2.1 First Report

The First Report of the Expert Group (1998) made projections for the supply and demand for "Engineering Professionals" and "Engineering Technicians", and for "Computer Science Professionals" and "Computer Science Technicians". In the terminology of the report, a technological "professional" is a person who has completed a four year primary degree or a higher degree, while a "technician" is a person who has completed a diploma or a certificate.

The report examined three scenarios, and concluded that policy should be based on the scenario reflecting the highest level of employment growth, which would require a significant increase in graduate numbers above that already planned. This was justified by reference to a range of economic policy and industrial policy objectives, to labour market conditions, to international projections of demand, and to the expectation that overproduction of graduates would at worst result in young people having skills with which they could earn high incomes abroad.

The report projected the following average annual demand for engineers and engineering technicians from 1998 to 2003:

Engineering Professionals: 2,000

Engineering Technicians: 1,800.

The report made a number of proposals about increasing the number of qualified people available each year. These proposals were in addition to commitments to increases that were already in place. The main specific proposals relevant to engineering were:

- provision of multi-skilling/conversion courses in other words, graduate diplomas and taught masters courses under the Advanced Technical Skills (ATS) programme;

- more full time education provision, which formed the basis for planning to put in place more places in electronic engineering; and

- implementation of the Accelerated Technician Programme, under which an intake of students separate from the usual CAO intake works towards a certificate level qualification over a period of 18 months, through a combination of college-based learning and industrial experience.

2.2.2 Second Report

The section of the Second Report of the Expert Group (1999) addressing information technology revisited the issue of demand for engineering degree and technician graduates. It found that the mix of qualifications required by the electronics hardware sector had changed, with degree professionals representing 20% of employment (compared to 13% in the First Report), and technicians representing 22% (compared to 25.5% in the First Report).

The Report noted a number of points tending to modify the supply of graduates in engineering. These included:

- an extra intake of over 500 into undergraduate electronic engineering programmes; and

- that the demands of the electronic hardware sector meant that extra technician places had tended to be allocated to engineering technician programmes, rather than to computing.

Many of the recommendations in the First and Second Reports have been implemented.

2.2.3 Third Report

The section of the Third Report of the Expert Group (2001) addressing information technology again addressed supply and demand for engineers and engineering technicians.

As with the First Report, projected demand for engineering professionals and technicians was based on economy-wide job projections from the FAS/ESRI Manpower Forecasting Model, with projected demand from the information technology industries replaced by projections from a study of the skills needs of the electronic hardware sector.

The report's projections for average annual demand and supply of graduates from 2001 to 2005 are set out in Table 2.1.

Table 2.1 Annual Average Demand and Supply of Third Level Skills in Information Technology, 2001 2005, from Third Report of Expert Group

	Demand	Supply	Balance
Engineering Professionals	2,459	1,580	-879
Engineering Technicians	839	1,099	260
Total	**3,298**	**2,679**	**-619**

The projections represented an increase in demand for engineering professionals, and a sharp decrease in the share of electronics hardware employment represented by engineering technicians from 25.5% in the First Report and 22% in the Second Report, to 14%.

The projections were based on research work completed in December 2000 on behalf of the Expert Group. Prior to the publication of the Report in 2001, the Expert Group considered the likely impact of the IT industry downturn that was then becoming apparent, and concluded that it was "unlikely to have a major impact on the IT sector in

Ireland in the medium- to long-term". However, it recognised that "a prolonged recession in the U.S. economy could have a negative impact on future growth in the sector in Ireland".

The main recommendations of the Report relevant to engineering were as follows.

- The investment of €165m in IT education and training over five years, targeted on the following areas:

  1 - increased provision of part time education and company upskilling to increase access to third level education for mature students, and for marginalised and disadvantaged groups;

  2 - increased provision of part-time postgraduate conversion courses;

  3 - urgent measures to improve completion rates in IT-related studies in third level institutions; and

  4 - new provision for equipment renewal and the development of state-of-the-art facilities for third level education in IT-related areas.

- Urgent action at second level to ensure that future levels of intake into full-time third-level education in IT-related areas remains constant, including:

  - review of structures of careers guidance so that it is effective, relevant, accessible to all students and fully resourced;

  - better information for prospective 3rd level students on the content of third level IT programmes in IT-related areas, and on the career paths they lead to;

  - promotion of awareness of IT careers, with particular efforts to be made to attract females;

  - action "to promote the study of honours Maths, Physics and Chemistry Leaving

  Certificate level", which was seen as being necessary to secure further intake into third-level Engineering courses.

- Promotion and expansion of partnerships between third-level educators and industry.

- Encouragement of the immigration of IT professionals into Ireland.

There has been good progress in implementing the recommendations of the Third Report.

2.3 Reports by the Institution of Engineers of Ireland

2.3.1 Introduction

During 2000, the IEI published three documents addressing the supply of engineers and engineering technicians in Ireland. These were:

- A Review of Our Engineering Manpower Shortages at Degree and Technician Levels Discussion Paper, March 2000;

• To Ensure Future Prosperity … More Engineers Needed Now! Proceedings National Conference 2000, October 5th & 6th 2000; and

• Solving the Shortage of Engineers Problem, Submission to Government, October 2000.

2.3.2 Review of Manpower Shortages Discussion Paper

This document reviewed the Institution's past responses to "emerging shortages of professional engineering manpower". It highlighted a "serious shortage" of engineers and engineering technicians of all types, referring to data from the 1999 FAS/Forfas/ESRI Vacancies Survey in support of this view. It identified a number of factors that would tend to boost demand for engineers; the National Development Plan, investment in research, technology development and innovation, and construction industry growth.

The report set out a number of proposals, including a key recommendation that called for targets to be set for the proportion of graduates to come from engineering. It argued that degree level numbers should rise sufficiently to account for 20% of graduates at that level, and sub degree (i.e. diploma and certificate) numbers should rise to account for 30% of graduates.

2.3.3 IEI National Conference Proceedings, 2000

The conference proceedings included thirteen papers addressing the supply and demand for engineers an engineering technicians in Ireland. Conclusions and recommendations emerging from the conference were set out in a Submission to Government.

2.3.4 Solving the Shortage of Engineers Problem, Submission to Government

This document set out the conclusions and recommendations that emerged from the IEI National Conference of 2000. The key conclusions set out were that:

• there was a significant shortage of engineers and technicians;

• if unaddressed, this shortage could adversely impact on economic growth and on implementation of the National Development Plan; and

• measures should be put in place to solve the problem.

The main recommendations were in the following areas.

• Funding for the STEPS[1] programme by government and industry should be increased in order to allow it to be expanded.

• The IEI and industry should seek to attract more women into the profession through promotional activities and through more flexible and family-friendly working arrangement.

• A range of measures should be taken to promote and improve the study of higher-level Mathematics, Physics and Chemistry at second level.

• Issues relating to the nature and content of engineering programmes, and relating to progression from diploma and certificate level to degree level, should be reviewed.

• Continuing professional development should be promoted.

1 STEPS is an initiative to promote Engineering (and also Science and other areas of Technology) as a career, which is funded by the Department of Education & Science and industry, and operated by the IEI.

2.4 Report of Task Force on the Physical Sciences

Concern over the supply of school leavers interested in pursuing studies in science and engineering at third level led to the appointment of a group to review the reasons for a fall in the numbers of students studying Physics and Chemistry at second level. In 1990, 16% of Leaving Certificate students took Chemistry, and 20% took Physics. In 2001, just 12% took Chemistry, and 16% took Physics. The Report of the Task Force notes that acceptances of third level degree places in science, engineering and technology (including computing) courses fell from 33% of the total in 1999 to 30% in 2001. Acceptances of certificate and diploma places fell from 51% in 1997 to 46% in 2001.

Key issues identified by the Report of the Task Force included the following.

- While just 3% of the student cohort was in schools not offering any physical science subject to Leaving Certificate level, there were large variations in participation rates. Many schools were found to operate with relatively few Leaving Certificate physical sciences students.

- Student choice was found to be the main factor affecting take-up of physical sciences subjects. Key perceptual issues were a perception that physics and chemistry are difficult, and a perception that the work of scientists and technologists is difficult, complicated, boring and poorly paid.

- Preliminary findings confirmed that the perception that it is more difficult to get higher grades in the physical sciences were based on fact. The analysis suggested that the same issue was true of higher level mathematics.

- The mathematical competence of students in schools and higher education institutions was seen as being a major issue. The report highlighted a high failure rate in Ordinary Level Leaving Certificate Mathematics, which worsened significantly in 2001. A failure rate of 19% among males significantly reduced the pool of potential candidates to study engineering at diploma and certificate level, and for unaccredited degree courses. According to the report, "students' perception of the difficulty of mathematics and their poor performance at the subject both act as barriers to participation in the sciences at third level".

- The report took the view that measures to enhance recruitment will need to be complemented by aggressive measures to address high rates of non-completion of third level science, engineering and technology courses.

Among the large number of specific actions recommended, the following are of particular relevance to the current report:

- a review of Mathematics at second level;

- ensuring equity in grading physical science subjects in the Leaving Certificate;

- promoting recruitment to higher education science, engineering and technology;
- promoting access, transfer and progression into higher education science, engineering and technology;

- promoting quality in teaching and learning within undergraduate science, engineering and technology; and

- providing physical infrastructure to support quality in the teaching and learning environment, through refurbishment and equipment upgrading of laboratories.

Since the report was published, Leaving Certificate statistics for 2002 have shown:

- A modest improvement in the percentage of Leaving Certificate students taking Chemistry and Physics;

- A sharp decline in the number of students receiving high grades in Higher Level Mathematics, which suggests that the apparent shortcomings in equity of grading may have worsened; and

- A very slight improvement in the percentage of students taking Ordinary Level Mathematics reaching or exceeding the D3 threshold that is a requirement for many courses, from 83.4% to 85.3%.

2.5 A Sample of International Engineering Skills Studies

A number of studies of engineering skills undertaken in other countries were reviewed. These included:

- UK Review of the Supply of Scientists and Engineers, Consultation Paper, Gareth Roberts, June 2001, HM Treasury. Also, Summary of the Responses to the June 2001 Consultation Paper, November 2001;

- Germany Memorandum des Ingenieurdialogs: Zukunftssicherung des Ingenieurs in Deutschland, May 2001, Federal Ministry of Education and Research; and

- Australia Supply and Demand for Scientists and Engineers, Sally Borthwick and Terry Murphy, Skills Analysis and Research Branch, Department of Employment, Education, Training and Youth Affairs, March 1998.

2.5.1 The Roberts Review in the UK

The brief of the Roberts Review was to focus on supply and demand for scientists and engineers to participate in research and development, rather than on the full range of destinations.

The Consultation Paper raises a number of issues about second level education that parallel current concerns in Ireland.

- There is a concern about the teaching of the physical sciences and Mathematics at second level that parallels the concerns that inspired the creation of the Task Force on the Physical Sciences in Ireland.

- Some universities and companies are reported as thinking that Mathematics and Science are perceived to be 'hard' subjects at school, which constrains the number of pupils taking these subjects at A-level.

Of cautionary interest, given the current fall-off in applicants for Irish engineering courses, is a view that "the quality of students entering (UK) science and engineering degree courses from school had declined, as well as the quality of science and engineering graduates emerging from them."

2.5.2 Memorandum on the Future of the Engineering Profession in Germany

According to the Memorandum, the overall number of students beginning courses in engineering in Germany peaked around 1990, and fell steeply before starting to rise again in 1998. In Mechanical Engineering, the number of students beginning fell from approximately 33,000 in 1990 to approximately 20,000 in 1997, before rising to around 23,000 in 1999. In Electrical/Electronic Engineering, the number fell from approximately 22,000 in 1989 to approximately 12,000 from 1995 to 1997, before rising to around 14,000 in 1999.

Based on this intake data, the Memorandum projected a resulting fall in engineering graduate numbers from 52,000 in 1996 to 31,000 in 2002. The rise was intake was expected to lead to some increase in graduate numbers after 2002, reaching 34,800 in 2004. This was in a context where demand for engineers was expected to rise.

Set against this, however, is the fact that over 50,000 engineers were out of work in Germany in 2000, equivalent to approximately 5% of those in employment. Of these, 64% were older than 45. Many in this group were having difficulty in finding work. While Ireland does not have a significant problem with unemployment among mature engineers the existence of such a problem in a country with a much longer history of engineering-intensive industry is cautionary.

The main areas where recommendations relevant to the current report were made were in:

- promoting the study of engineering;
- updating and restructuring third level engineering programmes; and
- promoting continuing education for engineers.

2.5.3 Supply and Demand for Scientists and Engineers in Australia

One of the main topics of this report was "whether the supply and quality of scientists and engineers is adequate for present and future labour market requirements.

The report concluded that "there appear to be no major imbalances between overall supply and demand for scientists and engineers in the workforce, judging from data on wage relativities, vacancy levels and unemployment rates". Comparing projections of science and engineering enrolments in higher education with demand projections taken from another study, it did not anticipate "any substantial imbalances between the overall supply and demand for scientists and engineers over the next decade". However, it did observe that long term projections of demand need to be treated with some caution.

Of interest in the Irish context is that the report expressed some concern over some trends in subject choices at second level, including the share of enrolments in advanced Mathematics, Physics and Chemistry.

2.6 Reports from International Engineering Institutions

In addition to overseas skills studies, skills related documents from a number of engineering institutions were reviewed. The institutions concerned include:

- IEEE-USA - The USA division of the Institute of Electrical and Electronic Engineers;
- ICE - The Institute of Civil Engineers; and

- IChemE - The Institute of Chemical Engineers.

IEEE-USA's major concern in relation to skills is to do with immigration policy. The organisation sees policies promoted by industry to resolve technological labour shortages as depressing pay, and exposing engineers to risks of unemployment. The Institute believes that immigration disrupts the operation of market signals that should act to attract more applicants for courses in engineering when shortages appear. Thus, in the latter half of the 1990s, the intake into computer-related courses in the US increased, just as industry organisations were expressing concern about falling student numbers. While there is a significant time delay between the appearance of a shortage and the emergence of more graduates from undergraduate courses, the IEEE-USA view of the experience of demand for IT professionals in the 1990s is that suitable people can be attracted from other backgrounds at times when demand is expanding quickly.

As with the findings referred to earlier in relation to Germany, IEEE-USA has found significant unemployment among engineers, even at times of high demand, and particularly among more mature age groups.

The main concern of the Institute of Civil Engineers in relation to skills is that it sees a persistent shortage of civil engineers in the UK. The Institute regularly undertakes surveys, which appear to confirm this view. The Institute would like to see more students studying civil engineering, and entering the profession.

The **Institute of Chemical Engineers** highlights evidence showing that Chemical Engineering is the third best paying profession in the UK, after medical doctors and solicitors. It uses this evidence in material to attract people into the profession.

2.7 Key Conclusions from Literature Review

The main points emerging from the literature review include the following.

- Previous Expert Skills Group Reports have effectively addressed demand for engineers through addressing the needs of two sectors; an electronic hardware sector, and a rest-of-economy sector. The majority of similar studies from overseas do not address the balance between supply and demand for engineers in this quantitative manner. However, as a number of other specific sectors are major employers of engineering graduates, there is a good case for a more detailed sectoral breakdown, such as that used in this report.

- Concerns about the supply of engineers are not unique to Ireland. Many of the issues identified as being important in Ireland, such as subject choice in school and the need to promote engineering as a career, are also widely highlighted by studies in other countries.

- While there are instances of significant shortages of engineers, there is no sense of any significant persistent shortages of engineers globally. It is noteworthy, however, in the context of the findings that emerge later from the analysis of supply and demand for engineering graduates in Ireland that the Roberts Review has found a possible shortage of electronic engineers in the UK, while the evidence from Germany is that electrical/electronic engineering suffered from the greatest percentage decline in student intake during the 1990s. It is also noteworthy that the Institute of civil engineers has found what it regards as a persistent shortage of civil engineers in the UK.

3. Demand Analysis

3.1 Introduction

3.1.1 Sectoral Classification

The analysis of demand for engineers projects demand for a number of sectors, and aggregates the projections together. The following sectors are addressed.

Information and communications technology (ICT) industries:

- Software & information technology (IT) services;
- Electronics hardware and integrated circuit (IC) production;
- Integrated circuit (IC) design; and
- Telecommunications services.

Construction-related industries:

- Construction industry and engineering consultancies; and
- Local authorities.

Medical devices, and pharmaceuticals & chemicals (pharmachem).

Rest of economy.

3.1.2 Levels of Qualification

The levels of qualification at which projections are made are as follows:

- Degree (primary degrees, higher degrees and postgraduate diplomas); and
- Diploma or certificate (undergraduate qualifications)

3.1.3 Engineering Disciplines

This study addresses supply and demand for most, but not all, engineering disciplines. **Software engineering and closely-related computing disciplines are excluded from consideration in order to minimise overlap with the Expert Group on Future Skills Needs' work on Software skills**[1]. Courses with "Computer Engineering" and "Telecommunications Engineering" in their titles, whose content tends to have affinities both with electronic engineering and computing courses, have been classified as forming part of engineering for the purposes of the study.

The study addresses the following disciplinary areas within engineering:

- Biomedical Engineering;
- Building Services Engineering;
- Chemical / Process Engineering;
- Civil Engineering;

1 The reason for omitting computer engineering graduates for this sector is because they effectively form a part of a bigger computer graduate pool. Survey evidence indicated it was impossible for employers in this sector to distinguish demand for computer engineering graduates from all other types of computing graduates. Hence, although projections for the demand for computer engineers for various subsectors were made except for this one sector, software and IT services sector, the total figures for engineering demand excludes all computer engineering graduates for ease of comparison between projected demand and supply.

- Computer Engineering;
- Electronic Engineering;
- Electrical Engineering;
- Mechanical Engineering;
- Mechatronic Engineering;
- Manufacturing / Industrial Engineering;
- Telecommunications Engineering; and
- Other Engineering.

3.1.4 Data Sources and Methodologies

The approaches taken to developing projections vary between sectors, and between levels of qualification. This is partly because the available data sources and the systems of classification they use are diverse, and partly because differences between sectors make different approaches necessary.

Two main approaches are taken. One builds up a model of demand primarily from employment projections and data on the occupational mix in the sector. The other also uses employment projections, but bases the projections of demand for engineers and engineering technicians on an understanding of the relationship between employment trends and graduate recruitment. Both approaches are informed by expert industry and development agency input.

For both approaches, projections of total demand for engineers and engineering technicians are disaggregated by engineering discipline, based on a combination of historical data and views as to the future mix that is likely to be required.

3.1.5 Limits to Use of Projections

The projections made reflect the vision of the future of Irish industry set out in Chapter 1, and provide a basis for understanding what the engineering skills requirements will be if that is to be achieved. The projections are not intended as predictions that this will necessarily be the outcome, nor do they imply that the outcome described is necessarily the most likely one.

Projections of demand broken down by engineering discipline should be treated with particular caution. They are intended to give no more than an approximate indication as to the relative demand between different disciplines.

3.2 Industries Employing Engineers and Engineering Technicians

Figures 3.1 to 3.3 show how the mix of Irish industries recruiting new engineering graduates has varied over a ten year period[2]. The key points to emerge are that:

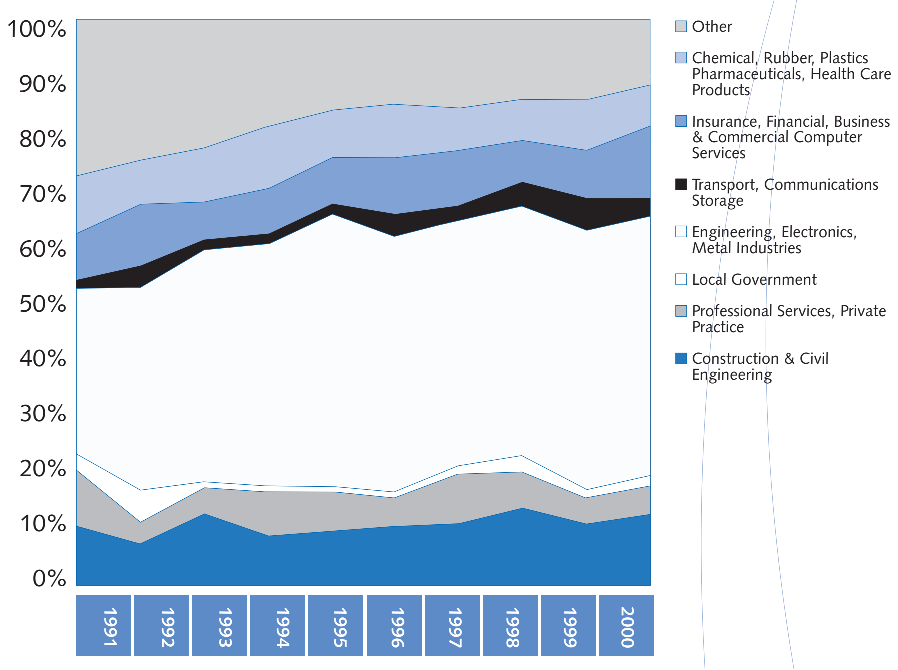
- the share of employment of new primary degree and of diploma and certificate graduates accounted for by "other" sectors fell substantially over the period;
- the share of graduates at primary degree and at diploma and certificate level accounted for by each sector is not highly volatile;

2 The same data are presented in terms of absolute numbers in figures 1.8 to 1.10.

• a higher proportion of higher degree graduates, than of graduates at lower levels go to the "other" industries, which tend not to be core employers of engineering graduates; and

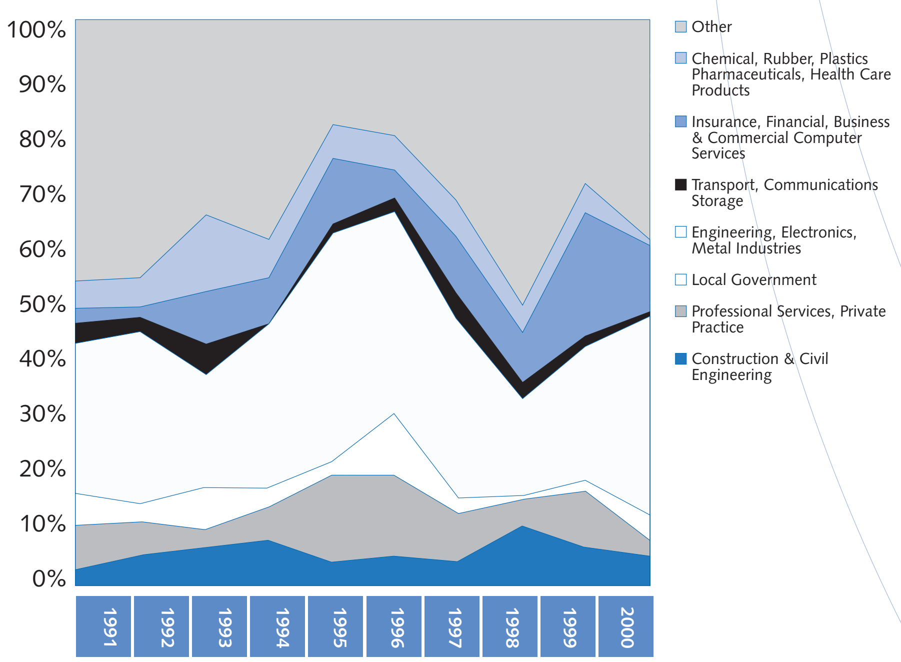
• the industry destinations of higher degree graduates are volatile.

Figure 3.1 Recruitment of New Primary Degree Graduates by Irish Employers Classified by HEA Industry Graduates of 1991 to Graduates of 2000



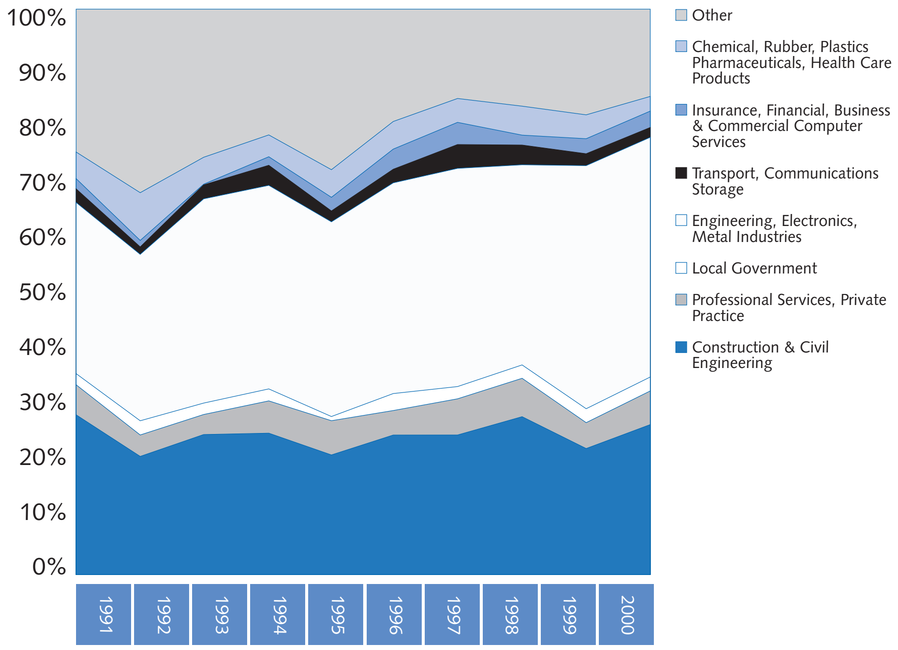
Source: Grossed up from data from First Destination of Award Recipients in Higher Education, edition from 1991 to 2000, HEA.

Figure 3.2 Recruitment of New Higher Degree Graduates by Irish Employers Classified by HEA Industry Graduates of 1991 to Graduates of 2000



Source: Grossed up from data from First Destination of Award Recipients in Higher Education, edition from 1991 to 2000, HEA.

Figure 3.3 Recruitment of New Dip and Cert Graduates by Irish Employers Classified by HEA Industry Graduates of 1991 to Graduates of 2000



Source: Grossed up from data from First Destination of Award Recipients in Higher Education, edition from 1991 to 2000, HEA.

However, there are benefits to be gained from a more detailed analysis of the data than that which is published by the HEA.

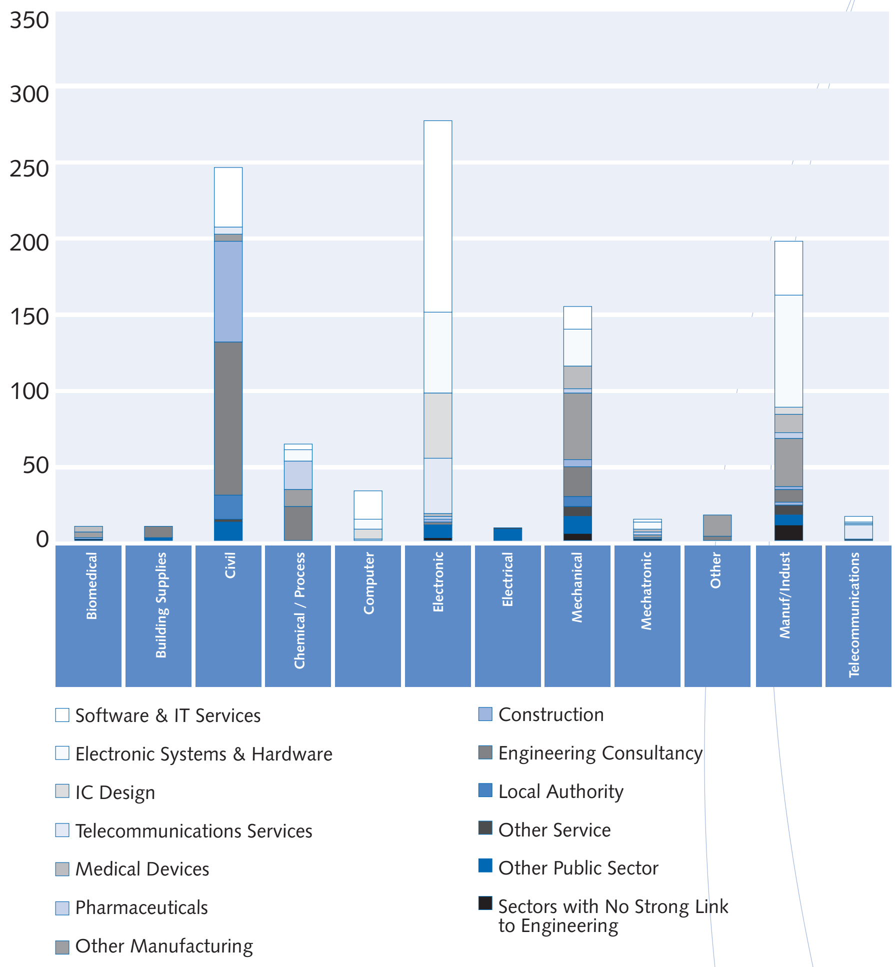
The process of producing a more detailed analysis is very labour-intensive. Thus, as a matter of practicality, this analysis was undertaken for the graduates of just the most recent year for which the survey had been completed 2000.

The data in Figures 3.1 and 3.3 suggest that a more detailed analysis of data on graduate destinations for graduates of 2000 is likely to be reasonably representative of earlier years for primary degrees and for diplomas and certificates, and is likely to form a reasonable starting point for future projections. Data for higher degree graduates of 2000 (Figure 3.2) is less representative of earlier years, but the numbers involved are relatively small, and the data for 2000 are sufficiently representative of the averages of earlier years, so that they can be used with some care.

Figures 3.4 to 3.7 set out estimates of the number of new engineering graduates of 2000 entering various industries, for primary degrees, postgraduate qualifications, diplomas and certificates based on an analysis of the First Destination databases of the HEA and HETAC. The detailed numbers behind these charts are set out in Appendix A. The analysis undertaken has classified each engineering course in accordance with the disciplinary framework being used for the study.

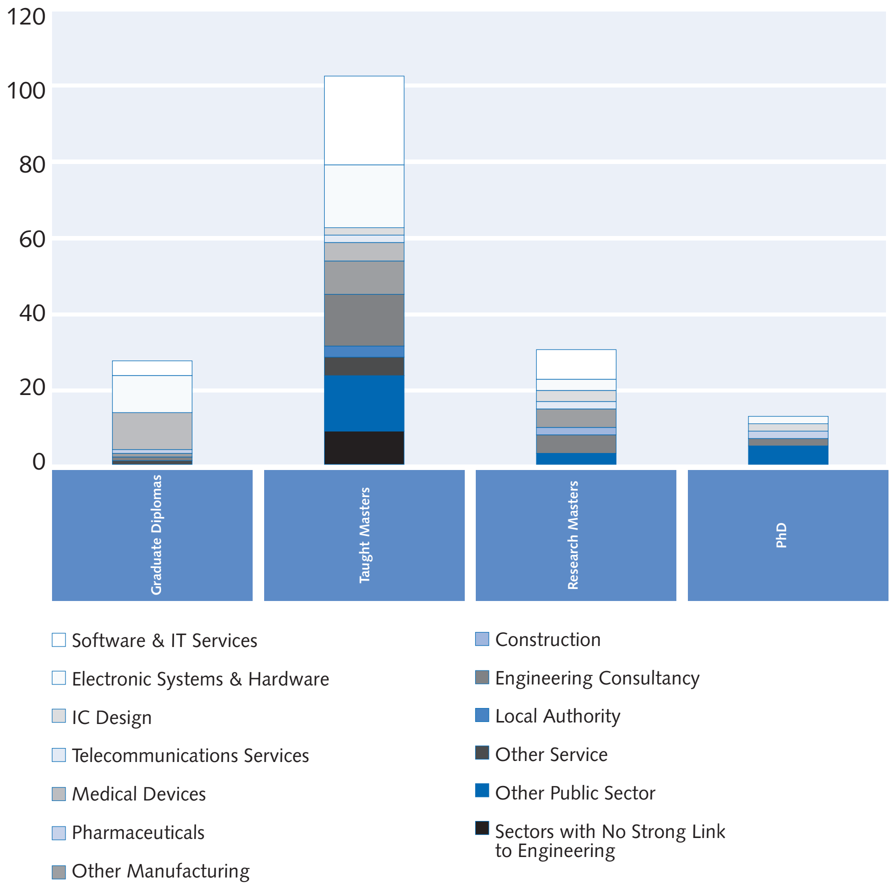
Two different industry classification systems are used. For primary degree and postgraduate qualifications, a majority of graduates have their employer recorded in the First Destination database. Thus, it was possible to reanalyse the data recorded in accordance with a classification system tailored to the requirements of the current study. In the case of certificate and diploma graduates, however, most just have the industry recorded, and thus it was necessary to use the standard HEA First Destination industry classification, which provides a lower degree of resolution.

Figure 3.4 Estimates of Numbers of Primary Engineering Degree Graduates of 2000 Entering Employment in Ireland in Various Sectors



Source: Based on grossing up an analysis of employers recorded in the HEA's First Destination database for graduates of 2000.

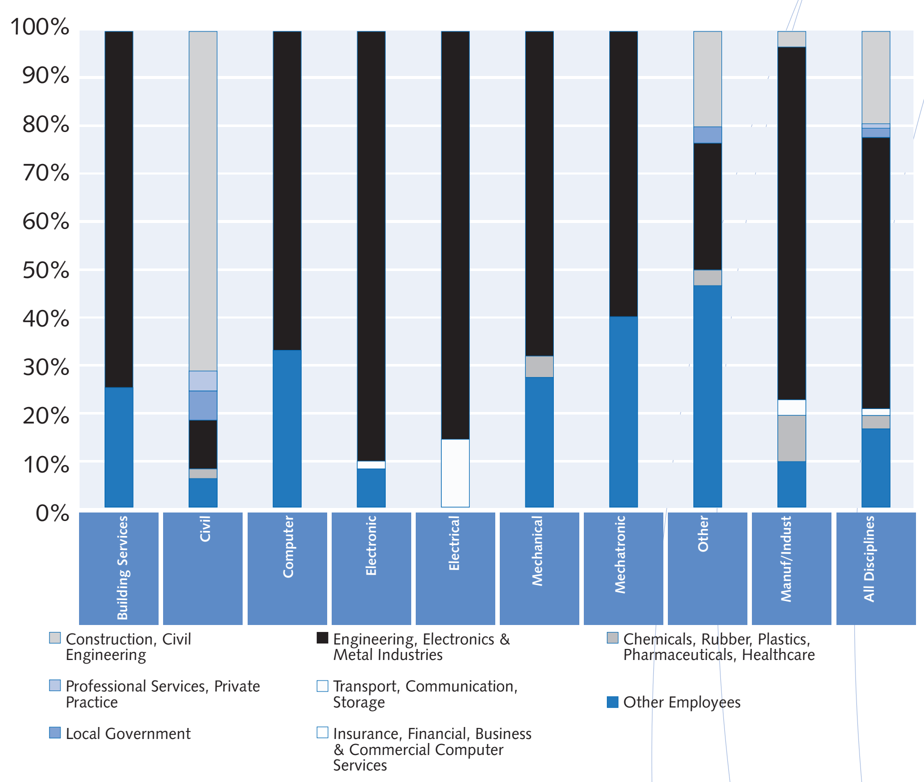
Figure 3.5 Estimates of Numbers of Postgraduate Engineering Graduates of 2000 Entering Employment in Ireland in Various Sectors



Source: Based on grossing up an analysis of employers recorded in the HEA's First Destination database for graduates of 2000.

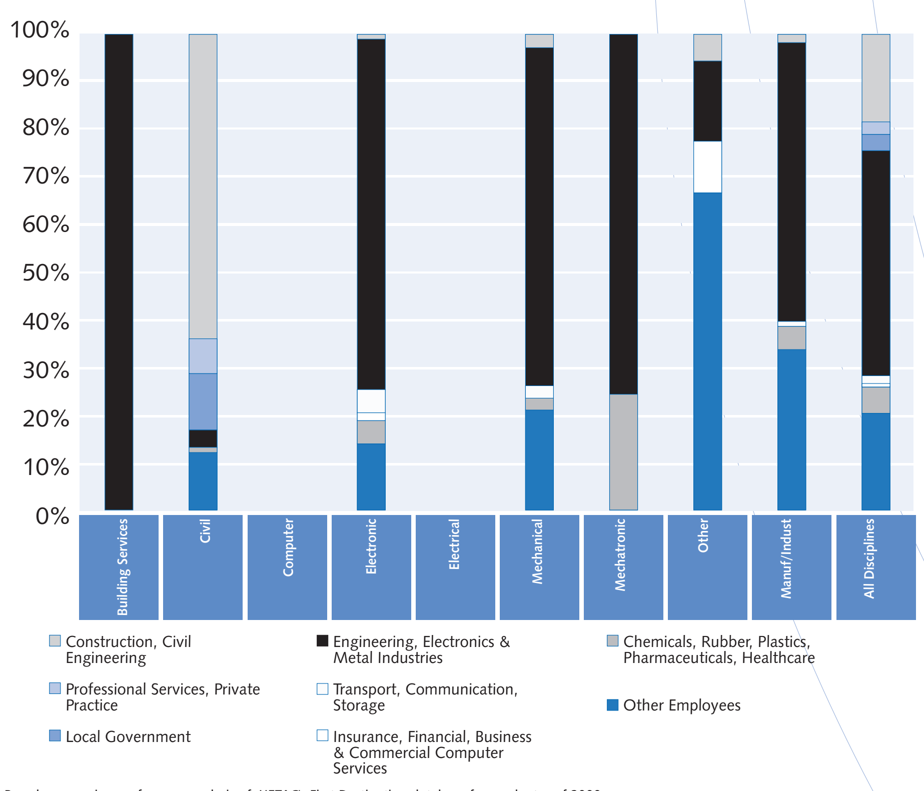
The Demand and Supply of Engineers & Engineering Technicians

Figure 3.6 Estimates of Percentages of Diploma Graduates Qualifying in 2000 Entering Employment in Ireland in Various Sectors



Source: Based on grossing up from an analysis of HETAC's First Destination database for graduates of 2000.

Figure 3.7 Estimates of Percentages of Certificate Graduates Qualifying in 2000 Entering Employment in Ireland in Various Sectors



Source: Based on grossing up from an analysis of HETAC's First Destination database for graduates of 2000.

The main point emerging from these charts is that a very large part of total Irish demand for graduates in engineering comes from just two broad sectors of industry:

- Information & Communications Technology Industries (software & IT services, electronic systems and hardware, integrated circuit design, telecommunications services); and

- Construction-Related Industries (construction, engineering consultancy[3] and local authorities).

75.2% of primary degree engineering graduates of 2000 entered these two areas.

The data available on diploma and certificate graduates suggest a pattern that is very similar to that for degree graduates. ICT industries are likely to form the main sources of employment within "Engineering, Electronics & Metal Industries", "Transport, Communication, Storage" and "Insurance, Financial, Business & Commercial Computer Services". Construction-related industries are likely in total to be closely equivalent to a combination of "Construction, Civil Engineering", "Local Government and " Professional Services, Private Practice". The analysis shows 80.8% of engineering diploma graduates and 74% of certificate graduates of 2000 entering these industry classifications.

51.5% of postgraduates of 2000 entered these broad industry areas. The main differences in destinations between primary degree graduates and graduates of postgraduate courses are that postgraduates were much more likely to enter education or the public service, and that the medical devices sector recruited a significant proportion of the graduates from small number of taught postgraduate courses.

Many other sectors that are economically and socially important recruit smaller numbers of engineers, but are heavily dependent on those that they recruit. Most manufacturing industries rely on engineers to function and to contribute to innovation. A range of service industries also rely heavily on engineers. These include rail transport, aviation and electricity supply among others.

Because most engineering graduates are recruited by a small number of industry sectors, the main focus of the work on projecting future demand has also been on a small number of sectors. In addition to the broad ICT and construction-related areas, projection exercises have also been undertaken for two industries that are economically important, and which have significant requirements for specific types of engineering graduate. These are medical devices and pharmaceuticals/chemicals.

3.3 Current State of Demand for Engineering Graduates

After a period of very rapid economic progress from the mid-1990s, growth in the Irish economy slowed during 2001 and did not recover during 2002. The slowdown can be traced to a sharp fall in the rate of increase of global demand for information and communications products and services that became apparent late in 2000. This led a general global economic slowdown. At the time of writing, neither the market for ICT products and services nor general global economic conditions have recovered.

The slowdown has impacted on all of the main sectors in Ireland employing Engineering graduates. Key aspects of the impact of the slowdown on the broad ICT area include the following.

- There have been significant job losses in the electronic hardware sector.

- Growth in employment in software and IT services slowed sharply during 2001, and it seems likely that there has been a net loss of jobs during 2002.

3 Engineering consultancy in Ireland is predominantly related to construction, but there are other strands, of which chemical and process engineering is the most significant.

- Sharp slowdowns in downstream markets have sharply reduced the rate of growth in employment in the integrated circuit (IC) design industry. With some job losses, it is likely that employment may have fallen during 2002.

- The development of telecommunications services has slowed sharply.

In addition to losses in employment of engineers and engineering technicians, the market for new graduates in disciplines that depend on these sectors for employment opportunities is soft. The main engineering disciplines affected are Electronic Engineering, Production/Manufacturing Engineering, Computer Engineering and Telecommunications Engineering. Demand for Mechanical Engineers will also suffer, although they are better diversified in terms of usual industry destinations.

In most other manufacturing sectors, growth has slowed during 2001 and 2002, although generally not to the same extent as in the broad ICT sector. The likelihood is that these other sectors will continue to recruit in 2003, although at a lower rate than in recent years.

In the broad construction area:

- growth in employment in construction continued up to early 2002, but employment is now falling; and

- many local authorities have recruited significant numbers of engineers during 2002.

As the primary research for this report was being undertaken in the first half of 2002, demand for engineers and engineering technicians from the construction industry and engineering consultancies still appeared to exceed supply. However, there were signs that the labour market was softening.

- Some colleges indicated that there were fewer pre-graduation job offers to final year civil engineering students.

- Construction companies and engineering consultancies surveyed mostly indicated that they expected slow growth in the number of engineers and engineering technicians they employ.

Since then, the available evidence is that the labour market has continued to soften, with many companies that recruited substantial numbers of civil engineers in recent years now seeking to consolidate at around their current employment levels. Future demand for engineers for construction-related work will be sensitive to public spending on infrastructure under the National Development Plan and the National Spatial Strategy.

3.4 Demand from ICT Sectors

3.4.1 Economic Background

The ICT sector periodically goes through periods of slow market growth, and has always emerged from them strongly in the past. Such slowdowns occurred previously around 1975, 1980-1982, 1987-1988 and 1990-1993.

Viewed from a labour market perspective, the current downturn in growth in demand for ICT products and services is the worst in the global sector's history. For example, in the trough of the (previous worst) 1991 downturn, the year on year change in US employment in SIC 737 (Computer and Data Processing Services) fell briefly to 2.4%. It has now been below that level since November 2001, and was -1.6% over the year to December 2002[4].

Figure 3.8 Year-on-Year Growth in Employment in US SIC 737 Computer & Data Processing Services Jan 1973 to Dec 2002

Source: Based on data from Bureau of Labor Statistics

Macroeconomic data from the US shows that the ICT sector downturn there has gone through a number of phases.

1. In Q3 2000, there was a sharp downturn in economic growth, which continued through 2001 (Figure 3.9). This was compounded by a slide in the share of GDP devoted to investment in fixed assets, which also started in Q3 2000 and which has continued to the present (Figure 3.10). For two quarters, the share of investment in fixed assets devoted to information technology continued to rise, insulating the ICT sector from the general fall in investment in fixed assets.

2. In Q1 and Q2 2001, there was a sharp fall in the share of investment in fixed assets devoted to information technology (Figure 3.11), which compounded both the continuing fall in GDP and the continuing slide in the share of that GDP devoted to investment in fixed assets. This marked the start of the downturn in ICT spending as seen through macroeconomic indicators[5].

3. In Q4 2001, GDP growth started to recover. At the same time the share of investment in fixed assets devoted to information technology also started to recover. However, the slide in the share of GDP devoted to investment in fixed assets continued. This appears to now be the main factor driving the continuation of the US ICT market downturn.

Thus, the main factor depressing US ICT spending now appears to be a general reluctance to invest in productive capability. Explanations for the continuation of the downturn based on a general loss of confidence in the productive value of investment in ICTs, or on a general overhang of excessive past investment specifically in ICTs[6], are not consistent with the data.

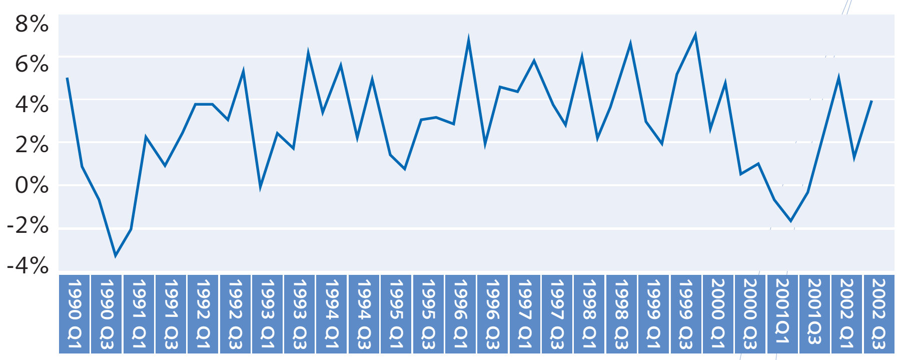
It is reasonable to expect that the slide in the share of GDP devoted to investment in fixed assets will not continue indefinitely (it is already close to a 10-year low), and this gives good cause for expecting that the downturn in ICT spending in the US will also come to an end.

4 The US is the most useful example because it is the biggest single market for ICT products and services, representing approximately 37% of total ICT demand, and approaching 50% of demand for software and IT services. (Source of data: EITO 2002) Moreover, trends in the US often lead trends in Europe.

5 A Morgan Stanley report of November 2000, projecting a fall in ICT spending from the start of 2001, is widely remembered as marking the start of the downturn.

6 An exception here is in telecommunications, where a significant amount of excess capacity overhangs many parts of the market for new investment.

Figure 3.9 US Real GDP Growth (seasonally adjusted at annual rates) Q1 1990 to Q3 2002

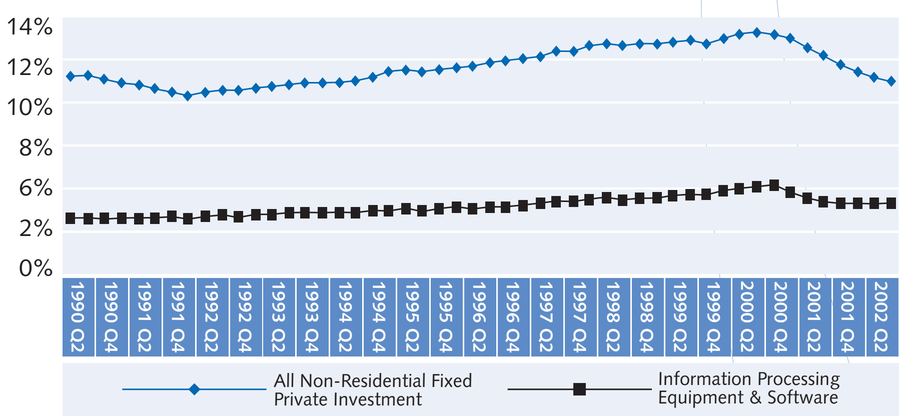


Source: Based on data from Bureau of Economic Analysis

If US spending on ICTs recovers, this will bode well for a more general global industry recovery because:

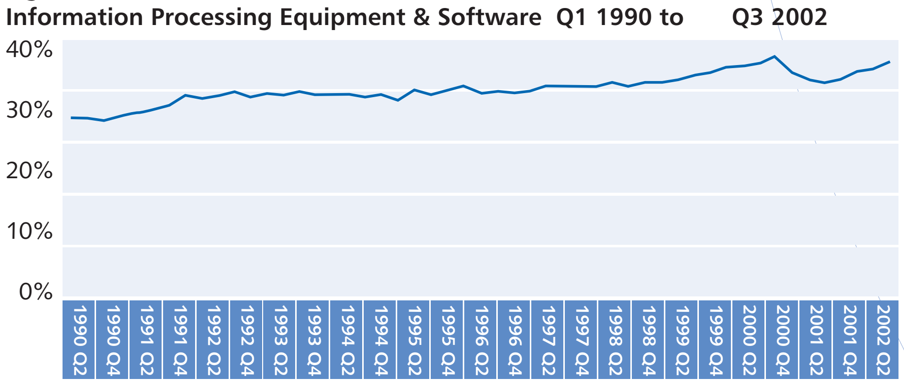
- the US accounts for close to 40% of the total world ICT market; and
- there is a positive correlation between growth and productive investment in the US, and in the rest of the world.

Figure 3.10 US Non-Residential Fixed Private Investment (All and ICT) as % of GDP Q2 1990 to Q3 2002



Source: Based on data from Bureau of Economic Analysis

Figure 3.11 Share of US Non-Residential Fixed Private Investment Accounted for by Information Processing Equipment & Software Q1 1990 to Q3 2002



Source: Based on data from Bureau of Economic Analysis

Consistent with this, the industry expects a recovery to occur again on this occasion[7]. The capital markets also expect a recovery. Although the value of major global technology stocks is now much lower than it was in 1999 or 2000, current valuations still reflect expectations of strong future growth.

There is significant doubt as to the timing and eventual strength of the recovery. It does not appear to be immediately imminent. Industry commentators tend to suggest, however, that it will start during 2003. Best estimates of the likely strength of the recovery are that the rate of market growth will fall short of that achieved in the late 1990s, but that it will still present attractive opportunities for ICT industry growth.

The outlook for telecommunications must be distinguished from the outlook for other end markets. The global take-up of broadband services, and the willingness of end-users to pay for them, has been less than was envisaged through the late 1990s and into 2001. Thus, the timing of the recovery depends to a significant extent on industry's success in overcoming barriers to adoption. For this reason, the recovery of those parts of ICT industries that depend on telecommunications end markets may lag behind the recovery of other ICT areas. This is of direct relevance to Irish employment in telecommunications services, but it is also relevant to significant sections of the electronic hardware, software and IC design industries.

The sections that follow present projections for four main constituent parts of the broad ICT sector:

- Software & IT Services;
- Electronic Systems and Hardware;
- IC Design; and
- Telecommunications Services.

3.4.2 Software and IT Services

Software and IT Services as an Employer of Engineers

The software and IT services sector was the single biggest recruiter of engineers with primary degrees and postgraduate qualifications graduating in 2000. It recruited half of all electronic engineering graduates at these levels who entered employment in Ireland, more than half of all computer engineering graduates, and substantial minorities of the graduates in most other engineering disciplines.

It seems likely that most of these were recruited to do work that was not very much different to that undertaken by graduates in computing. As there was a shortage of software developers, as employers in this area have traditionally recruited staff from diverse backgrounds, and as engineering graduates are generally seen as being well suited to software development, it was natural that significant numbers should have been recruited.

The computer-related elements of engineering courses provide good preparation for software development work, and many other aspects of an engineering course may also prove relevant, depending on the systems being developed. A team that includes both computing and engineering graduates may be better suited to some work than a team with just computing graduates.

History of Software and IT Services Industry

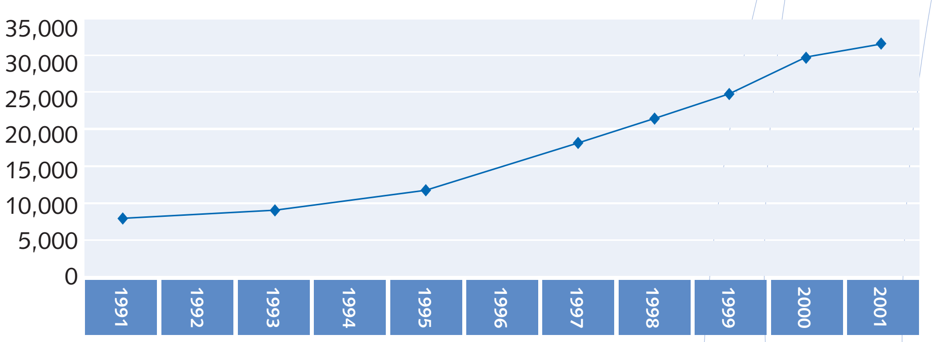
Ireland occupies a unique position in the global software and IT services industry. It is a major localisation and distribution centre, and a significant development centre, for many of the worlds leading software companies. One consequence of this is that it is the world's leading exporter of software and IT services, with a 29% share of OECD exports of software products and a 19% share of exports of computer and information services in 2000[8].

7 This can be seen from the survey undertaken, from consultations with industry interests, and from a review of the international technology industry press.
8 Information Technology Outlook, 2002, OECD.

It is also an important centre of software-related entrepreneurial activity, with numbers employed in Irish-founded software and IT services companies approximately matching those in units established by overseas companies.

While the origins of the industry lie in the early 1970s, it first came to prominence as a significant international player, and as an important contributor to the Irish economy, in the late 1980s and early 1990s. In 1991, a survey by the newly-established National Software Directorate found that the software sector (including most IT services) employed 7,793 staff. This has grown to an estimated 31,800 at the end of 2001.

Figure 3.12 Employment in Irish Software and IT Services Industry



Source: National Software Directorate data to 2000. Estimate for 2001 is based on average growth from 2000 to 2001 across a sample of software companies.

In percentage terms, growth in employment peaked at 25% per annum between 1995 and 1997. From then until 2001, employment growth was constrained by the supply of suitable labour. Sales growth peaked in 1999.

Current State of Software and IT Services Industry

Overall employment growth in the sector slowed sharply during 2001, with some companies continuing to increase employment, some remaining at about the same employment level, and others reducing employment. No hard statistics are yet available for 2002, but it appears from aggregating the available anecdotal evidence that there has been a loss of employment. For purposes of modeling future demand, it is assumed that this loss will amount to 10% of 2001 employment.

This loss appears to be concentrated particularly in some areas. A significant number of indigenous companies undertook major growth initiatives around 1999, shortly before the market downturn started. Many of these have had to reduce staffing levels to a level consistent with survival under adverse market conditions, while continuing to position themselves for growth once markets recover. Many other indigenous companies at varying stages of development have also found that they cannot maintain employment under current market conditions. Irish operations of overseas companies have mostly been more successful at maintaining employment, but there have been losses in areas such as software for telecommunications systems.

It appears likely that net losses of employment will continue to accumulate until good evidence appears that an upturn in market demand is imminent.

Competitive Position of Industry

While competition from locations such as Eastern Europe and India is becoming greater, and while real pay levels have increased significantly since the mid 1990s, the Irish industry appears to have remained competitive through building its skill levels, focusing on product development, and moving into higher value-added market segments. In some cases, companies have moved parts of their development work to locations with lower labour costs.

Compared to many similar industry concentrations in other countries, the Irish industry is well diversified. This gives it some protection from problems that are specific to particular end markets. The Irish industry appears well positioned to remain competitive over the long term. It has created a substantial and world-class base of experience in software development, and in building technology enterprises. Heavy investment in ICT-related research by the State, through Science Foundation Ireland, the Higher Education Authority and Enterprise Ireland, appears likely to reinforce this.

The Irish sector appears to be positioned well to take advantage of any market upturn through building the sales of existing units, through a substantial pool of experienced people interested in forming new businesses, and through attracting more inward investment. It is also positioned well to ride future fluctuations in the market's fortunes.

Employment Projections

Even at times when ICT markets are relatively stable, software employment projections represent no more than an informed and reasonable guess as to how the industry may progress. With more than usual uncertainty at present, the future is correspondingly less certain.

Two alternative projections are illustrated in Table 3.13. One takes a relatively positive view of the future, although by no means the most positive view that could be plausible. The second assumes a recovery in IT markets to a growth rate that falls significantly short of that achieved in previous recoveries, and is thus much less positive.

A number of points are common between the projections.

- Employment falls by 10% in 2002.
- Employment falls by a further 5% in 2003, with strong signs of a recovery occurring in the latter half of the year.
- Projections are calculated on the basis that the population of software companies can be thought of as falling into two groups. One is that of the indigenous entrepreneurial companies that tend to be clients of Enterprise Ireland. The other combines operations founded by overseas companies with those that are the result of buyouts of Irish companies by overseas companies. The former group is assumed to always make up one third of employment, with this proportion being maintained through buyouts by overseas companies.

Points that differ between the projections are as follows.

- In the more positive projection, growth in employment in indigenous entrepreneurial companies is assumed to be 20% per annum[9]. The remainder of the sector is assumed to add a net 1,000 jobs in 2004, and a further 2,000[10] in each subsequent year.
- In the less positive projection, growth in employment in indigenous entrepreneurial companies is assumed to be 10% per annum . The remainder of the sector is assumed to add a net 500 jobs in 2004, and a further 1,000 in each subsequent year.

When considering the projections, it should be noted that the compound rate of growth in employment in the US SIC 737: Computer & Data Processing Services sector was 10.7% per annum over the 30 years to June 2002. This is not much different to the net outcome for the Irish industry set out in Projection 1. As the rate of employment growth

9 The annual employment growth rate for this part of the sector consistently exceeded 20% from the mid 1990s up to and including 2000. Enterprise Ireland suggests that it is plausible that growth of 20% per annum can be regained.

10 During the latter half of the 1990s, the overseas-owned part of the sector regularly added more than 2,000 jobs per annum. The projection of 2,000 per annum reflects a view that conditions for inward investment in software will be less positive than during the 1990s, tempered by the likelihood that a bigger base of existing employment will create more opportunities for organic growth.

in the Irish industry exceeded that of the US through the 1990s, this suggests that there is some potential for the outcome to exceed Projection 1 (see Table 3.13).

Projections of Demand for Engineering Graduates

There are hazards to projecting demand for engineering graduates from this sector. In many cases, they are recruited into positions that are not easily distinguishable from ones that take many more graduates in computing. Nonetheless, there is a long and stable history of recruitment of degree level engineering graduates by the sector. Also, there are significant numbers of positions within the sector for which a graduate in engineering might have an advantage over a graduate in computing. For example, a graduate in electronic engineering might be a very desirable recruit for a software development position where the capability to understand electronic systems is important.

The projection of demand for engineering graduates has been constructed on the following basis.

- 5.2% of those employed in the sector will have engineering degrees other than in computer engineering[11].

- For this sector, demand for computer engineering graduates is difficult to distinguish from that for computing graduates. Thus, in order to avoid having what is effectively a demand for computing graduates impinge upon estimates of supply and demand for engineering graduates, the demand for computer engineering graduates has not been specified in Tables 3.14 and 3.15.

- 1.0% of those employed in the sector will have engineering diplomas or certificates[12].

- The existing population of engineers in the sector will be subject to 2% attrition per annum, whether through leaving for other industries, leaving the country or leaving the software workforce for other reasons[13]. This is assumed to be elevated to 5% in 2002 and 2003, reflecting evidence that economic difficulties have increased the number of people leaving the sector.

Table 3.14 sets out the projections of demand for graduates and technicians in software and IT services from 2003.

11 This assumption is based on fitting actual Engineering graduate recruitment in 2000 to the model previously used on behalf of the Expert Group to project demand for Computing graduates.

12 This is based on the finding in the 1998 "Manpower, Education and Training Study of the Irish Software Sector" commissioned by FAS that 2% of software staff recruited in the previous year were from Engineering or (non-Computing) Science diploma or certificate backgrounds.

13 This is the annual rate of attrition used in previous software sector projections for the Expert Group. It reflects the fact that the age profile of the sector is very young.

Table 3.13 Employment Projections for Irish Software and IT Services Industry

Year	Employ-ment	Annual Growth	Projection 1		Projection 2	
			Employment Projection	Assumed Annual Growth	Employment Projection	Assumed Annual Growth
1991	7,793					
1993	8,943	7.1%				
1995	11,784	14.8%				
1997	18,200	24.3%				
1998	21,630	18.8%				
1999	24,891	15.1%				
2000	30,000	20.5%				
2001	31,800	6.0%				
2002			28,620	-10.0%	28,620	-10.0%
2003			27,189	-5.0%	27,189	-5.0%
2004			30,002	10.3%	29,095	7.0%
2005			34,002	13.3%	31,065	6.8%
2006			38,268	12.5%	33,101	6.6%
2007			42,820	11.9%	35,204	6.4%
2008			47,674	11.3%	37,377	6.2%
2009			52,853	10.9%	39,623	6.0%
2010			58,376	10.5%	41,944	5.9%
2011			64,268	10.1%	44,342	5.7%
2012			70,552	9.8%	46,820	5.6%

Table 3.14 Projections of Demand from the Software & IT Services Sector for Engineers and Engineering Technicians (excluding Computer Engineering)

	Projection 1		Projection 2	
	Degree	Diploma & Certificate	Degree	Diploma & Certificate
2002	-83	-61	-83	-16
2003	0	0	0	0
2004	175	34	127	25
2005	239	46	133	26
2006	257	49	138	27
2007	276	53	144	28
2008	297	57	150	29
2009	319	61	156	30
2010	342	66	162	31
2011	367	71	168	32
2012	394	76	175	34

Tables 3.15 and 3.16 disaggregate the projections in Table 3.14 by discipline, based on the disciplinary mix of primary degree graduates from 2000 recruited by the sector. Note that the detail of the projections only gives a very general indication of demand for graduates from each discipline. It is presented here mainly to allow a reader to track how the projections of total demand for each discipline presented later have been built up.

Table 3.15 Projection of Demand from Software & IT Services Sector for Engineering Degree Graduates, by Discipline

	Civil	Chemical/ Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial	Telecom-munica -tions
Projection 1								
2002	-15	-1	*	-46	-5	-1	-14	-1
2003	0	0	*	0	0	0	0	0
2004	30	3	*	97	10	3	29	3
2005	42	4	*	132	14	4	39	4
2006	46	4	*	142	15	4	42	4
2007	49	4	*	154	16	4	45	4
2008	53	4	*	165	18	4	49	4
2009	57	5	*	176	19	5	52	5
2010	61	5	*	190	20	5	56	5
2011	66	5	*	204	22	5	60	5
2012	71	6	*	216	24	6	65	6
Projection 2								
2002	-15	-1	*	-46	-5	-14	-14	-1
2003	0	0	*	0	0	0	0	0
2004	23	2	*	70	8	21	21	2
2005	24	2	*	73	8	22	22	2
2006	25	2	*	76	8	23	23	2
2007	26	2	*	80	9	24	24	2
2008	27	2	*	83	9	25	25	2
2009	28	2	*	86	9	26	26	2
2010	29	2	*	89	10	27	27	2
2011	30	3	*	93	10	28	28	3
2012	21	3	*	97	10	29	29	3

* No specific demand for Computer Engineering graduates is included here. As explained earlier, they effectively form a part of a bigger Computing graduate pool.

Table 3.16 Projection of Demand from Software & IT Services Sector for Diploma and Certificate Graduates, by Discipline

	Civil	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial	Telecom-munica -tions
Projection 1							
2002	-2	*	-11	-1	0	-2	0
2003	0	*	0	0	0	0	0
2004	5	*	21	3	0	5	0
2005	7	*	28	4	0	7	0
2006	8	*	29	4	0	8	0
2007	8	*	33	4	0	8	0
2008	9	*	35	4	0	9	0
2009	9	*	38	5	0	9	0
2010	10	*	41	5	0	10	0
2011	11	*	44	5	0	11	0
2012	12	*	46	6	0	12	0
Projection 2							
2002	-2	*	-11	-1	0	-2	0
2003	0	*	0	0	0	0	0
2004	4	*	15	2	0	4	0
2005	4	*	16	2	0	4	0
2006	4	*	17	2	0	4	0
2007	4	*	18	2	0	4	0
2008	4	*	19	2	0	4	0
2009	5	*	18	2	0	5	0
2010	5	*	19	2	0	5	0
2011	5	*	20	2	0	5	0
2012	5	*	21	3	0	5	0

* No specific demand for Computer Engineering graduates is included here, as, for purposes of this sector, they effectively form a part of a bigger Computing graduate pool.

3.4.3 Electronic Systems and Hardware

The Sector as an Employer of Engineers

In terms of total industry employment, this is predominantly a manufacturing industry, more than a design and development industry. For this reason, approximately 64% (118) of the primary degree level engineering graduates of 2000 recruited by the sector were in disciplines likely to be related to Production / Manufacturing Engineering, Mechanical Engineering, Mechatronic Engineering and Chemical / Process[14] Engineering.

Reflecting an increasing trend towards involvement in design and development work, the remaining 36% (66) were in disciplines more likely to be involved in: Electronic Engineering; Computer Engineering; and Telecommunications Engineering. However, some of these would instead have been recruited to work in production-related roles such as component engineering or test engineering.

In addition, the industry recruited 32 graduates with postgraduate engineering qualifications, who appear likely from their disciplinary background to have split approximately equally between production and development-related activities.

Engineering graduates at diploma and certificate level entering the industry will predominantly have been recruited to work in production, with a small proportion working in support of development activity. The electronic hardware and IC production

14 Some of these would have been recruited for process-related work in integrated circuit manufacturing.

sector is a subset of the First Destination Report's "Engineering, Electronics and Metal Industries" sector, and we estimate that it took 73% of that sector's total recruitment of new graduates in engineering of 2000. This would have amounted to 408 certificate and diploma graduates. **The industry is the single biggest source of employment for diploma and certificate graduates in all engineering disciplines except civil and the diverse group of disciplines aggregated for the purposes of this study as "Other Engineering".**

History of Electronic Hardware and IC Production Industry

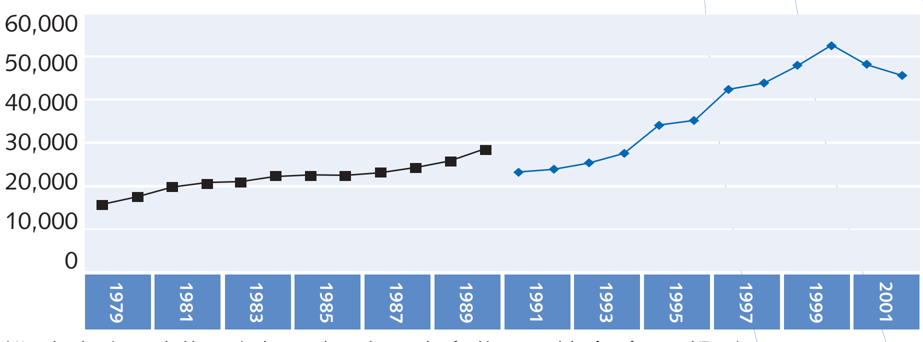
Following on a number of inward investment projects in electronics during the 1970s, inward investment in electronics continued strongly during the 1980s, and ramped up rapidly from 1995 to 2000. Major landmarks included the arrival of Digital Equipment Corporation in 1982, and the arrival of Intel in 1989.

Over time, the profile of the industry has changed significantly. While it began as primarily a labour-intensive assembly industry, there has been a continuous trend towards more sophisticated manufacturing activities, and the addition of other activities in areas such as product design, software development, logistics management, marketing and customer services.

Job losses since 2000, and indeed previous job losses in the industry too, have been concentrated predominantly in manufacturing, and, indeed, predominantly in the lower value added assembly activities that could most easily be moved to other locations, and which are not among the more intensive users of engineering skills.

Ireland is the country that is second most dependent on ICT manufacturing as a source of manufacturing employment (approximately 13%), just behind Korea. It is the country that is by far the most dependent on manufacturing of computer and office machinery (a subset of ICT manufacturing) (approximately 7%)[15].

Figure 3.17 Employment in Irish Electronic Systems and Hardware*



* Note that there is some double counting between the employment data for this sector and that for software and IT services.

Source: Census of Industrial Production data. Based on NACE 33 & 34 for 1979 to 1990, and NACE 30, 31 & 32 from 1991 onward. There were several changes in CIP methodology between 1990 and 1991, the most significant of which was a change in the system of industry classification from NACE 70 to NACE Rev.1. The fall between 1990 and 1991 reflects the change in classification. The estimate for 2002 is based on the trend in the Survey of Industrial Employment. These NACE categories include electrical engineering firms.

Current State of Electronic Systems and Hardware Industry

As with software and IT services, the industry is waiting for an upturn. Many companies have cut back employee numbers in response to reduced demand, while retaining enough to be able to respond to an upturn in demand. Some that were previously growing quickly have just slowed their rate of growth. Job losses are continuing, mainly in assembly operations.

Competitive Position of Industry

The industry faces a competitive position that is significantly different to that of the 1990s. Labour costs have risen to a level at which there is unlikely to be much further inward investment in basic assembly operations, and at which basic assembly

15 Information Technology Outlook 2002, OECD. Based on 1999 data.

operations already in the country will be threatened if they are unsupported by other sources of competitive advantage.

In spite of this, the long term prospects for the industry are positive. While there will be occasional closures even after the current downturn ends, the industry is well positioned to continue its migration to higher value added activities that can form a sustainable basis for competitiveness. Thus, future demand from the sector for engineers and engineering technicians is likely to be driven mainly by:

- existing manufacturing operations migrating to more knowledge intensive manufacturing and logistics processes;
- existing operations moving more heavily into design and development work; and
- inward investment with a strong focus on design and development.

Employment Projections

The employment projections that follow have been prepared on the following basis.

- Manufacturing employment will continue to fall into 2003 (mainly affecting parts of the sector that are not intensive employers of engineers), but will rise at 500 per annum thereafter, with the continued movement of some functions outside Ireland being more than balanced by an ongoing progression into more knowledge intensive activities and by continuing inward investment in higher value-added activities.
- Expansion of design and development activities through new inward investment, expansion of existing development activities and migration of manufacturing operations into development work will add a total of 1,000 jobs to the sector each year, starting in 2004. (This is in addition to job gains in parts of the software and IT services sector that may overlap with the electronic systems and hardware sector).
- Integrated circuit design activities are treated as being located in the IC design sector, and demand for engineers and engineering technicians for this work is not included here in the electronic systems and hardware projections.

Table 3.18 Employment Projections for Irish Electonic Systems and Hardware Sector

Year	Employment	Employment Projection	Annual Growth	Assumed Annual Growth
1999	48,649		9.1%	
2000	52,737		9.3%	
2001	48,258		-7.8%	
2002		42,811		-12.0%
2003		40,671		-5.0%
2004		42,171		3.7%
2005		43,671		3.6%
2006		45,171		3.4%
2007		46,671		3.3%
2008		48,171		3.2%
2009		49,671		3.1%
2010		51,171		3.0%
2011		52,671		2.9%
2012		54,171		2.8%

Projections of Demand for Engineering Graduates

The projection of demand for engineering graduates has been constructed on the following basis.

- The net effect of a combination of industry growth that is much slower than in the late 1990s and faster progression into higher value added activities will result in a modest reduction in recruitment of degree level engineers into manufacturing activities in the industry. This is modeled as recruitment of 100 new primary degree graduates in manufacturing related disciplines each year. It will lead to a reduction in demand for new technician level graduates to an estimated 200 each year.

- 40% of staff in new and existing design and development operations will be degree level engineers, and another 15% will hold engineering diplomas and certificates[16]. (There will also be a significant requirement for computing graduates.)

A word of caution should be noted in interpreting these projections. They are projections of a future that may occur, and which will yield benefits if they occur, and if Ireland has the manpower supply required to take advantage of them.

There is a particular difficulty is preparing plausible projections for Electronic Systems and Hardware, which is that the sector is undergoing something of a discontinuity, with a sharp (and probably persistent) decline in lower skill activities, and with significant growth in higher value-added activities anticipated once ICT markets recover. With such a discontinuity, the projection of future demand is, of necessity, cruder than for most other sectors.

16 This mix assumes that perhaps another 15% of staff would have degrees or diplomas in Computing.

Table 3.19 Projections of Demand from the Electronic Systems and Hardware Sector for Engineers and Engineering Technicians

Year	Degree	Certificate & Diploma
2003	100	200
2004	300	275
2005	300	275
2006	300	275
2007	300	275
2008	300	275
2009	300	275
2010	300	275
2011	300	275
2012	300	275

The rapid change in the engineer-technician mix depicted in the projection is intended to reflect a rapid shift from a historical situation where the majority of demand is for technicians to a future where the majority of demand is for degree level engineers.

The part of the projection above that depends on new design and development operations is very sensitive to the success of IDA Ireland in attracting a relatively small number of high value projects. Actual demand in any given year could be much higher or much lower.

Tables 3.20 and 3.21 disaggregate the projections in Table 3.19 by discipline. This is based on the assumption that all of the degree engineers recruited for design and development, and 15% of those recruited for manufacturing will be from electronic engineering, computer engineering or telecommunications engineering backgrounds. The assumption is that the other 85% of those recruited for manufacturing will be from Production / Manufacturing Engineering, Mechanical Engineering or Mechatronic Engineering backgrounds.

Diploma and certificate graduates recruited for design and development are assumed to be drawn from electronic engineering or computer engineering. Those recruited for manufacturing are assumed to be drawn from a mix of disciplines.

Table 3.20 Projection of Demand from Electronic Hardware & IC Production Sector for Degree Graduates, by Discipline

	Civil	Chemical/ Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac- turing/ Industrial	Telecom- munica -tions
2003	0	6	9	59	17	3	51	5
2004	0	6	15	92	19	4	57	8
2005	0	6	15	92	19	4	57	8
2006	0	6	15	92	19	4	57	8
2007	0	6	15	92	19	4	57	8
2008	0	6	15	92	19	4	57	8
2009	0	6	15	92	19	4	57	8
2010	0	6	15	92	19	4	57	8
2011	0	6	15	92	19	4	57	8
2012	0	61	15	92	19	4	57	8

Table 3.21 Projection of Demand from Electronic Hardware & IC Production Sector for Diploma and Certificate Graduates, by Discipline

	Civil	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial	Telecom-munica -tions
2003		4	125	28	9	34	
2004		5	168	39	13	49	
2005		5	168	39	13	49	
2006		5	168	39	13	49	
2007		5	168	39	13	49	
2008		5	168	39	13	49	
2009		5	168	39	13	49	
2010		5	168	39	13	49	
2011		5	168	39	13	49	
2012		5	168	39	13	49	

3.4.4 Integrated Circuit Design

The Sector as an Employer of Engineers

The integrated circuit design sector is founded mainly on degree graduates in electronic engineering, along with some graduates in related disciplines such as computer engineering and computing.

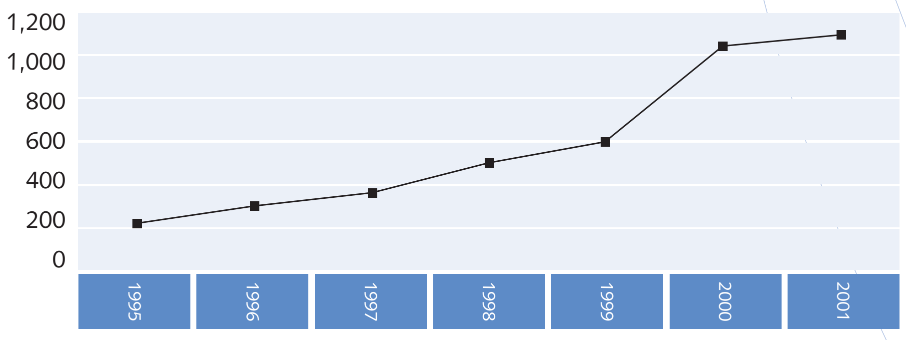
History of IC Design Sector

During the 1980s, the first integrated circuit design activities were established in Ireland by overseas companies, partly arising out of integrated circuit production operations, and partly as a separate activity taking advantage of the availability of significant numbers of graduates in electronic engineering.

The industry grew very rapidly during the 1990s, with several new operations being established (some indigenous and some overseas-owned), and with substantial growth in existing companies. This was a major factor behind a shortage of electronic engineering graduates over the period. Major landmarks include the establishment of operations by Analog Devices (1976) and Silicon & Software Systems (1986), and the flotation of Parthus (2000).

The industry grew particularly quickly during 2000. A number of companies established design centres in parts of Ireland away from their initial base, and overseas, in order to gain access to sufficient new staff.

Figure 3.22 Employment in Irish IC Design Sector (excluding units associated with production operations)



Source: Census of Industrial Production data.

Current State of IC Design Industry

The industry has been affected by the global technology sector downturn, and there have been some job losses. It is not yet clear what the overall impact on employment in the sector has been during 2002, although demand for IC design staff appears to have held up better than that for software developers in the software and IT services sector.

As a large part of the requirement for IC design work is related to telecommunications services, the difficulties currently being experienced in global telecommunications markets are having a significant impact on the sector.

Competitive Position of Industry

The competitive position is fairly positive. Ireland has established itself as a key location for inward investment in IC design, and it appears that the development of an agglomeration of operations in the area is reinforcing this position. IDA Ireland suggests that inward investment is likely to be limited mainly by the supply of suitable staff over the medium term.

Ireland has also established itself as a location in which significant indigenous IC design companies can emerge. While indigenous companies have not been immune to the global downturn in demand, there is a reasonable prospect that they will be able to grow strongly once the recovery starts.

Employment Projections

The employment projections that follow have been prepared on the basis of the basis that specialist design operations have the potential to grow employment at a rate of 20% per annum once the upturn in technology markets occurs, falling back to 11% over time. In the absence of more reliable data, it is assumed that employment remains constant through 2002 and 2003.

Table 3.23 Employment Projections for IC Design Sector (excluding units attached to production operations)

Year	Employment	Employment Projection	Annual Growth	Assumed Annual Growth
1997	361		34.3%	
1998	485		20.0%	
1999	582		79.2%	
2000	1,043		6.3%	
2001	1,109			
2002		1,109		0.0%
2003		1,109		0.0%
2004		1,331		20.0%
2005		1,582		18.9%
2006		1,863		17.8%
2007		2,172		16.6%
2008		2,509		15.5%
2009		2,870		14.4%
2010		3,250		13.3%
2011		3,644		12.1%
2012		4,045		11.0%

Projections of Demand for Engineering Graduates

The projections of demand for engineering graduates have been constructed on the following basis:

- 70% of jobs in the sector will require a technological qualification:
  - 70% of these will require an electronic engineering or computer engineering degree;
  - 10% of will require a diploma or certificate in electronic engineering or computer cngineering; and
  - 20% will require other technological qualifications, typically a degree in computing;

- The population of engineers in the sector will be subject to 2% attrition per annum, whether through leaving for other industries, leaving the country or leaving the software workforce for other reasons.

- There will be an additional demand from IC design units attached to IC production units equivalent to 25% of the demand from unattached units.

Table 3.24 Projections of Demand from the IC Design Sector for Engineers and Engineering Technicians

Year	Degree	Certificate & Diploma
2003	14	2
2004	149	21
2005	170	24
2006	191	27
2007	213	30
2008	233	33
2009	252	36
2010	268	38
2011	281	40
2012	290	41

Tables 3.25 and 3.26 disaggregate these projections by discipline. The disaggregation is based on the assumption that all of the engineering graduates recruited will be in electronic engineering, computer engineering or telecommunications engineering. As with other sectors, the detail of these projections is indicative only.

Table 3.25 Projection of Demand from IC Design Sector for Degree Graduates, by Discipline

	Civil	Chemical/ Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial	Telecom-munica -tions
2003			2	11				1
2004			18	119				13
2005			20	135				15
2006			23	152				17
2007			25	169				19
2008			27	185				21
2009			30	200				22
2010			32	213				24
2011			33	223				25
2012			34	230				26

Table 3.26 Projection of Demand from IC Design Sector for Diploma and Certificate Graduates, by Discipline

	Civil	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial	Telecom-munica -tions
2003		0	2				0
2004		3	17				2
2005		3	19				2
2006		3	21				2
2007		4	24				3
2008		4	26				3
2009		4	28				3
2010		5	30				3
2011		5	32				4
2012		5	33				4

3.4.5 Telecommunications Services

The Sector as an Employer of Engineers

The sector is a significant employer of engineers and engineering technicians. It recruited 58 degree level engineering graduates of 2000. The "Transport and Communications" sector recruited 36 graduates with diplomas and certificates in engineering from the same year. Most of these are likely to have gone to telecommunications services companies. This sector is addressed separately from other ICT sectors because it is an important sector from a policy point of view, and because it was convenient to do so from the point of view of developing an overview of the whole ICT sector[17].

History of Telecommunications Services Sector

Originally mainly the preserve of the Department of Posts and Telegraphs, and later of the State-owned Telecom Eireann, the Irish telecommunications services market was deregulated progressively through the 1990s. As in other parts of the world, a stream of new services emerged in areas such as mobile telephony and Internet services. Combined with completion of the digitalisation of the public telephony network, and increases in demand for existing services, this drove substantial investment, as in other countries. The high level of investment lasted through 2000.

[17]However, because the number of Engineers and Engineering Technicians recruited by the sector turned out to be quite small, because other employment data were not easily available, and because the sector is going through a volatile period, it is not analysed here to the same level of detail as other sectors.

However, the market for new telecommunications services has not developed as quickly as was predicted, and this has led to a global slowdown in investment. The general slowdown has been reflected in Ireland.

Current State of Telecommunications Services Sector

Investment in the telecommunications services is continuing. For example, a number of third generation mobile telephony licenses have recently been taken up, with the first services due to be in place during 2003.

Competitive Position of Industry

The industry is not a major exporter. OECD statistics show that Ireland imported US$342m of "communication services" in 2000, and exported US$328m worth of services[18].

Projections of Demand for Engineering Graduates

The projections made are based on discussions with industry informants as to the changes in graduate recruitment that might plausible occur in the context of the current downturn in activity, and in the context of a future recovery.

The projection of demand for engineering graduates has been constructed on the basis[19] that:

- Demand for new graduate engineers and engineering technicians will have fallen to 50% of the level for graduates of 2000 in 2002; and
- This will increase to 80% in 2004, and will average 100% thereafter.

Table 3.27 Projections of Demand from the Telecommunications Services Sector for Engineers and Engineering Technicians

Year	Degree	Certificate & Diploma
2003	38	23
2004	46	29
2005	58	36
2006	58	36
2007	58	36
2008	58	36
2009	58	36
2010	58	36
2011	58	36
2012	58	36

Tables 3.28 and 3.29 disaggregate these projections by discipline. The disaggregation is based on the mix of graduates of 2000 recruited by the sector (in the case of diploma and certificate graduates by the mix recruited by the "Transport and Communications" industry).

18 Information Technology Outlook 2002, OECD.
19 Industry consultation indicate that this is a reasonable view.

Table 3.28 Projection of Demand from Telecommunications Services Sector for Degree Graduates, by Discipline

	Civil	Chemical/ Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial	Telecom-munica -tions
2003	3		1	27				7
2004	4		1	33				8
2005	5		1	41				11
2006	5		1	41				11
2007	5		1	41				11
2008	5		1	41				11
2009	5		1	41				11
2010	5		1	41				11
2011	5		1	41				11
2012	5		1	41				11

Table 3.29 Projection of Demand from Telecommunications Services Sector for Diploma and Certificate Graduates, by Discipline

	Civil	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial	Telecom-munica -tions
2003			16	2		5	
2004			20	3		6	
2005			25	4		7	
2006			25	4		7	
2007			25	4		7	
2008			25	4		7	
2009			25	4		7	
2010			25	4		7	
2011			25	4		7	
2012			25	4		7	

3.4.6 Total Projected ICT Sector Demand

Tables 3.30 and 3.31 summarise all of the ICT sector demand projections, totaling the projections set out in sections 3.4.2 to 3.4.5. At all levels, the main demand is projected to be for graduates in electronic engineering and the closely related areas of computer engineering and telecommunications engineering. Significant demand for graduates from other engineering disciplines is also projected mainly for work related to manufacturing or (particularly at degree level) for work related to software development.

Table 3.30 Projection of Demand from Total ICT Sector for Degree Graduates, by Discipline

	Civil	Chemical /Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac- turing/ Industrial	Telecom- munica -tions	Total (excluding Computer)
Based on Software & IT Services Projection 1									
2003	3	5	*	97	17	3	51	13	189
2004	34	9	*	341	29	7	86	32	538
2005	47	10	*	400	33	8	96	38	632
2006	51	10	*	427	34	8	99	40	669
2007	54	10	*	456	35	8	102	42	707
2008	58	10	*	483	37	9	106	44	746
2009	62	11	*	509	38	9	109	46	784
2010	66	11	*	536	39	9	113	48	822
2011	71	11	*	560	41	10	117	49	858
2012	76	12	*	579	43	10	122	51	893
Based on Software & IT Services Projection 2									
2003	3	5	*	97	17	3	51	13	189
2004	27	8	*	314	27	6	78	31	491
2005	29	8	*	341	27	6	79	36	526
2006	30	8	*	361	27	6	80	38	550
2007	31	8	*	382	28	6	81	40	576
2008	32	8	*	401	28	6	82	42	599
2009	33	8	*	419	28	6	83	43	620
2010	34	8	*	435	29	6	84	45	641
2011	35	9	*	449	29	7	85	47	661
2012	36	9	*	460	29	7	86	48	675

Table 3.31 Projection of Demand from Total ICT Sector for Diploma and Certificate Graduates, by Discipline

	Civil	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac- turing/ Industrial	Telecom- munica -tions	Total (excluding Computer)
Based on Software & IT Services Projection 1								
2003	0	*	143	30	9	39	0	221
2004	5	*	226	45	13	60	2	351
2005	7	*	240	47	13	63	2	372
2006	8	*	243	47	13	64	2	377
2007	8	*	250	47	13	64	3	385
2008	9	*	254	47	13	65	3	391
2009	9	*	259	48	13	65	3	397
2010	10	*	264	48	13	66	3	404
2011	11	*	269	48	13	67	4	412
2012	12	*	272	49	13	68	4	418
Based on Software & IT Services Projection 2								
2003	0	*	134	30	9	39	0	221
2004	4	*	220	44	13	59	2	342
2005	4	*	228	45	13	60	2	352
2006	4	*	231	45	13	60	2	355
2007	4	*	235	45	13	60	3	360
2008	4	*	238	45	13	60	3	363
2009	5	*	239	45	13	61	3	366
2010	5	*	242	45	13	61	3	369
2011	5	*	245	45	13	61	4	373
2012	5	*	247	46	13	61	4	376

3.5 Demand from Construction-Related Industries

3.5.1 Introduction

This section examines demand for engineers and engineering technicians from the construction industry itself, from engineering consultancies, and from local authorities. First Destination data on the "Construction, Civil Engineering" industry, which includes the whole construction industry and many engineering consultancies, plays an important role in the analysis. For this reason, the construction and engineering consultancy industries are addressed together.

3.5.2 Construction and Engineering Consultancy

Construction and Engineering Consultancy as an Employer of Engineers

The overwhelming majority of civil engineering graduates entering employment in Ireland enter the construction industry or the engineering consultancy industry.

- A detailed analysis of HEA First Destination data for graduates of 2000 shows 26.9% of civil engineering primary degree graduates entering Irish employment going to the construction industry, and 40.7% going to engineering consultancies, or a total of 67.6%.

- An analysis of HEA/HETAC First Destination data for graduates of 2000 shows 75.5% of civil engineering diploma graduates entering Irish employment going to the "construction, civil engineering" industry, and a further 4.1% going to the "professional services, private practice industry", or a total of 79.6%.

- For civil engineering certificate graduates, the analysis shows 71.1% of these graduates going to the "construction, civil engineering" industry, and a further 7.2% going to the "professional services, private practice industry", or a total of 78.3%.

The statistics show a similarly high rate of transfer from Building Services Engineering courses to the construction and engineering consultancy industries[20].

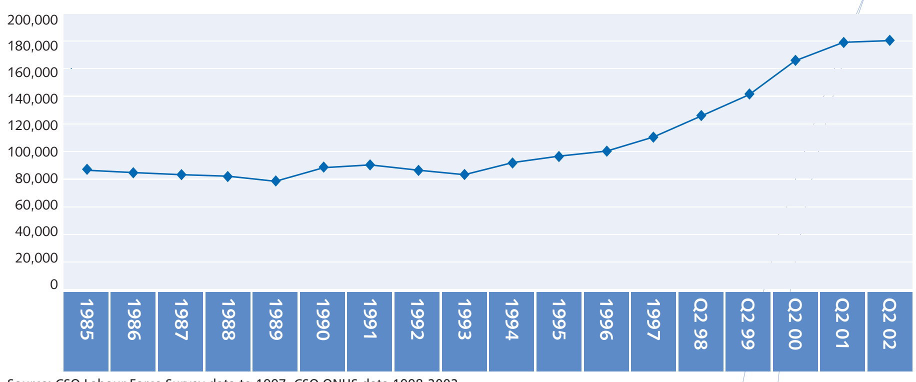
History of Construction and Engineering Consultancy Industry

Over the ten years to 1993, the numbers employed in the construction industry did not change significantly. Since then, employment has more than doubled, from 83,200 in Q2 1993 to 181,100 in Q2 2002. This reflected strong economic performance through the economy generally, and also heavy investment in infrastructure by the State, particularly through the National Development Plan, which commenced in 2000. Towards the end of this period, employment growth leveled off, and it is possible that employment is now falling[21].

Comparable employment figures for the engineering consultancy industry are not available. For the purposes of this study, it is assumed that employment in the industry is closely related to employment in construction. This is reasonable, as the two industries are broadly complementary.

20 Due to the small number of graduates in this area, the number of responses available is too small to justify giving more than this broad indication.
21 The two main sources of data on construction industry employment are the Quarterly National Household Survey, which is carried out quarterly, and the Index of Construction Employment, which is carried out monthly. A comparison of the two series showed that the QNHS data tends to increase and decrease at a significantly faster rate than the Index data. Thus, it was necessary to choose between the two series for purposes of this study. The QNHS was chosen as it implicitly covers firms of all sizes, while the Index of Construction Employment counts only firms with 5 or more employees in an industry that has large numbers of small subcontractors. The Index of Construction Employment suggests that employment is falling. The evidence from QNHS data is less clear.

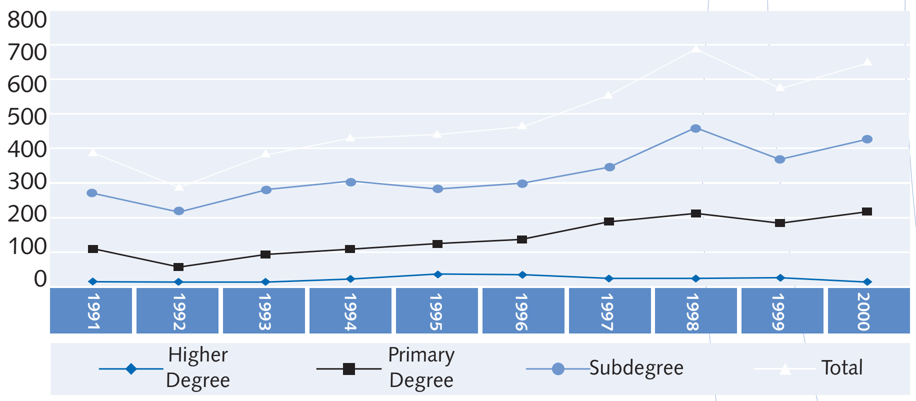
Figure 3.32 Irish Construction Industry Employment



Source: CSO Labour Force Survey data to 1997. CSO QNHS data 1998-2002.

Construction industry growth was reflected by a substantial rise in the number of engineering graduates recruited by the construction and engineering consultancy industries.

Figure 3.33 Recruitment of New Engineering Graduates by "Construction, Civil Engineering" Industry and "Professional Services, Private Practice" Industry*



* Dates quoted relate to year of graduation, with the survey being conducted over the following Spring and Summer.
Source: Based on grossing up data from HEA's annual "First Destination of Award Recipients in Higher Education" report.

In Figure 3.32, the fall in the numbers of primary degree and subdegree engineers entering the industry in 1999 arises from a shift in favour of other industries. This seems to mainly reflect the recruitment of larger than usual numbers of civil engineering graduates by the software industry in that year[22].

A shortage of civil engineers arose from around 1999. In a survey undertaken for this study, the number of vacancies for civil engineers was 9.3% of the total number in employment. The equivalent figure for civil engineering technicians was 10.3%[23]. While vacancies existed in significant numbers for both construction companies and engineering consultancies, the vacancy rate in local authorities was much higher, at just over 20% for both civil engineers and civil engineering technicians. In part, at least, this high local authority vacancy rate appeared to reflect the fact that the survey coincided with a time when many new engineering positions had been authorised in the recent past. Interview evidence also supports the view that there has been a shortage of civil engineers and civil engineering technicians.

Current State of Construction and Engineering Consultancy Industry

Overall, growth in the construction industry has ceased, and employment is now falling. This appears to reflect mainly the slowdown in general economic activity. An excess of demand over supply for civil engineers continued up to mid-2002, and it is not yet clear whether it has persisted since then. The market is certainly softer than it was early in 2002.

22 The consultants have corrected for an issue with the 1999 survey analysis.
23 The National Survey of Vacancies in the Private Non-Agricultural Sector 2001/02, ESRI/FAS/Forfas, has found a vacancy rate of 7% for Engineering Professional positions in the construction sector, and a vacancy rate of 16% for Engineering Technicians.

Outlook for Construction and Engineering Consultancy Industry

The outlook for the industry depends on factors such as the future rate of economic growth, and on future investment in infrastructure. There is significant uncertainty about these factors over the medium term, and over the period to 2012. However, the general shape of expectations is that economic growth will continue to exceed the EU average, and that heavy investment in infrastructure will continue over the period of the National Development Plan (2000 to 2006), and beyond that period through future plans, including the National Spatial Strategy.

Employment Projections

Table 3.34 sets out projections for construction employment over the period to 2012, which are used as an input into the projections of demand for engineering graduates[24].

Table 3.34 Employment Projections

Year	Employment
2003	180,700
2004	176,800
2005	177,600
2006	177,800
2007	173,600
2008	170,300
2009	167,300
2010	167,600
2011	167,600
2012	167,600

Projections of Demand for Engineering Graduates

Historically, the construction and engineering consultancy sectors have recruited substantial numbers of graduates, even at times of falling construction sector employment. This appears to be caused by a combination of two factors.

1. The ratio of engineers engaged in construction-related work to total construction sector employment has been rising.

2. While career progression may slow during a period of falling employment, it does not stop. This constantly makes room for new graduates at entry level, with some of the excess numbers at more senior levels presumably moving out of the sector, some moving into management, others presumably being underemployed temporarily, and others working overseas.

On the assumption that these factors continue to operate as in the past, there is an implication that a substantial part of the industry's total demand for engineering graduates is likely to be based on a fraction of current construction employment, while a smaller part will be based on a fraction of the increase in construction employment. The projection in Table 3.35 is calculated on the following basis:

- A formula relating recruitment of engineering graduates to employment and employment change, established by regressing graduate recruitment for graduates of 1991 to 1998 against construction industry employment for 1992 (Q2) to 1999 (Q2), and against the year-on-year changes in construction industry employment[25];

- An allowance for the fact that the age profile of engineers and engineering

24 The projections to 2010 were prepared by FAS on behalf of the Expert Group as a part of a study of demand and supply for construction trades people, carried out in parallel with the study of Engineering skills.

25 This approach suggests a much higher level of demand for graduates than would be suggested by a model that treats growth in the number of Civil Engineers as the main driver of demand. There is some uncertainty about which approach will prove to be a better predictor of demand. However, as the policy implications of both approaches are similar (no requirement for additional college places in Civil Engineering), this uncertainty is not considered to be an important issue.

Technicians is lower than in the past, suggesting that the rate at which entry level positions are created through career progression by those already in industry may be lower than it was during the 1990s, under conditions of slower industry growth[26];

- An assumption that the mix of levels of qualification will remain as it has in recent years with approximately 35% at degree level.

Table 3.35 Projections of Demand from the Construction and Engineering Consultancy Sector for Engineers and Engineering Technicians

Year	Degree	Certificate & Diploma
2003	224	415
2004	235	437
2005	234	435
2006	218	405
2007	215	399
2008	211	392
2009	218	406
2010	218	405
2011	218	405
2012	232	430

Tables 3.36 and 3.37 disaggregate overall degree and diploma/certificate projections by discipline. The projections of demand for Chemical/Process Engineers (in Engineering Consultancies) have been boosted to take account of the fact that growth in the pharmaceutical and chemical industries is projected to be greater than for construction. There will be additional demand from the key part of the engineering consultancy sector that is not related to construction.

Table 3.36 Projection of Demand from the Construction and Engineering Consultancy Sector for Degree Graduates, by Discipline

	Building Services	Civil	Chemical / Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial
2003	11	159	31		2	13	2	8
2004	12	167	33		2	14	2	8
2005	12	166	33		2	14	2	8
2006	11	155	34		2	13	2	7
2007	11	152	35		2	13	2	7
2008	11	149	36		2	13	2	7
2009	11	155	36		2	13	2	7
2010	11	155	36		2	13	2	7
2011	11	155	37		2	13	2	7
2012	12	164	37		2	14	2	8

26 This allowance is made by reducing projected demand from that suggested by regression by an arbitrary 20%.

Table 3.37 Projection of Demand from the Construction and Engineering Consultancy Sector for Diploma and Certificate Graduates, by Discipline

	Building Services	Civil	Computer	Electronic	Mechan-ical	Mechat-ronic	Manufac-turing/ Industrial
2003	26	372		4	4		9
2004	27	393		4	4		9
2005	27	391		4	4		9
2006	25	364		4	4		8
2007	25	358		4	4		8
2008	25	351		4	4		8
2009	25	365		4	4		8
2010	25	364		4	4		8
2011	25	364		4	4		8
2012	27	386		4	4		9

3.5.2 Local Authorities

The Sector as an Employer of Engineers

Local authorities are major employers of engineers. They employ mainly civil engineers, but also some from other disciplines including mechanical, electrical and building services.

Table 3.38 sets out data on job offers made in relation to engineering positions from the Local Appointments Commission (with some supplementary information on Civil Service appointments).

Table 3.38 Offers of Engineering Positions in Public Service

	1998	1999	2000	2001
Senior Engineer	3	12		11
Executive/Senior Executive Engineer	146	92		59
Assistant Engineer		1		
County Engineer				1
City Engineer	2			
Deputy City Engineer		1		
Borough Engineer	1			
Town Engineer	1			1
Divisional Engineer	1			
Total Local Authority	**154**	**106**		**72**
Civil Service - Engineers, Technicians & Related Grades	23	24		20

As many of the engineers recruited by local authorities have industry experience, the number recruited directly from college is much less than the total number recruited. Table 3.39 sets out the numbers recruited direct from college.

Table 3.39 Engineering Graduates of Years 1991 to 2000 Recruited by Local Authorities

Year	Higher Degree	Primary Degree	Certificate & Diploma	Total
1991	3	16	16	34
1992	4	26	21	52
1993	10	7	19	35
1994	5	6	23	34
1995	4	10	9	23
1996	18	11	32	61
1997	4	15	25	4
1998	1	28	33	62
1999	3	18	34	54
2000	6	21	32	59

Source: Based on grossing up data from First Destination of Award Recipients in Higher Education, HEA.

An analysis of HEA First Destination data for graduates of 2000 shows 6.5% of civil engineering primary degree graduates entering Irish employment going to local authorities. An analysis of HEA/HETAC First Destination data for the same year shows 6.1% of civil engineering diploma graduates entering Irish employment going to local authorities with 9.0% of civil engineering certificate graduates entering Irish employment going to the sector.

Prospects of Engineering Employment in Sector

Responses to the survey of employers of engineers indicate that a number of local authorities had approval for substantial increases in their complements of engineering staff during 2002. As local authorities continue to invest in infrastructure, and take on increasingly active postures in areas such as traffic, waste disposal, water supply, and environmental regulation, the requirement for additional engineers each year appears likely to increase above the levels of recent years over the long run.

Projections of Demand for Engineering Graduates

However, there is significant uncertainty about the level of future recruitment of engineers and engineering technicians by Local Authorities over the short to medium term. Authorities responding to the survey of employers mostly only had visibility of recruitment for the current year, and future recruitment is very much a function of Government decisions outside their control. For the immediate future, it seems likely that constraints on public spending will limit recruitment.

The projections are made on the following basis.

- The main concern is new graduate recruitment by local authorities, rather than total recruitment. Construction and engineering consultancy projections assume a significant outflow of engineers each year, and to destinations that include employment by local authorities.

- The expected increased level of demand for new graduates can be described by a continuation of the average level of recruitment of graduates from 1998 to 2000 over the period to 2004, followed by a step up to a level 20% higher as public spending constraints ease. This is based on the assumption that infrastructural developments will require a stream of new Engineers and Engineering Technicians similar to that of recent years, and that there will be a further increase in recruitment as budgetary constraints ease, which is assumed to happen in 2005[27].

27 Following the ICT upturn projected for 2004.

The projections are provided in Tables 3.40 to 3.42.

Table 3.40 Projections of Demand Local Authorities for Engineers and Engineering Technicians

Year	Degree	Certificate & Diploma
2003	25	33
2004	25	33
2005	30	40
2006	30	40
2007	30	40
2008	30	40
2009	30	40
2010	30	40
2011	30	40
2012	30	40

Tables 3.41 and 3.42 disaggregate the overall degree and diploma/certificate projections by discipline.

Table 3.41 Projection of Demand from Local Authorities for Degree Graduates, by Discipline

	Building Services	Civil	Chemical / Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial
2003	1	18				5		1
2004	1	18				5		1
2005	1	22				6		1
2006	1	22				6		1
2007	1	22				6		1
2008	1	22				6		1
2009	1	22				6		1
2010	1	22				6		1
2011	1	22				6		1
2012	1	22				6		1

Table 3.42 Projection of Demand from Local Authorities for Diploma and Certificate Graduates, by Discipline

	Building Services	Civil	Chemical / Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial
2003		40						
2004		40						
2005		40						
2006		40						
2007		40						
2008		40						
2009		40						
2010		40						
2011		40						
2012		40						

3.6 Demand from Medical Devices and Pharmaceutical/Chemical Industries

3.6.1 Introduction

This section examines demand for engineers and engineering technicians from the medical devices and pharmaceutical/chemical (or "pharmachem") industries[28]. These are two of the main industries in which inward investment occurs. There is also significant activity by Irish-founded companies in both. Most biotechnology enterprises requiring significant numbers of engineers form a part of one or other of these industries.

The supply of engineers and engineering technicians is important to both of these industries. Both require significant numbers of Production/Manufacturing Engineers. In addition, the medical devices industry requires significant numbers of graduates in areas such as Biomedical Engineering for product development work. The pharmachem industry requires significant numbers of Chemical Engineers, both for direct employment, and to staff the engineering consultancies that provide them with services.

First Destination data on the "Chemicals, Rubber, Plastics, Pharmaceuticals, Healthcare" industry plays an important role in the analysis. Together, the medical devices and pharmachem industries account for most employment in this area. Thus, as the rubber and plastics industries have reduced employment in recent years, and the medical devices and pharmachem industries have been growing, it is reasonable to assume that most engineering graduates recruited by the "Chemicals, Rubber, Plastics, Pharmaceuticals, Healthcare" industry since 1999 will have gone into medical devices and pharmachem companies, and that the majority of graduates recruited in earlier years will also have gone that way.

Table 3.43 Overall Graduate Recruitment by "Chemicals, Rubber, Plastics, Pharmaceuticals, Healthcare" Industry

Year	Higher Degree	Primary Degree	Certificate & Diploma	Total
1991	5	53	39	97
1992	6	37	74	118
1993	8	47	44	99
1994	10	74	41	126
1995	10	63	53	126
1996	10	83	50	143
1997	9	67	47	123
1998	5	75	66	147
1999	8	103	57	169
2000	1	86	32	120

Source: Based on grossing up data from First Destination of Award Recipients in Higher Education, HEA.

At degree level, the medical devices sector recruited mainly Mechanical and Production / Manufacturing Engineers, along with a significant proportion of the small number of Biomedical Engineers graduating, and another 15 with postgraduate qualifications[29]. The pharmachem sector recruited mainly Chemical/Process Engineers, along with a few from Electronic Engineering, Mechanical Engineering and Production/Manufacturing Engineering, and another three with postgraduate qualifications.

28 Engineering consultancies active in pharmachem work are treated as a part of the engineering consultancy sector, and are the main source of the significant demand for Chemical / Process Engineers projected for that sector.
29 Including a graduate diploma in quality management.

Table 3.44 Overall Recruitment of Primary Degree Graduates of 2000 by "Chemicals, Rubber, Plastics, Pharmaceuticals, Healthcare" Industry

Industry / Engineering Discipline	Biomedical	Building Services	Civil	Chemical / Process	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
Medical Devices	4	0	0	4	0	2	0	16	2	0	13	0	**36**
Pharmaceuticals & Chemicals	0	0	0	20	0	2	0	3	2	0	4	0	**30**

Source: Based on analysis of HEA First Destination of Award Recipients database for 2000.

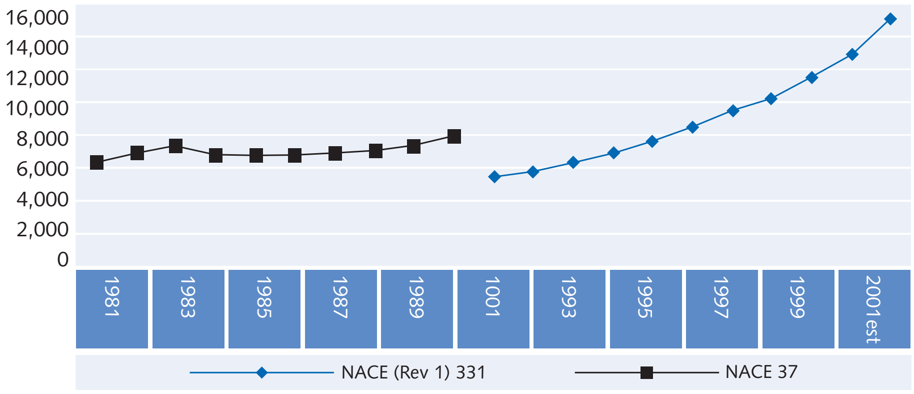
The available data does not allow the 32 diploma and certificate engineering graduates entering the "Chemicals, Rubber, Plastics, Pharmaceuticals, Healthcare" industry to be divided between the medical devices and pharmachem industries. However it is reasonable to think that a greater share would have gone to medical devices sector, given that the medical devices sector tends to depend on people with engineering qualifications for technicians, whereas the pharmachem sector recruits significant numbers with diplomas and certificates in the sciences.

3.6.2 Medical Devices

History of the Medical Devices Sector

The medical devices sector is made up of both overseas-owned and indigenous companies. Thirteen of the world's top twenty five medical devices companies have operations in Ireland. The industry grew rapidly through the 1990s, with a succession of new projects and expansions of existing companies. Estimates of current employment depend on the base used. The Irish Medical Devices Association estimates that the industry (including diagnostics companies) employed approximately 20,000 in 2000, while the CSO, apparently using a narrower definition, found employment of 12,991 in Early Estimates from the 2000 Census of Industrial Production.

Figure 3.45 Employment in NACE (Rev 1) 331 (Manufacture of Medical and Surgical Equipment and Orthopaedic Appliances) and of NACE 37 (Instrument Engineering)*



* The CSO changed the coding system in the Census of Industrial Production between 1990 and 1991. The old NACE 37 was approximately equivalent to the new NACE (Rev.1) 33. The major part of NACE (Rev. 1) 33 is made up of NACE (Rev. 1) 331 Manufacture of Medical & Surgical Equipment and Orthopaedic Appliances.

Source: Census of Industrial Production, CSO. Estimate for 2001 based on trend in Survey of Industrial Employment.

Current State of Medical Devices Sector

Through the latter half of the 1990s, new investment and reinvestment had the effect of moving the sector into higher value added activities. Now, the trend is to push this further by adding research and development facilities. An Irish Medical Devices Association survey shows that 600 people in the sector were engaged in research and development in 2001, with €50m being spent on R&D[30]. The economic downturn has reduced the industry's rate of growth in 2002, and has led to some job losses.

Outlook for Industry

The outlook for the sector is good. In future, Ireland is most likely to be successful in attracting higher value added medical devices activities. As these will be less labour intensive (but more engineering-intensive) than many of the operations established in recent years, it is likely that the rate of employment growth will be lower. Net employment growth may be close to zero until the global economic downturn ends, but it is likely to recover to a significant level thereafter.

There is likely to be significant growth in research and development, requiring a mix of high level skills in areas including Engineering, Materials Science, Chemistry, Physiology, Computing and a range of disciplines related to Biotechnology. Increasingly, innovations are likely to come from teams representing mixes of different disciplines. The medical devices sector is likely to be one of the main Irish industry sectors that exploits innovations in biotechnology.

Employment Projections

The employment projections are developed on the basis that it will be possible to sustain growth of 6% per annum in medical devices employment over the long term.

Table 3.46 Employment Projections for Medical Devices Sector

Year	Employment	Employment Projection	Annual Growth	Assumed Annual Growth
1997	9,513		11.3%	
1998	10,198		7.2%	
1999	11,487		12.6%	
2000	12,991		13.1%	
2001	15,091		16.2%	
2002		15,091		0.0%
2003		15,544		3.0%
2004		16,476		6.0%
2005		17,465		6.0%
2006		18,513		6.0%
2007		19,624		6.0%
2008		20,801		6.0%
2009		22,049		6.0%
2010		23,372		6.0%
2011		24,774		6.0%
2012		26,261		6.0%

Projections of Demand for Engineering Graduates

The projections have been prepared on the following basis.

- The sector will require 75 recruits for research work each year, 40% of whom (30) will ideally be from relevant Engineering backgrounds. This 30 should be made up mainly of graduates with relevant research degrees, along with some primary degree graduates in Biomedical Engineering.

30 Irish Medical Devices & Diagnostics Industry Economic Impact Analysis 2000-2003, IMDA, 2002

- Demand for other new engineering graduates will amount to 38 primary degree graduates and 25 diploma and certificate graduates in 2002[31], and will increase from this level as industry growth resumes.

Table 3.47 Projections of Demand from the Medical Devices Sector for Engineers and Engineering Technicians

Year	Degree	Certificate & Diploma
2003	69	26
2004	71	28
2005	74	29
2006	76	31
2007	79	33
2008	81	35
2009	85	36
2010	88	39
2011	91	41
2012	95	44

Tables 3.48 and 3.49 disaggregate these projections by discipline. The requirement for degree graduates in Biomedical Engineering should be taken as including a significant mix of research degree graduates in Biomedical Engineering and in relevant areas of Mechanical Engineering and Materials Science.

Table 3.48 Projection of Demand from the Medical Devices Sector for Degree Graduates, by Discipline

	Biomedical Engineering	Civil	Chemical / Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial
2003	29				3	18	3	16
2004	30				3	19	3	16
2005	32				3	19	3	17
2006	33				3	20	3	17
2007	34				3	21	3	18
2008	36				3	21	3	18
2009	38				3	22	3	19
2010	39				3	23	3	20
2011	40				3	24	3	21
2012	40				4	25	4	22

Table 3.49 Projection of Demand from Medical Devices Sector for Diploma and Certificate Graduates, by Discipline

	Biomedical Engineering	Civil	Chemical / Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac-turing/ Industrial
2003	8				3	5	3	9
2004	8				3	5	3	9
2005	8				3	5	3	10
2006	9				3	6	3	10
2007	9				3	6	3	11
2008	10				3	7	3	12
2009	10				3	7	3	12
2010	11				4	7	4	13
2011	12				4	8	4	14
2012	13				4	8	4	15

31 This is based approximately on the skills requirements set out in the IMDA Economic Impact Report 2000-2003.

3.6.3 Pharmaceuticals & Chemicals

History of Pharmachem Sector

Inward investment in pharmaceuticals and chemicals began in the 1960s. Overseas-owned pharmaceutical plants, and plants producing fine chemicals, much of which are pharmaceutical precursors, now form the main core of a major industry. Figure 3.50 below presents an employment history of NACE 24, which also includes man-made fibres. Employment in man-made fibres has been falling at least since 1990, and now forms just a small part of NACE 24[32].

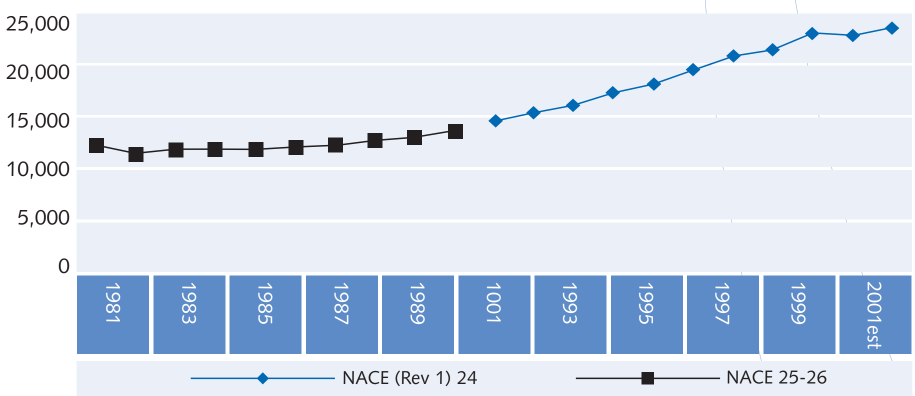
Employment in the industry grew rapidly through the 1990s, at rates of up to 7.5% per annum (or a little more if manmade fibres were excluded, and more again if the focus was just on pharmaceuticals and pharmaceutical precursors).

Outlook for Industry

After a couple of years during which the industry's rate of employment growth had fallen, inward investment in biotechnology pharmaceutical production and research appears to be increasing the rate of increase in pharmachem employment. As the value added per employee in pharmaceuticals is high, inward investment is less sensitive to labour costs than in many other industries. Heavy investment by the State in developing a biotechnology research base[33] should contribute to sustaining the industry's growth in the long term. An industry research base is already emerging through the establishment of private biotechnology research laboratories by companies such as Wyeth.

The recent ICSTI statement on Embedding the PharmaChem Industry in Ireland highlights a major opportunity for Ireland to strengthen its position in the global market by increasing involvement in drug development through process development and optimisation. This will require significant numbers of graduates in the sciences and engineering, including significant numbers of chemical engineers.

Figure 3.50 Employment in NACE (Rev.1) 24 (Chemicals, Chemical Products & Manmade Fibres), and its Predecessors NACE 25-26



Source: Census of Industrial Production. Estimate for 2001 based on trend in Survey of Industrial Employment.

Employment Projections

Employment projections for the pharmachem sector are developed on the basis that it will be possible to sustain increases employment at the rate of 6% per annum over the long term. This seems reasonable, given IDA predictions of growth.

32 Employment of no more than a few hundred.
33 The main channels are through Science Foundation Ireland, funding for research at third level through the HEA, and through a number of Enterprise Ireland channels.

Table 3.51 Employment Projections for Pharmachem Sector

Year	Employment	Employment Projection	Annual Growth	Assumed Annual Growth
1997	20,951		7.4%	
1998	21,415		2.2%	
1999	22,958		7.2%	
2000	22831		-0.6%	
2001	23,702		3.8%	
2002		24,887		5.0%
2003		26,380		6.0%
2004		27,963		6.0%
2005		29,641		6.0%
2006		31,419		6.0%
2007		33,305		6.0%
2008		35,303		6.0%
2009		37,421		6.0%
2010		39,666		6.0%
2011		42,046		6.0%
2012		44,569		6.0%

Projections of Demand for Engineering Graduates

The projections have been prepared on the following basis.

- Annual demand for graduates in engineering will tend to increase as the size of the industry increases.
- Recruitment in 2000 was depressed by a low rate of industry growth, and possibly by competition for graduates from other industries.
- Development of capabilities in drug development will boost the demand for engineering graduates, particularly for chemical engineers.

Tables 3.52 to 3.54 illustrate the projections.

Table 3.52 Projections of Demand from the Pharmachem Sector for Engineers and Engineering Technicians

Year	Degree	Certificate & Diploma
2003	46	21
2004	49	22
2005	53	24
2006	56	25
2007	60	27
2008	63	28
2009	67	30
2010	72	32
2011	76	34
2012	82	36

Table 3.53 Projection of Demand from the Pharmachem Sector for Degree Graduates, by Discipline

	Biomedical Engineering	Civil	Chemical / Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac- turing/ Industrial
2003			30		3	4	3	6
2004			32		3	5	3	6
2005			35		3	5	3	6
2006			37		3	5	3	7
2007			39		4	5	4	7
2008			42		4	6	4	8
2009			45		4	6	4	8
2010			48		4	6	4	9
2011			51		5	7	5	9
2012			55		5	7	5	10

Table 3.54 Projection of Demand from Pharmachem Sector for Diploma and Certificate Graduates, by Discipline

	Biomedical Engineering	Civil	Chemical / Process	Computer	Electronic	Mechan -ical	Mechat -ronic	Manufac- turing/ Industrial
2003					3	7	2	8
2004					3	8	2	9
2005					4	8	2	10
2006					4	9	3	10
2007					4	9	3	11
2008					4	10	3	11
2009					5	11	3	12
2010					5	11	3	13
2011					5	12	3	14
2012					5	13	4	14

3.7 Rest of Economy

The sectors for which separate projections have been made account for 81% of the primary degree engineering graduates of 2000 who entered employment in Ireland, and for a similarly high proportion of diploma and certificate engineering graduates. As these sectors are expected to form the main drivers of demand into the future, it is reasonable to abstract the rest of the economy into a single unit for projection purposes.

One plausible possibility is that the general recruitment of new labour market entrants into these other parts of the economy will fall in line with demographic trends, and that recruitment of engineering graduates will fall in proportion. This is the basis for the projection that follows. This outcome is plausible, given the fact that the share of engineering graduates accounted for by "other" sectors has been falling over time.

Demand levels are calculated on the basis of the 22 year old age cohort in each year. An exception to this approach has been made for electrical engineering, where industry information suggests that there is a requirement for some more graduates, and that demand is likely to at least be maintained over time. Indeed, there is a possibility that significantly more graduates could be required into the future as in-plant power generation becomes more common.

Tables 3.55 and 3.56 provide the projections.

Table 3.55 Projection of Demand from Rest of Economy for Degree Graduates, by Discipline

	Biomedical	Building Services	Civil	Chemical / Process	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Manufacturing / Industrial	Telecommunications
2003	8	1	31	18	*	24	18	99	4	25	82	1
2004	8	1	30	18	*	23	18	97	4	25	80	1
2005	8	1	29	17	*	22	18	93	4	24	78	1
2006	8	1	28	16	*	21	18	90	4	23	74	1
2007	7	1	27	16	*	21	18	87	4	22	73	1
2008	7	1	27	16	*	21	18	86	4	22	71	1
2009	7	1	27	16	*	21	18	87	4	22	72	1
2010	7	1	26	15	*	20	18	84	4	21	69	1
2011	7	1	24	14	*	18	18	77	3	20	64	1
2012	6	1	23	13	*	18	18	73	3	19	61	1

Table 3.56 Projection of Demand from Rest of Economy for Diploma and Certificate Graduates, by Discipline

	Biomedical	Building Services	Civil	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Manufacturing / Industrial
2003		29	39	*	174	26	81	21	58	38
2004		29	39	*	171	26	80	21	57	37
2005		29	39	*	173	26	81	21	58	38
2006		28	38	*	166	25	77	21	56	36
2007		26	35	*	153	23	71	19	52	34
2008		24	33	*	146	22	68	18	49	32
2009		25	34	*	150	22	70	19	50	33
2010		25	34	*	150	22	70	19	51	33
2011		24	32	*	144	21	67	18	48	31
2012		23	31	*	139	21	65	17	47	30

3.8 Summary Projections for Total Economy

Tables 3.57 and 3.58 present the "total economy" projections, which represent the sum of the sectoral projections. The disciplines for which most demand is projected are civil engineering and electronic engineering, both at degree level and at diploma and certificate level. The demand for civil engineering graduates is driven mainly by construction activity, while the demand for electronic engineering graduates is driven by projections of a resumption of growth in ICT industries.

Table 3.57 Projection of Demand from Total Economy for Engineering Degree Graduates, by Discipline

	Biomedical	Building Services	Civil	Chemical / Process	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
Based on Software & IT Services Projection 1													
2003	37	13	211	84	*	129	18	156	15	25	164	14	866
2004	38	14	249	92	*	372	18	169	19	25	197	33	1,226
2005	40	14	264	95	*	430	18	170	20	24	206	39	1,320
2006	41	13	256	97	*	456	18	168	20	23	205	41	1,338
2007	41	13	255	100	*	486	18	167	21	22	208	43	1,374
2008	43	13	256	104	*	513	18	169	21	22	211	45	1,415
2009	45	13	266	108	*	539	18	172	22	22	216	47	1,468
2010	46	13	269	110	*	565	18	171	22	21	219	49	1,503
2011	47	13	272	113	*	588	18	168	22	20	219	50	1,530
2012	46	14	285	117	*	608	18	168	24	19	224	52	1,575
Based on Software & IT Services Projection 1													
2003	37	13	211	84	*	129	18	156	15	25	164	14	866
2004	38	14	242	91	*	345	18	167	18	25	189	32	1,179
2005	40	14	246	93	*	371	18	164	18	24	189	37	1,214
2006	41	13	235	95	*	390	18	161	18	23	186	39	1,219
2007	41	13	232	98	*	412	18	160	18	22	187	41	1,243
2008	43	13	230	102	*	431	18	160	19	22	187	43	1,268
2009	45	13	237	105	*	449	18	162	19	22	190	44	1,304
2010	46	13	237	107	*	464	18	161	19	21	190	46	1,322
2011	47	13	236	111	*	477	18	156	20	20	187	48	1,333
2012	46	14	245	114	*	489	18	154	21	19	188	49	1,357

Table 3.58 Projection of Demand from Total Economy for Engineering Diploma and Certificate Graduates, by Discipline

	Biomedical	Building Services	Civil	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
Based on Software & IT Services Projection 1												
2003	8	55	451	*	327	26	127	35	58	103	0	1,190
2004	8	56	477	*	407	26	142	39	57	124	2	1,338
2005	8	56	477	*	424	62	145	39	58	130	2	1,365
2006	9	53	450	*	420	25	143	40	56	128	2	1,326
2007	9	51	441	*	414	23	137	38	52	128	3	1,296
2008	10	49	433	*	411	22	136	37	49	128	3	1,278
2009	10	50	448	*	421	22	140	38	50	130	3	1,312
2010	11	50	448	*	427	22	140	39	51	133	3	1,324
2011	12	49	447	*	426	21	139	38	48	134	4	1,318
2012	13	50	469	*	424	21	139	38	47	136	4	1,341
Based on Software & IT Services Projection 1												
2003	8	55	451	*	327	26	127	35	58	103	0	1,190
2004	8	56	476	*	401	26	141	39	75	123	2	1,329
2005	8	56	474	*	412	26	143	39	58	127	2	1,345
2006	9	53	446	*	408	25	141	40	56	124	2	1,304
2007	9	51	437	*	399	23	135	38	52	124	3	1,271
2008	10	49	428	*	395	22	134	37	49	123	3	1,250
2009	10	50	444	*	401	22	137	38	50	126	3	1,281
2010	11	50	443	*	405	22	137	39	51	128	3	1,289
2011	12	49	441	*	402	21	136	38	48	128	4	1,279
2012	13	50	462	*	399	21	136	38	47	129	4	1,299

3.9 Demand for Higher Degree Graduates

The projections in this chapter do not distinguish between demand for primary degree graduates and that for higher degree graduates. Other studies by the Expert Group on Future Skills Needs have projected that there will be a major need for graduates with research degrees into the future, to staff many of the research and development positions that are expected to emerge.

The analyses of graduate destinations undertaken for this study show that there is not yet a clearly-identifiable shortage of graduates with research degrees in Engineering. A substantial percentage still go overseas to find employment, and, more than half of the PhD graduates of 2000 who entered employment in Ireland were employed by the education sector.

Figure 3.59 First Destinations of Engineering Research Graduates of 2000

Destination	Research Masters	PhD
Employed Ireland	51.6%	52.5%
Employed Overseas	30.9%	40.5%
Work Experience	0.0%	0.0%
Further Study / Research	17.5%	4.7%
Other Training	0.0%	0.0%
Teacher Training	0.0%	0.0%
Seeking Employment	0.0%	0.0%
Not Available for Employment / Study	0.0%	2.3%
Total	**100.0%**	**100.0%**

Source: Based on analysis of HEA First Destination Database for 2000

However, the vision of the future projected in the current report is one in which there will be very much more product development work undertaken in Ireland than in the past. Across all sectors, this will lead to a much greater need for graduates with research degrees. Such degrees are particularly likely to be useful for the new development-related positions projected to be required in:

- Electronic Systems and Hardware;
- IC Design;
- Higher value-added parts of Software & IT Services;
- Medical Devices;
- Pharmachem; and
- Biotechnology.

4. Supply Analysis

4.1 Introduction

This chapter addresses the supply of engineers and engineering technicians now and into the future. It begins by setting supply in a historical context. This is followed by an analysis of the supply for the immediate future, based on the numbers of students already in the third level system. It distinguishes between graduate numbers, and the number of graduates who are likely to actually be available to Irish employers.

The following section continues with a longer term view of supply, examining demographic trends, the impact of perceptions of career prospects on applications to study engineering, subject choice at second level and general perceptions of engineering among second level students. It also examines supply side measures by employers.

The final section presents some summary conclusions about graduate supply into the future. The impact of immigration on the balance between supply and demand is addressed in Chapter 5.

4.2 History of Supply of Engineers

Not all engineering graduates are actually available for employment. A substantial proportion of those graduating with a certificate proceed to study for a diploma, and many of those graduating with diplomas continue to study for a degree. Over time, the proportion progressing in this way has increased, and this is why the percentage of those graduating at these levels that progress to employment in Ireland has fallen in recent years despite strong labour market demand.
At degree level, the percentage of those graduating and entering employment in Ireland has increased substantially over time, mainly reflecting a greater propensity to remain in Ireland rather than emigrating. The data are shown in Table 4.1.

Table 4.1 Numbers of Engineering Graduates Employed in Ireland, graduating 1991 to 2000

	Certificates & Diplomas		Primary Degrees		Higher Degrees	
	% Employed in Ireland	Number Employed in Ireland	% Employed in Ireland	Number Employed in Ireland	% Employed in Ireland	Number Employed in Ireland
1991	33.1%	803	45.2%	516	60.1%	106
1992	32.6%	886	41.6%	480	70.8%	116
1993	33.6%	978	42.2%	524	60.1%	133
1994	33.9%	986	48.0%	638	56.8%	145
1995	33.5%	1,039	54.9%	747	63.3%	170
1996	35.7%	1,034	61.0%	856	68.7%	164
1997	39.6%	1,116	62.9%	934	60.8%	139
1998	44.2%	1,327	66.6%	1,032	61.1%	132
1999	41.3% *	1,360	68.5%	1,174	61.9%	150
2000	38.3%	1,298	70.7%	1,215	58.2%	137

* An interpolation has been substituted for the published data here.

Source: Percentages of graduates employed in Ireland are drawn from First Destination of Award Recipients in Higher Education , HEA, 1991-2000. Numbers are based on grossing up First Destination data.

4.3 Supply for the Immediate Future

This section sets out projections of graduate numbers based on a course-by-course analysis of the number of students already enrolled on full time undergraduate courses in engineering. It follows this with an analysis of First Destination of Award Recipients data for the graduates of 2000, disaggregated by the same course categories as the projections of full time graduate numbers, and uses this analysis to inform an assessment of the proportion of new graduates likely to be available to Irish industry into the future. It applies this assessment to the projections of graduate numbers to produce projections of the supply of engineering graduates expected to actually be available to Irish employers.

Tables 4.2-4.4 set out projections of engineering graduate numbers based on student numbers in academic year 2001/02, and on relationships between student and graduate numbers derived from a combination of historical data and information derived from interviews with colleges. The projections extend to the typical year of graduation of students commencing their course in academic year 2001/02[1].

At degree level, the main points to note are that the output of civil engineers is expected to increase significantly, while the output of electronic engineers is expected to fall, after peaking in the current year. The output of bio-medical engineers is expected to increase from a low base. Overall degree graduate numbers are expected to level off, with little change between 2003 and 2005. Note that a graduate diploma conversion programme is expected to add approximately 28 to the effective number of chemical engineering graduates in each year.

Table 4.2 Projections of Full Time Primary Degree Level Engineering Graduate Numbers (extending to the expected year of graduation of the first years of academic year 2001/02)

Degree Level	2001	2002	2003	2004	2005
Bio-Medical	15	17	40	43	37
Building Services	29	19	26	15	20
Civil (incl. Environmental and Construction Mgt.)	335	402	385	418	435
Chemical / Process	89	68	76	76	86
Computer	120	144	134	155	162
Electronic	475	534	541	527	470
Electrical	8	4	7	6	6
Mechanical	303	294	264	275	264
Mechatronic	40	42	28	28	56
Other	90	116	144	129	131
Manufacturing / Industrial	264	261	304	312	305
Telecommunications Engineering	22	21	28	21	9
Total	**1,790**	**1,922**	**1,977**	**2,005**	**1,981**

At diploma level, the main points to note are again to do with an upturn in output of civil engineering graduates, and a downturn in electronic engineering. Overall, numbers of diploma graduates are not expected to change much over the period covered.

1 The projections have been prepared at the level of the individual course. There are approximately 250 full time undergraduate courses involved.

Table 4.3 Projections of Full Time Diploma Level Engineering Graduate Numbers (extending to the expected year of graduation of the first years of academic year 2001/02)

Degree Level	2001	2002	2003	2004
Building Services	75	66	75	78
Civil	358	366	444	454
Computer	50	65	50	40
Electronic	351	361	358	304
Electrical	25	15	15	24
Mechanical	192	188	172	189
Mechatronic	23	26	30	23
Other	121	99	99	98
Manufacturing / Industrial	244	250	250	267
Total	**1,439**	**1,922**	**1,977**	**2,005**

Table 4.4 shows that, at certificate level, civil engineering graduate numbers are again increasing, as are bio-medical engineering numbers. Again, electronic engineering graduate numbers are falling. An overall rise in certificate numbers reflects mainly the civil engineering increase.

Table 4.4 Projections of Full Time Certificate Level Engineering Graduate Numbers (extending to the expected year of graduation of the first years of academic year 2001/02)

Certificate Level	2001	2002	2003
Bio-Medical	7	46	38
Building Services	57	88	97
Civil	700	807	827
Construction Economics	25	24	35
Computer	9	16	14
Electronic	449	445	371
Electrical	22	22	35
Mechanical	272	240	275
Mechatronic	25	27	32
Other	95	89	97
Industrial / Production / Manufacturing / Quality	118	118	126
Total	**1,779**	**1,922**	**1,947**

4.4 First Destination of Award Recipients Analysis

Every year from around March to June, HETAC and the careers services of the universities and DIT survey graduates of the previous calendar year. One of the questions asked is about their "Present Situation".

This section presents an analysis of the degree level data (which is held by the HEA) and of the certificate and diploma level data for HETAC-validated graduates[2]. The primary degree, certificate and diploma level analyses are presented using the same disciplinary breakdown used for projections of graduate numbers earlier. Analyses of postgraduate qualifications are presented without a disciplinary breakdown[3]. It should be noted that sampling error may have affected areas with smaller numbers of graduates to a material extent.

Table 4.5 presents the analysis for primary degrees. It can be seen that graduates overwhelmingly enter employment on completing their degree, and that with some exceptions they are employed in Ireland. It is likely that many of those recorded as "Not available for Employment or Study" have taken a year off to travel, prior to starting work in Ireland.

2 The analysis that follows works on the assumption that the destinations of DIT graduates are not much different to those of graduates in the same engineering disciplines from the other Institutes of Technology (whose qualifications are validated by HETAC).

3 This is partly because specific disciplinary information is not included in the database for some Engineering postgraduates, and because the numbers are quite small in most disciplinary areas.

Table 4.5 First Destinations of Primary Degree Engineering Graduates of 2000, (%)

	Employed in Ireland	Employed Outside Ireland	Work Experience	Further Study / Research	Other Training	Teacher Training	Seeking Employment	Not Available for Employment / Study
Biomedical Engineering	90.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0
Building Services Engineering	85.7	14.3	0.0	0.0	0.0	0.0	0.0	0.0
Civil Engineering	79.0	4.4	0.0	11.1	1.6	0.0	0.8	3.2
Chemical Engineering	79.7	7.2	0.0	10.9	2.2	0.0	0.0	0.0
Computer Engineering	62.0	25.5	0.0	5.4	0.0	0.0	3.6	3.6
Electronic Engineering	72.4	6.1	0.0	13.8	0.6	0.0	2.1	5.1
Electrical Engineering	88.9	0.0	0.0	0.0	0.0	0.0	0.0	11.1
Mechanical Engineering	65.3	9.1	0.0	12.6	7.9	0.0	1.4	3.7
Mechatronic Engineering	60.0	8.0	0.0	4.0	0.0	0.0	12.0	16.0
Other Engineering	57.1	21.4	0.0	10.7	0.0	0.0	3.6	7.1
Manufacturing / Industrial Engineering	69.1	4.8	0.9	12.2	4.3	0.9	1.7	7.0
Telecommunications Engineering	93.3	6.7	0.0	0.0	0.0	0.0	0.0	0.0

The significant proportion of "Other Engineering" primary degree graduates shown working overseas reflects mainly the inclusion of aeronautical engineering in the category. Table 4.6 presents the analysis for Higher Degrees. The most notable feature is the high rate at which research degree graduates, particularly PhDs, enter employment overseas.

Table 4.6 First Destinations of Higher Degree Engineering Graduates of 2000, (%)

	Employed in Ireland	Employed Outside Ireland	Work Experience	Further Study / Research	Other Training	Teacher Training	Seeking Employment	Not Available for Employment / Study
Grad Dip	77.0	3.0	0.0	2.9	0.0	0.0	2.9	14.3
Taught Masters	71.1	16.2	0.0	8.5	0.0	0.8	1.7	1.7
Research Masters	56.7	25.8	0.0	17.5	0.0	0.0	0.0	0.0
PhD	52.5	40.5	0.0	4.7	0.0	0.0	0.0	2.3

Table 4.7 estimates the percentages of diploma graduates proceeding to various destinations. The relatively high percentages of computer engineering and production / manufacturing engineering graduates proceeding to further study appear to reflect the opportunities for add-on degrees. While diploma graduates in most engineering disciplines have to study for further two years to obtain a BE degree, those in computer engineering and production / manufacturing engineering have greater opportunities to study for one-year add-on degrees that lead to other bachelor's level qualifications.

Table 4.7 First Destinations of HETAC Diploma Engineering Graduates of 2000, (%)

	Employed	Work Experience	Further Study / Research	Seeking Employment	Not Available for Employment / Study
Biomedical Engineering	68.1	0.0	24.3	0.0	7.6
Building Services Engineering	63.5	0.0	36.5	0.0	0.0
Civil Engineering	46.9	0.0	46.4	1.9	4.8
Computer Engineering	14.2	0.0	81.0	4.7	0.0
Electronic Engineering	58.5	0.0	39.7	0.0	1.9
Electrical Engineering	65.7	0.0	34.3	0.0	0.0
Mechanical Engineering	44.9	0.0	55.1	0.0	0.0
Mechatronic Engineering	88.8%	0.0%	11.2%	0.0%	0.0%
Other Engineering	63.3%	0.0.%	34.7%	2.0%	0.0%
Production/Manufacturing Engineering	45.6%	1.5%	50.0%	1.5%	1.5%

It was not possible in this analysis to separate employment overseas from employment in Ireland. This is not a major issue as only 1.2% of engineering diploma graduates from 2000 were found to have gone into employment overseas in the published report for 2000.

Table 4.8 estimates the percentages of certificate graduates proceeding to various destinations. In most areas, the rate of transfer to further study is high. Areas where the rate of transfer to employment is relatively high tend to be those most directly relevant to manufacturing.

Table 4.8 First Destinations of HETAC Certificate Engineering Graduates of 2000, (%)

	Employed	Work Experience	Further Study / Research	Seeking Employment	Not Available for Employment / Study
Building Services Engineering	32.6	00.0	67.4	0.0	0.0
Civil Engineering	16.3	0.6	81.9	0.2	1.0
Computer Engineering	0.0	0.0	100.0	0.0	0.0
Electronic Engineering	30.2	0.4	66.4	0.8	2.3
Electrical Engineering	65.7	0.0	34.3	0.0	0.0
Mechanical Engineering	26.7	1.4	69.7	0.7	0.7
Mechatronic Engineering	47.3	0.0	46.8	3.0	3.0
Other Engineering	27.8	0.0	69.2	1.5	1.5
Manufacturing/Industrial Engineering	64.6	2.9	27.8	2.9	1.9

4.5 Estimating Availability of Graduates to Employers

4.5.1 Primary Degree and Above

Except where it is important to focus specifically on postgraduates, the demand-supply analysis groups degree and higher degree graduates. Primary degree graduates who go on to postgraduate study in Ireland are treated as being available to industry, on the basis that most will eventually become available, and on the basis that typically the number of degree graduates entering postgraduate study will tend to be matched by the number leaving it through graduation or dropping out in any given year.

On this basis, and taking into account the First Destination data presented in Tables 4.7 and 4.8, it is estimated for the purposes of forecasting the supply of graduates that 87%[4] of primary degree graduates in most disciplines, and 80% of the graduates in "Other Engineering" will be available to Irish employers[5].

4.5.2 Diplomas and Certificates

At diploma and certificate level, it is not appropriate to count graduates progressing to further study who will appear later with a qualification at a higher level, as this would lead to double counting. As the differences between disciplines in terms of progression to further study appear to be more systematic than at degree level, estimates of availability are prepared for each discipline.

Table 4.9 Assumed Rates of Availability to Irish Employers of Diploma and Certificate Level Engineering Graduates

	% Diploma Graduates Available to Irish Industry	% Certificate Graduates Available to Irish Industry
Biomedical Engineering		30.0%
Building Services Engineering	66.3%	39.3%
Civil Engineering	57.5%	26.2%
Computer Engineering	26.8%	10.0%
Electronic Engineering	63.5%	40.2%
Electrical Engineering	68.3%	69.0%
Mechanical Engineering	49.8%	37.2%
Mechatronic Engineering	88.8%	57.8%
Other Engineering	67.9%	37.6%
Manufacturing/Industrial Engineering	54.3%	74.8%

These are presented in Table 4.9. The numbers in this table are based on the First Destination data presented earlier, and are calculated on the basis that the proportion of graduates available to industry will be all graduates except those proceeding to further study, plus a further 10% of those proceeding to further study who are assumed to fail to graduate, and to become available for employment at their original level of qualification shown in Table 4.9. This is discounted by a small amount (1.2% in the case of diplomas and 0.2% in the case of certificates[6]) to take account of emigration.

4.6 Projections of Supply of New Graduates Available to Industry

Tables 4.10 to 4.12 apply the above percentages (filling gaps with figures that are typical of the level of qualification where necessary) to the projections of graduate numbers to produce a projection of the supply actually available to industry.

Table 4.10 Supply of Degree Level Engineering Graduates Available to Irish Industry

Degree Level	2001	2002	2003	2004	2005
Biomedical	13	15	35	37	32
Building Services	25	17	23	13	17
Civil	291	350	335	364	378
Chemical / Process	77	59	66	66	75
Computer	104	125	117	135	141
Electronic	413	465	471	458	409
Electrical	7	3	6	5	5
Mechanical	264	256	230	239	230
Mechatronic	35	37	24	24	49
Other	78	101	125	112	114
Manufacturing / Industrial	230	227	264	271	265
Telecommunications Engineering	19	18	24	18	8
Total	**1,556**	**1,673**	**1,720**	**1,742**	**1,723**

4 This is significantly higher than the 70.7% of primary degree graduates of 2000 who directly entered employment in Ireland because it takes into account the likelihood that many of those undertaking further studies and many of those not immediately available for work will eventually enter employment in Ireland, and because the Irish labour market in a number of engineering disciplines was not tight in 2000/01.
5 It is reasonable to think that much of the variation between disciplines seen in these tables may originate from factors specific to one year, or to sampling errors.
6 Based on published First Destination data for diploma and certificate graduates of 2000.

Table 4.11 Supply of Diploma Level Engineering Graduates Available to Irish Industry

Degree Level	2001	2002	2003	2004
Biomedical Engineering				
Building Services	50	44	50	52
Civil	206	210	255	261
Computer	13	17	13	11
Electronic	223	229	227	193
Electrical	17	10	10	16
Mechanical	96	94	86	94
Mechatronic	20	23	27	20
Other	82	67	67	67
Manufacturing / Industrial	132	136	136	145
Total	**839**	**830**	**871**	**859**

Table 4.12 Supply of Certificate Level Engineering Graduates Available to Irish Industry

Certificate Level	2001	2002	2003
Bio-medical	2	14	11
Building Services	22	35	38
Civil	183	211	217
Computer	1	2	1
Electronic	180	179	149
Electrical	15	15	24
Mechanical	101	89	102
Mechatronic	14	16	18
Other	36	33	36
Manufacturing / Industrial	88	88	94
Total	**642**	**682**	**690**

4.7 Longer Term View of Supply of Graduates

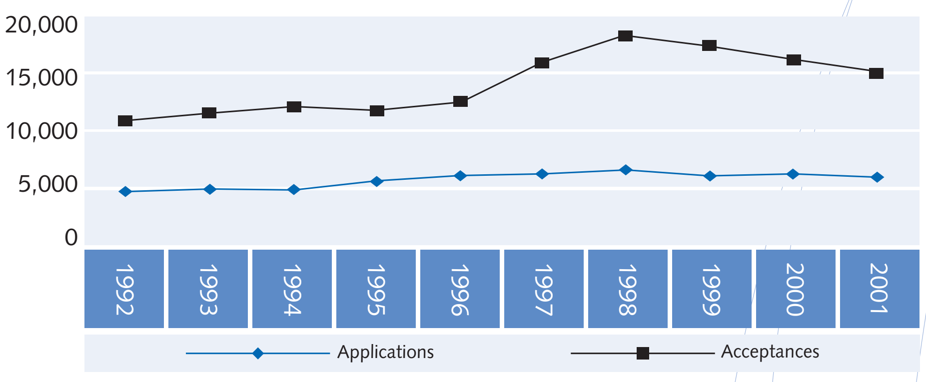
4.7.1 Introduction

Until around 1996, the number of college places available was the main factor limiting the number of students beginning engineering courses in Ireland. In combination with factors such as non-completion rates and the rate of transfer onto add-on courses, it was consequentially also the main factor limiting the number of engineering graduates.

During the latter half of the 1990s, increases in the number of third level places available, combined with a demographically-driven leveling-off in numbers of college applicants, led to a situation where the excess of demand for college places over supply was reduced, and in the case of some courses, eliminated (see Figure 4.13).

One of the areas particularly affected was that of engineering certificates. In some cases, reduced demand left colleges unable to fill all of their places. In many other cases, it led to the recruitment of students with lower levels of prior academic achievement than had been accepted previously.

Figure 4.13 Applications and Acceptances for Engineering / Technology Certificate and Diploma Courses[7]



Source: Data from CAO.

At degree level, a similar pattern has been observed since around 2000. Increases in third level places generally, and particularly in computing, appear to have led to reductions in the number of applications for many engineering degree courses. As at certificate level, reduced demand has left colleges unable (or in some cases unwilling) to fill all of the places that they could have made available[8]. In some cases, it led to the recruitment of students with lower levels of prior academic achievement than had been accepted previously.

Thus, the supply of engineering graduates is now in large part a function of the number and quality of applicants for engineering courses. As relatively few mature students applying for admission to third level have a strong mathematical and scientific/technical background, this means that the supply of degree level graduates is mainly a function of the number and mix of school leavers applying to study engineering.

A study by MRBI in 2002 for the Expert Group on Future Skills Needs and Forfás found that personal ability and personal interest were the main factors affecting individual decisions about applying to study engineering. The likelihood is that the overall ability profile of school leavers does not vary much from year to year. Thus, it is likely that the number of school leavers applying to study engineering in any year will be a function of the overall number of school leavers (affected by demographic trends), and of the level of interest that they have in engineering. Key factors that influence the number of school leavers applying to study Engineering include the following:

- Demographic trends;
- Perceptions of opportunities for engineering graduates;
- Perceptions of engineering among school students; and
- Subject choice at Leaving Certificate and Junior Certificate level.

4.7.2 Demographic Trends

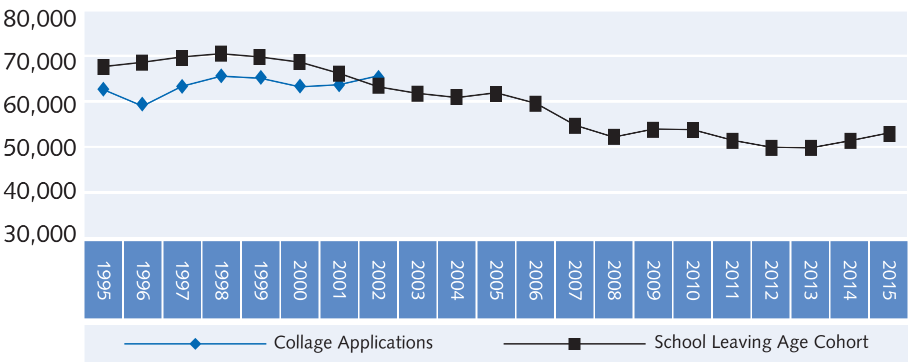
The number of students of school leaving age peaked in 1998. It has fallen since, and is expected to fall further, to 60,000 around 2006, and 50,000 around 2012 (see Figure 4.14). Increased applications from mature students have largely compensated for the overall fall in college applications by school leavers so far, but it seems unlikely that mature student applications will continue to grow sufficiently to compensate for demographic trends over the longer term.

All other things being equal, if the school leaver demographic trend were reflected in applications for engineering courses, degree output would fall from the 1,720 projected for 2002, to 1,441 in 2010 and 1,208 in 2016[9,10].

7 As indicated earlier, CAO's Engineering / Technology category includes engineering courses and many computing courses.
8 The requirement for a C in Higher Level Leaving Certificate Mathematics for IEI accredited courses tends to limit the proportion of applicants that can be accepted onto degree level Engineering courses.
9 2010 and 2016 are four years (typical duration of an Engineering degree) after 2006 and 2012.
10 Relatively few mature students enter Engineering.

In the past, the number of applicants admitted to study each discipline at third level was relatively insensitive to the number of applications from people who met the qualifying threshold. Now, a combination of demographic change, and growth in the number of college places available, has changed the balance between supply and demand across a wide range of courses. This has made the numbers entering engineering sensitive to shifts in student interests and sentiment than at present. The fact that we are still close to the beginning of the demographic downturn suggests that numbers entering engineering are likely to become more sensitive to such shifts over time.

Figure 4.14 Projection of Leaving Certificate Age Cohort



Source: Based on projections in the "Report of Review Committee on Post-Secondary Education and Training Places", 1999, with interpolations based on CSO data on births.

4.7.3 Impact of Perceptions of Industry Prospects

The current year has provided substantial evidence that applications for engineering courses can be affected by perceptions of career opportunities among school leavers. Overall applications for engineering courses have fallen sharply. This is reflected in Central Applications Office data for engineering and computing courses presented in Table 4.15.

Table 4.15 Applications for Third Level Engineering / Technology+ Courses, 1992 - 2002

	Engineering/Technology Degree		Engineering/Technology Cert/Dip	
	1st Preference Applications	% Change	1st Preference Applications	% Change
1992	5,263		10,854	
1993	6,098	15.9%	11,633	7.2%
1994	6,342	4.0%	12,140	4.4%
1995	6,743	6.3%	11,752	-3.2%
1996	6,491	-3.7%	12,565	6.9%
1997	8,219	26.6%	15,910	26.6%
1998	8,952	8.9%	18,200	14.4%
1999	9,515	6.3%	17,473	-4.0%
2000	9,743	2.4%	16,199	-7.3%
2001	9,460	-2.9%	15,034	-7.2%
2002*	7,577	-19.9%	11,657	-22.5%

+ The CAO's Engineering/Technology classification includes Engineering courses and most Computing courses.
* Numbers for 2002 here reflect the position before changes of mind.

The major increases in applications in 1997, 1998 and (at degree level) in 1999 were mainly for computing courses, while the more recent fall in applications reflects both a fall in computing applications and a fall in applications in some areas of engineering.

For 2001 and 2002, the CAO has released data that disaggregates[11] applications for engineering from those from computing. For the Institutes of Technology, it also includes a construction category, shown in Table 4.16. Much of what is termed

11 Note that applications for Engineering, Computing and Construction sum to an amount greater than that for the Engineering / Technology classification. This appears to reflect the inclusion of courses that are not included in the Engineering / Technology classification, which, for example, does not include all Computing courses.

construction by the Institutes of Technology has been treated as civil engineering for the purposes of this study.

The table demonstrates that the overall 19.9% fall in applications for engineering/technology degree courses is made up of a small overall rise in applications for engineering degree courses at universities, a sharp fall in applications for Engineering degree courses at Institutes of Technology, and a very steep fall in applications for computing degree courses both at universities and at Institutes of Technology.

Table 4.16 Changes in First Preference Applications for Engineering and Related Disciplines 2001-2002

		2001	2002	% Change
University	Engineering	2,653	2,690	1.4%
Degree	Computing	2,370	1,133	-52.2%
Institutes of	Engineering	1,897	1,622	-14.5%
Technology	Construction	2,243	2,194	-2.2%
Degree	Computing	1,758	1,157	-34.2%
Institutes of	Engineering	5,181	4,646	-10.3%
Technology	Construction	6,071	6,276	3.4%
Diploma & Cert	Computing	6,123	2,916	-52.4%

As we show later, the extent of the fall in total applications for engineering courses masks a much steeper fall in applications for courses associated closely with information and communications technologies. While total applications to study engineering at universities rose between 2001 and 2002, this masks a steep fall in applications to study electronic engineering and closely related disciplines.

At degree level, the fall in interest in engineering / technology courses (and a lesser fall for administration / business courses) has been balanced by a rise in interest healthcare and arts / social science courses. There was a similar shift in interest in favour of arts/social science courses at diploma and certificate level, which compounded the net shift away from engineering / technology courses that began in 1999[12,13].

Table 4.17 Changes in Degree Applications by Subject Area

	2001	2002	Change	2001	2002	Change	2001	2002	Change
Engineering	2,653	2,690	37	1,897	1,622	-275	5,181	4,646	-535
Computing	2,370	1,133	-1,237	1,758	1,157	-601	6,123	2,916	-3,207
Science	3,679	3,858	179	471	877	406	5,705	6,573	868
Construction				2,243	2,194	-49	6,071	6,276	205
Architecture	354	460	106						0
Business	7,252	7,292	40	2,631	2.805	174	14,497	14,678	181
Tourism/						-273	3,873	3,657	-216
Recreation/Leisure				1,509	1,236				
Law	1,804	2,301	497						0
Social/ Healthcare	4,705	5,380	675	914	1,316	402	3,716	4,744	1,028
Arts / Humanities	11,604	11,009	-595			0			0
Education	991	1,274	283			0			0
Other IoT				2,409	2,100	-309	7,170	5,980	-1,190
Total	**35,412**	**35,397**	**-15**	**13,832**	**13,807**	**-525**	**52,336**	**49,470**	**-2,866**

Table 4.18 presents more detail on changes in the number of applications for third level engineering courses.

12 The shift away from Engineering at diploma and certificate level started earlier, but this is masked in the statistics by a contemporaneous increase in the popularity of Computing.

13 As a part of the research for this report, colleges were asked to indicate how many total applications they had received for each Engineering course in 2001 and in 2002. An analysis in the Statistical Appendix (Table A.12) shows the average change in applications for degree level courses for which data was received, classified according to Engineering discipline. It sets this alongside the share of graduates in each of these disciplines entering Irish employment who were employed by the ICT sectors, demonstrating a strong correlation between dependence on ICT for employment and the extent of the fall in applications

Table 4.18 Average Percentage Change in Applications from 2001 to 2002 for Engineering Courses of Various Types, based on Responses to a Survey of Colleges

	Degree	Diploma	Certificate
Civil	9.0%		-1.0%
Building Services			7.0%
Chemical / Process	-2.0%		
Bio-medical	-4.0%		
Mechanical	-7.0%		-3.0%
Mechatronic		-17.0%	
Other Engineering	-9.0%	-33.0%	-26.0%
Common Entry	-14.0%		
Transportation-Related Engineering	-23.0%	5.0%	-2.0%
Manufacturing / Industrial	-27.0%	-19.0%	-23.0%
Telecommunications Engineering	-35.0%		
Electronic	-36.0%		-39.0%
Computer	-37.0%		

The decrease in applications for engineering that took place between 2001 and 2002 is mainly, if not entirely, a function of a loss of confidence in the information and communications technology industries, which were, by a large margin, collectively the single largest employer of new engineers graduating in 2000. This is apparent from interviews with engineering students and engineering academics.

The loss of confidence in the ICT industries appears to reflect a combination of continuing bad news about the sector internationally and in Ireland, with broadly accurate information on the current state of the market for new graduates in ICT-related disciplines. By contrast, applications for degree level civil engineering courses have risen significantly, while those for certificate courses have held steady. This appears to reflect a strong market for civil engineering graduates, strong growth until very recently in the construction industry, and an understanding that the National Development Plan 2000-2006 and its successors will provide a significant volume of work for civil engineers into the future.

The loss of confidence in the information and communications technology industries is not a one-off event. In Ireland and internationally, some of the main industries that employ engineers are subject to occasional downturns that temporarily reduce demand for new graduates.

For example, the early 1990s was also a time of poor opportunities in the ICT sectors across the developed world. This depressed graduate output in relevant technical disciplines in the US and some other developed economies, setting the stage for shortages in the latter half of the 1990s, when demand increased. The reality of slowdowns of this nature in the ICT industries is recognised in earlier reports by the Expert Group on Future Skills Needs.

Also, through much of the 1980s, poor economic conditions and consequential low investment in infrastructure in Ireland made civil engineering an unpopular choice relative to electronic and mechanical engineering in Irish universities. Thus, the decrease in applications for courses relevant to the ICT industries is not an unusual response to bad industry and labour market news either in the Irish context or internationally.

As indicated earlier, it is expected that growth in demand for ICT products and services will recover to a level that will allow ICT industries globally and in Ireland to resume growth. The likelihood is that this will eventually increase confidence in the career prospects of engineering graduates, leading to some recovery in the percentage of college applicants applying for engineering. However, the extent of this recovery will be sensitive to actual labour market conditions. It will also be sensitive to the speed with which, and extent to which, confidence in the future of the industry can be rebuilt.

4.7.4 Subject Choice at Leaving Certificate and Junior Certificate Levels

Relevance of Second Level Subjects to Study of Engineering at Third Level
The decision to apply to study engineering appears to be linked to subject choice at second level. This is partly a function of formal admission requirements - students admitted to degree courses accredited by the IEI will all have at least a C in Higher Level Mathematics, and some colleges have other subject requirements for engineering applicants.

It is also a function of student interests and behaviour. Based on interviews undertaken for this study, it is known that engineering students at all levels are likely to have had a particular interest in one, or usually more, of the following subjects at Leaving Certificate level: Mathematics; Physics; Chemistry; Physics & Chemistry; Applied Mathematics; Technical Drawing; Engineering; or Construction Studies.

Taking these subjects at second level is also useful preparation for students who go on to study engineering at third level. Thus, the number of students who take these subjects at Leaving Certificate level is an important factor influencing the demand for places on Engineering courses among school leavers.

There are two major causes for concern in this regard.

1. The percentage of students studying Physics or Chemistry[14] at Leaving Certificate level has fallen significantly since the early 1990s. In 1990, 20% of students to Physics in the Leaving Certificate, while 16% took Chemistry. By 2001, these figures had fallen to 16% and 12% respectively, although there has been a modest recovery in 2002.

2. The percentage of students taking Mathematics at Higher Level is very low (at 18.1%) relative to other subjects, despite a marked increase after a curriculum change that was first examined in 1994. Also, there are significant issues with student performance in Ordinary Level Mathematics.

These two factors tend to limit the number of school leavers interested in studying engineering, particularly at degree level.

Task Force on the Physical Sciences
The ***Task Force on the Physical Sciences*** was established to address the low numbers of students interested in studying ***Physics*** and ***Chemistry.*** Its report, published while this study of Engineering skills was underway, covers a wide range of issues[15]. It sets out a strategy and makes a series of recommendations.

The report makes recommendations that apply to engineering and technology at third level as well as to science. The main recommendations of relevance are those:

- to promote recruitment;
- to promote access, transfer and progression; and
- to promote quality in teaching and learning at undergraduate level.

Findings of the current study that are relevant to these recommendations are as follows.

- There is a need for a very much higher level of activity in promoting engineering as a career, and much of the additional work should be based in third level colleges.
- Increased activity in "taster courses" targeted on groups with the necessary skills, but with little existing knowledge or motivation to apply to study engineering, has the potential to increase the demand for engineering among college graduates.

14 Higher Level and Ordinary Level taken together.
15 The Task Force was established in November 2000. Its report was published in April 2002 under the title "Report and Recommendations of the Task Force on the Physical Sciences".

- Increased use of project-based and problem-based learning approaches, where appropriate, appears to present some opportunities for improving the quality of teaching and learning at undergraduate level in engineering.

The report of the Task Force also addresses ***Mathematics***, recommending that a Review of Mathematics should be undertaken, although the main focus of the recommendation is at Ordinary Level and Foundation Level, rather than at Higher Level. The report has highlighted a high failure rate in Ordinary Level Mathematics in 2001 (17% on average, and 19% for males), which "rendered one-sixth of school leavers ineligible for many science, engineering and technology courses"[16]. It noted that this "reduced the pool of potential candidates for engineering technology courses in institutes of technology"[17].

In particular, the report states

> *"The Chief Examiner's report on the ordinary level Mathematics exam for Leaving Certificate 2001 highlighted a "noticeable increase in the incidence of difficulties experienced by candidates". Causes suggested for low grades included the knock-on effects of difficulty with the old junior cycle syllabus (which was revised in 1999), and the increase in part-time work by students. Many science, engineering and technology departments in higher education report a lack of adeptness in basic mathematical skills on the part of students with ordinary level Mathematics.*
>
> *"Students' perception of the difficulty of mathematics and their poor performance in the subject both act as barriers to participation and success in the sciences at second and at third level. The risk in not addressing the problem with mathematics is that of undermining reform in science education.[18]"*

While endorsing strongly the Task Force's statements on Mathematics, this report highlights some other issues that might usefully be addressed by the Review of Mathematics.

1. The relatively low take-up of Higher Level Mathematics among Leaving Certificate students represents a significant obstacle to ensuring a sufficient supply of engineering graduates into the future.

2. The risk in not addressing the problem identified at Ordinary Level extends beyond science education, to engineering education, and most likely to education for all other numerate disciplines.

3. There is some indicative evidence to suggest that skewed incentives for students may bear a significant part of the responsibility for the low take up of Higher Level Mathematics, and for poor performance at Ordinary Level.

Take-Up of Higher Level Mathematics at Leaving Certificate Level

The take-up of Higher Level among Mathematics candidates at Leaving Certificate Level is very low relative to all other major subjects, as can be seen in Table 4.19. It is also low when compared to the level anticipated (25%) when the curriculum was last revised.

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Table 4.19 % of Students for Each Leaving Certificate* Subject Taking the Subject at Higher Level

Subject	% Higher Le vel	Subject	% Higher Le vel
Applied Mathematics	91.3%	Physics	68.1%
Music	88.0%	Accounting	65.9%
Chemistry	82.4%	German	62.6%
Agricultural Science	76.4%	History	62.2%
Economics	75.0%	Biology	60.7%
Physics & Chemistry	74.6%	Spanish	57.6%
Construction Studies	74.2%	English	55.2%
Geography	74.0%	Technical Drawing	49.5%
Home Economics (S&S)	70.7%	French	46.7%
Art	70.4%	Irish	31.1%
Engineering	70.0%	Mathematics	18.1%
Business Organisation	69.0%		

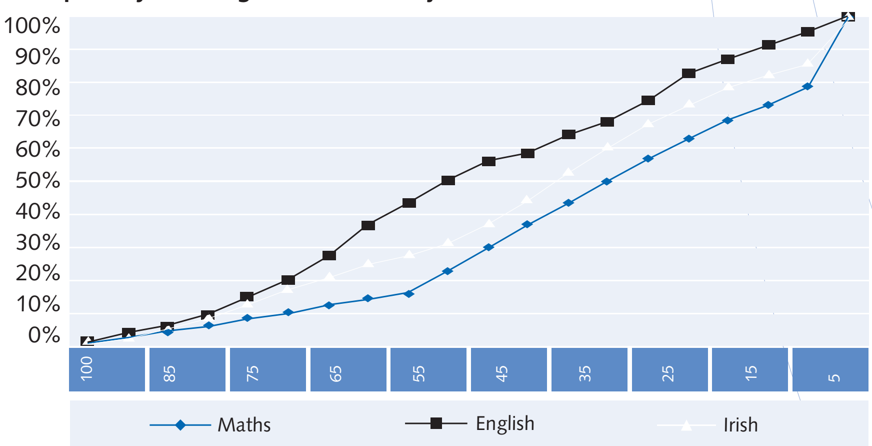
* Data for 2000. Only subjects with at least 1,000 examination candidates included.

Even in comparison with other "compulsory" subjects taken by almost all candidates (English, 55.2% and Irish, 31.1%) the percentage taking Mathematics at Higher Level is very low.

One consequence of the low take-up of Higher Level in Mathematics is that the overall yield that students get from the subject in terms of CAO points for admission to third level courses is very low. Figure 4.20 demonstrates this, by comparison with the other "compulsory" subjects[19]. The net effect is that, while, in principle, the points system treats Mathematics as being equal to other subjects, in practice the wider system of which the points system forms just a part rewards the study of Mathematics with fewer CAO points than for other subjects.

Figure 4.20 shows, for example, that just 22.6% of students taking Mathematics received results in the subject equivalent to 50 points or more in 2000, behind Irish at 31.5% and English at 50.1%.

Figure 4.20 % of Students At or Above Each Level of CAO Points* from Each of the "Compulsory" Leaving Certificate Subjects, 2000



* For simplicity, this neglects a small number of cases where colleges award bonus points for Mathematics[20].

While many Leaving Certificate students take seven or eight subjects, they can only count their best six towards points for college. They need at least Ordinary Level Mathematics to access most third level courses, but they do not need to take Mathematics at Higher Level to maximise their points. Thus, one possible partial explanation for the low number of students taking Higher Level Mathematics is that the incentives they face may encourage many students to study Mathematics at Ordinary level, even where they have the ability required to be successful at Higher Level.

19 Note that maximum points (for an A1) on a Higher Level Paper amount to 100, while maximum points (for an A1) on an Ordinary Level paper amount to 50.
20 Bonus points apply for Higher Level Mathematics at the University of Limerick, and for a number of courses at the Dublin Institute of Technology.

The relatively high numbers of students achieving high grades on the Ordinary Level Mathematics paper are consistent with this view. Why might a decision to take the Mathematics at Ordinary Level be rational for a student who has the ability to take it at Higher Level? There are five possible answers.

1. There may be an expectation that marking of Mathematics papers might be tough relative to other subjects.

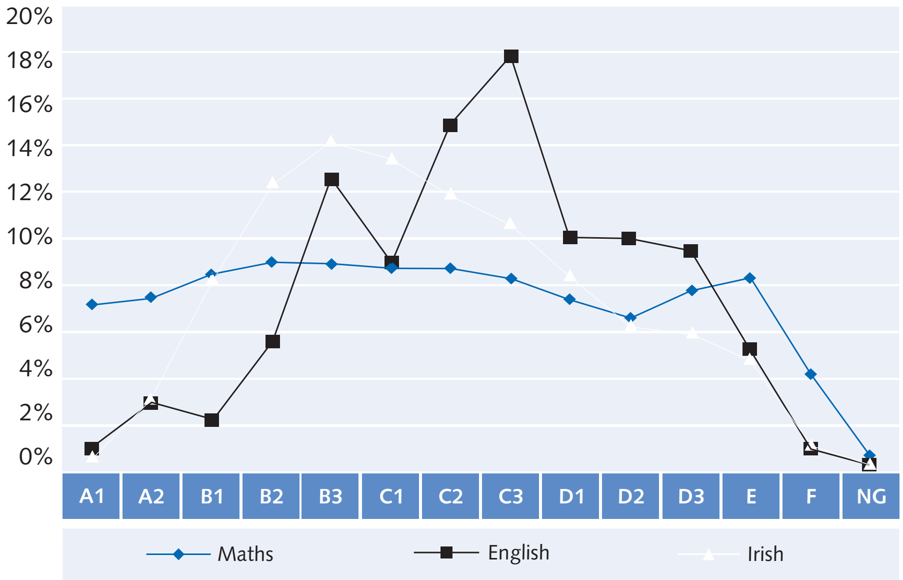
2. Mathematics might require more work than other subjects, biasing students against choosing it as one of their core subjects on which they plan to depend for CAO points.

3. Students may be particularly inclined to see Mathematics as being uninteresting.

4. There may be systematic problems with the way in which Mathematics is learned in school.

5. Arrangements to provide Mathematics teaching in schools may make it difficult for students to choose Higher Level.

Figure 4.21 Distribution of Grades for Each Leaving Certificate Compulsory Subject Taken at Ordinary Level, 2000



The available evidence suggests that at least the first three of these issues, and quite possibly the fourth and fifth also, may contribute to the low uptake of Higher Level Mathematics.

- The Report of the Task Force on the Physical Sciences highlights the fact that students taking Higher Level Chemistry and Physics tend to receive lower marks than would be expected based on their other Leaving Certificate results. In the analysis that compares different Leaving Certificate subjects, Mathematics also shows up as a subject in which the marking appears to be tough relative to other subjects.

- Engineering students interviewed for this study repeatedly made the observation that Mathematics is seen as being "hard" by many second level students. On being questioned in more detail, they generally indicated that it requires substantially more work than other subjects for success, and indicated a belief that many second level students find it uninteresting. The Report of the Task Force on the Physical Sciences refers to second level "students' perception of the difficulty of mathematics".

- Some members of the Expert Group on Future Skills Needs have suggested, based on their experience, that there may be difficulties with overly-large classes in Mathematics at second level that do not allow sufficient personal attention. They suggest that the sequential nature of the subject, where one topic builds on another, leads to a risk that a student may miss a critical explanation, undermining their understanding of a large part of the subject, and that the large size of many classes makes it difficult to counter this risk.

- Observations of inadequate arrangements to allow the study of Mathematics at Higher Level in some schools have formed a part of the explanation for the low uptake of Higher Level in the past, particularly in relation to female students. However, the fact that the percentage of female students taking the Higher Level paper doubled after a change in the curriculum in the early 1990s suggests that it may not now be as major a barrier as it was seen to be in the past[21].

If the assumption that marking of Higher Level Mathematics papers is tougher than for other subjects is correct, and if the assumption that Higher Level Mathematics entails substantially more work for students than other subjects at Higher Level is correct, then it may be reasonable to draw the conclusion that, taken together, the curriculum, system of assessment and CAO points system are biased against the study Higher Level Mathematics. If this is the case, then:

- there is an urgent need to bring marking of Higher Level Mathematics into line with other subjects, in the same way as the Task Force on the Physical Sciences has recommended for Physics and Chemistry; and

- there is a need to resolve the mismatch between the effort required for Higher Level Mathematics and the CAO points gained. As engineering academics interviewed are adamant that there is no scope to reduce the level or content of the current curriculum(indeed, many argue for the reverse), there may be a need for a change in the points system.

Junior Cycle

Subject choice at senior cycle is influenced by choice at junior cycle. Thus, a high uptake of science, and the significant numbers taking technical subjects, are positive for the ultimate supply of applicants for engineering. While Junior Certificate Mathematics has the lowest share among the major subjects of students taking it at Higher Level (at 36.5%), its share is still double that of Higher Level Leaving Certificate Mathematics (at 18.1%). In approximate terms, Higher Level Mathematics loses half of its students to Ordinary Level between the Junior Certificate and the Leaving Certificate, while in most other subjects Higher Level loses a much smaller part of its existing share (see table 4.22).

At Junior Certificate level, there are two main factors relating to the supply of applicants for engineering at third level that are of concern. One is that the low percentage of students taking Mathematics at Higher Level may reflect significant numbers of students who have the ability for engineering being filtered out before they even sit their Junior Certificate. The other is that substantial numbers of students who apparently had the ability to study Mathematics at Junior Certificate Higher Level are apparently not proceeding to continue Higher Level study for the Leaving Certificate.

21 The percentage of female students taking Mathematics at Higher level rose from 8.0% in 1993 to 16.1% in 2000. The equivalent percentages for males were 14.3% and 20.4%.

Table 4.22 % of Students for Each Junior Certificate* Subject Taking the Subject at Higher Level

Subject	Percentage at Higher Level in Junior Certificate 2000	Percentage at Higher Level in Leaving Certificate 2000	Subject	Percentage at Higher Level in Junior Certificate 2000	Percentage at Higher Level in Leaving Certificate 2000
Geography	79.0%	74.0%	Materials Technology	66.5%	
Music	78.8%		Spanish	65.8%	57.6%
Home Economics	76.3%	70.7%	Science	64.0%	
German	72.3%	62.6%	English	62.1%	55.2%
Technology	72.1%		Art, Craft & Design	57.5%	70.4%
History	70.0%	62.2%	Technical Graphics	53.8%	
French	68.1%	46.7%	Irish	39.9%	31.1%
Business Studies	67.6%		Mathematics	36.5%	18.1%
Metalwork	66.6%				

* Data for 2000. Only subjects with at least 1,000 examination candidates included.

4.7.5 Perceptions of Engineering Among School Students

As part of the analysis undertaken for this report, it has been possible to draw some conclusions about perceptions of engineering among school students, and about the attitudes that appear to predispose students to study engineering, based on interviews with engineering students.

One important factor is that a very active interest in studying engineering is mainly a male phenomenon. In 2000, 15.3% of primary degree graduates in engineering were female, and the percentages at certificate and diploma level were lower. Among the students interviewed for the study, males had mostly come from backgrounds characterised by an interest in mathematics, an interest in the physical sciences and/or an interest in technical Leaving Certificate subjects that they felt had put them on a track towards studying engineering. By contrast, **while some of the female students interviewed had considered themselves to be on a similar track towards engineering, many were able to point to some critical event that had diverted them into engineering. This was often related to one intervention or another designed to promote interest in engineering.**

It is apparent from these interviews with students that there are negatives as well as positives to studying engineering, and that these negatives deter many school leavers from applying to study it. Key issues emerging from the analysis are as follows.

- There is a very heavy workload, with contact time that far exceeds that of most other disciplines, along with a substantial requirement for study.
- The workload is perceived to be "hard" as well as heavy because of the mathematical content.
- There is very little spare time for part-time work, and there are significant learning problems associated with missing lectures, tutorials and laboratories for those who do work part-time.
- Many of those who choose not to work part time face relative poverty, in a third level system in which part time work is the norm.
- The social life available is limited arising from the workload and (often) the lack of an income from work.
- A significant number of classes are so predominantly male that they are seen as off-putting by some female students.

- Most of the students interviewed believe that the eventual financial rewards for studying engineering are fairly modest. They say that the promotional information they have seen about engineering has tended to reinforce this view.

- Many students say that they would find their courses more interesting, and that they would learn better, if more project work and problem solving work was built into their courses. They suggest that it should be possible to achieve this without displacing course content.

Some engineering academics interviewed believe that good opportunities for graduates across all disciplines have made students less ready to take up any area of study that they perceive to be difficult.

Engineering faces two other more diffuse issues in seeking to attract applicants. One is that there is very considerable ignorance about what is involved in studying and practicing engineering, both among male and female students. The other is that are barriers to choosing engineering that relate to its image and to the expectations of families, schools and peer groups. While these barriers exist among many male school leavers, they are much stronger for their female counterparts.

It is clear that promoting the image of engineering, and providing basic information, helps to attract both male and female students. With regards to providing very detailed information, the benefits appear to be more mixed.

With male school leavers, while some fail to choose engineering because they do not know enough about it, the experiences of those in colleges promoting engineering show that an improved knowledge of some aspects of studying the discipline also dissuades some male school leavers from applying. Some academics made reference to a study that had been undertaken in a UK university, showing that taster courses in engineering for second level students can actually reduce the number of applicants received.

In contrast, the barriers to choosing engineering are such that a female student who is suited to studying it is unlikely to make that choice unless she also has a better than usual pre-existing knowledge. Female engineering students appear to be disproportionately likely to be related to an engineering graduate, to have participated in an engineering taster course, or to have some other factor in their background that has given them a better than usual knowledge of the profession. **Thus, actions taken to promote the study of engineering among female school leavers appear much more likely to persuade them in favour of applying to study engineering, rather than against**. Moreover, the pool of female students available to be targeted has increased in size. As noted above, one of the main historical structural barriers to female students studying engineering at degree level has been greatly reduced by a doubling in the proportion of female Leaving Certificate candidates taking Mathematics at Higher Level since 1993.

4.8 Part-Time and Other Non-Standard Programmes

4.8.1 Part Time Programmes

There is a significant volume of part time education provision in engineering, both in the universities and in the Institutes of Technology. Table 4.23 presents data on part time provision in the universities. No comparable information is available in relation to the Institutes of Technology[22].

Table 4.23 Number of Part Time Engineering Students in HEA-Funded Institutions Academic Year 2000/2001

Type of Qualifiction	Number of Students Studying
Undergraduate Degree	82
Undergraduate Diploma & Certificate	0
Undergraduate Occasional	25
PhD	51
Masters	153
Postgraduate Diploma & Certificate	271
Postgraduate Occasional	0

Most part time provision serves to upgrade the qualifications of people who have existing qualifications in engineering, and are already working in engineering, and thus it affects the quality of the labour supply more than the quantity.

4.8.2 Other Non-Standard Programmes

There are two non-standard programmes designed to facilitate the achievement of certificate qualifications in technological disciplines by people with less than third level qualifications. These are the Accelerated Technician Programme and the Institute Trainee Programme. Both of these programmes operate across the Institutes of Technology, and in cooperation with industry.

The Accelerated Technician Programme provides a six month period in training with an employer between two six month periods of learning in an Institute of Technology. In 2002, there were over 400 enrolled on this programme, of whom approximately 60-70 were in Engineering courses (all of these were targeted on manufacturing).

The Institute Trainee Programme combines working with an employer, with a programme of release for study. There are currently approximately 250 students enrolled in courses in Manufacturing Technology under this programme.

The growth of both of these programmes is being limited by the current downturn in ICT manufacturing, which has lessened the interest of industry in using these programmes to improve their supply of technicians.

4.9 Supply-Side Measures by Employers

A survey of employers of engineers and engineering technicians was undertaken as a part of this study. The study targeted private sector and public sector organisations that were believed to employ engineers or engineering technicians in significant numbers. There were 125 responses from a wide range of industries and organisation types. A number of questions in the survey addressed measures being taken by employers that may impact on the supply of qualified professionals.

It appears that a substantial number of employers recruited from abroad, subcontracted within Ireland, or reskilled other employees in response to shortfalls in the supply of engineers and engineering technicians. While the proportion who have established overseas operations in response to shortfalls in supply in Ireland is not large, it is nonetheless significant.

22 An attempt was made to gather the information for this study, as a part of the survey of colleges, but there were too many gaps in the information returned to justify its inclusion in this report.

Table 4.24 Survey of Engineering Employers Responses to Question: "*Which of the following measures have you used to cope with shortfalls in the supply of engineers and engineering technicians in the Irish Labour market?"*

Prompted Response	% of Responses
Recruitment from abroad	53.6%
Establishing overseas operations	3.2%
Reskilling other employees	36.8%
Subcontracting in Ireland	39.2%
Subcontracting overseas	12.8%
Limiting acceptance of contracts/ orders	4.8%

It appears that a substantial proportion of employers are upskilling employees to the level of technician or to the level of engineer, as shown in Table 4.25. While much of this activity is at least partly intended to address labour market shortages, other reasons are also important. Presumably, these relate to upgrading the employer's workforce, and to rewarding employees with opportunities for advancement.

Table 4.25 Survey of Engineering Employers Responses to Question on Upskilling

	Yes	Partly	No
Are you upskilling any employees to work as engineering technicians at a level equivalent to certificate or diploma?	49.2%		50.8%
If "Yes", is the purpose to address labour market shortages?	10.3%	65.5%	24.1%
Do you find that this addresses your need for engineers effectively?	38.6%	33.3%	28.1%
Are you upskilling any employees to work as engineers at a level equivalent to Primary Degree?	42.6%		57.4%
If "Yes", is the purpose to address labour market shortages?	5.9%	64.7%	29.4%
Do you find that this addresses your need for engineers effectively?	34.7%	40.8%	24.5%

Table 4.26 shows that, most commonly, employers contribute to upskilling of employees to higher professional levels by paying fees, and/or providing time off for independent study. In a significant number of cases, they provide upskilling opportunities internally, or cooperate with an education institution to provide upskilling opportunities.

Table 4.26 Survey of Engineering Employers Responses to Question: "*What is the nature of any involvement your organisation has in upskilling people for engineering or technician work?*"

	Pay fees for Independent Study	Time off for Independent Study	Provide upskilling opportunities internally	Cooperate with education institution to provide upskilling opportunities
From operative or craft level to engineering technician	40.0%	30.4%	34.4%	24.8%
From engineering technician to professional engineer	48.8%	37.6%	34.4%	21.6%
Professional qualifications or higher degrees for existing engineers	57.6%	40.8%	30.4%	20.8%

Taking all of this evidence together, it is apparent that employers of engineers and engineering technicians do not accept passively what the labour market has to offer. They are active in upgrading the skills of their employees, and in assisting them to upgrade their own skills. They have also undertaken active measures to gain access to overseas labour markets, whether by sourcing staff from overseas, or, less commonly, by establishing operations overseas.

It should be borne in mind, that frequently the upskilling involved is not reflected by certification at a raised professional level[23]. Learning in-house tends to be uncertified. Even successful participation in part time learning at third level may lead to the award of ACCS credits that are never accumulated to make up a full qualification. While the IEI has mechanisms for recognising skills gained other than through obtaining third level qualifications with higher membership grades, the number taking advantage of these mechanisms is small.

4.10 Conclusions on Supply

After increasing continuously in recent decades, the numbers graduating in engineering at degree, diploma and certificate level will peak around 2003 or 2004. A steep reduction in applications to study in many key engineering disciplines in 2002, driven by a loss of confidence in the ICT industries among college applicants, suggests that there will, initially at least, be a steep fall away from that peak.

Even assuming that confidence in career opportunities in the ICT industries is restored quickly, demographic factors threaten to reduce the output of graduates in all disciplines, engineering included, markedly. All other things being equal, these factors could reduce the output of engineering degrees from 1,720 in 2002, to 1,441 in 2010 and 1,208 in 2016. Thus, unless demand for engineers decreases steeply, which is most unlikely to happen, there will be a need to attract a higher share of college applicants to engineering, if shortages are to be avoided.

Subject choice is an important issue. A range of course choices, including the physical sciences, technical subjects and Higher Level Mathematics appear to predispose and prepare students to study Engineering. Issues relating to the study of the physical sciences have already been addressed by the Report of the Task Force on the Physical Sciences. While the proportion of students taking Mathematics at Higher Level in the Leaving Certificate has increased, it remains very low, and it appears that there is scope to promote a further increase. This point should be examined as a matter of urgency by the Review of Mathematics recommended by the Report of the Task Force on the Physical Sciences.

Subject choice of second level is an important issue, there appears to be scope to attract more students to engineering. One particular target group could be female Leaving Certificate students taking Mathematics at Higher Level. This is a group that has increased greatly in size in recent years, and for which there is a reasonable prospect that better information might lead to more college applications.

Information from a survey of employers of engineers and engineering technicians indicates that many are active in upskilling their engineering staff.

23 The new qualifications framework under development by the NQAI seeks to address this issue.

5. Gap Analysis

5.1 Introduction

This chapter looks at the projected gap between supply and demand for engineering graduates, now and into the future. It also addresses the policy implications of the identified gaps.

5.2 Supply Scenarios

The chapter looks at two supply scenarios. These are set out below.

5.2.1 Supply Scenario 1

The first scenario assumes that recruitment into engineering courses falls in proportion to the falling size of the school leaving age cohort, and that this has a proportionate impact on the number of graduates these courses produce. It is assumed that applications for engineering courses revert in future to a level in line with the position in 2001, adjusted for the shrinking school leaving age cohort. For simplicity, it is assumed that colleges succeed on a once-off basis in maintaining the number of applicants they accept in 2002 at a level consistent with 2001, despite the dip in applications. Tables 5.1 and 5.2 provide the information on the supply of degree and diploma/certificate graduates to 2012.

Table 5.1 Degree Level Graduate Supply Under Supply Scenario 1

Year	Biomedical	Building Services	Civil	Chemical / Process	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
2003	35	23	335	96	117	471	6	230	24	125	264	24	**1,750**
2004	37	13	364	96	135	458	5	239	24	112	271	18	**1,772**
2005	32	17	378	105	141	409	5	230	49	114	265	8	**1,753**
2006	31	17	368	102	137	398	5	224	48	111	258	8	**1,707**
2007	31	16	362	101	135	392	5	220	47	109	254	8	**1,680**
2008	31	17	367	102	137	397	5	224	48	111	258	8	**1,705**
2009	30	16	352	98	131	381	5	214	46	106	247	7	**1,633**
2010	28	15	325	90	121	352	4	198	42	98	228	7	**1,508**
2011	26	14	310	86	116	335	4	188	40	93	217	7	**1,436**
2012	25	13	295	82	111	319	4	179	38	89	207	7	**1,369**

* The supply of Chemical Engineering degree graduates has been adjusted upwards from the data presented on primary degrees earlier, to take account of the output of a graduate diploma course at UL, which converts technical graduates (mainly science graduates) into Chemical Engineers, and is accredited by the Institute of Chemical Engineers.

Table 5.2 Diploma and Certificate Level Supply Under Supply Scenario 1

Year	Biomedical	Building Services	Civil	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
2003	11	88	96	472	14	376	34	188	45	103	0	**1,561**
2004	11	89	96	469	12	336	39	192	37	102	0	**1,522**
2005	10	85	105	454	12	325	38	186	36	98	0	**1,471**
2006	10	84	102	444	11	318	37	182	35	96	0	**1,439**
2007	10	83	101	443	11	317	37	182	35	95	0	**1,434**
2008	10	83	102	438	11	314	36	179	35	95	0	**1,421**
2009	9	78	98	413	11	296	34	169	33	90	0	**1,341**
2010	9	73	90	387	10	277	32	158	31	84	0	**1,255**
2011	9	72	86	381	9	272	32	156	30	82	0	**1,233**
2012	9	73	82	387	10	277	32	159	31	83	0	**1,254**

5.2.2 Supply Scenario 2

The second scenario takes the first scenario as a starting point, and assumes that the fall in applications experienced in 2002 is maintained. Thus, for example, the steep fall in electronic engineering applications is maintained, and the rise in civil engineering applications is also maintained. As a simplification, because the relationship between numbers of applications and numbers of graduates is difficult to predict analytically, it is assumed that every 1% fall in applications[1] leads to a 0.5% fall in graduate numbers at degree level, or to a 0.7% fall at diploma and certificate level[2]. It is further assumed that there is no growth in output in any area, even where additional applicants are available.

Tables 5.3 and 5.4 provide the supply of degree and diploma/certificate graduates under this scenario.

Table 5.3 Degree Level Graduate Supply Under Supply Scenario 2

Year	Biomedical	Building Services	Civil	Chemical / Process	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
2003	35	23	335	96	117	471	6	230	24	125	264	24	**1,750**
2004	37	13	364	96	135	458	5	239	24	112	271	18	**1,772**
2005	31	17	378	104	115	335	5	222	49	109	229	7	**1,601**
2006	30	17	368	101	112	326	5	216	48	106	223	7	**1,559**
2007	30	16	362	100	110	321	5	212	47	104	220	7	**1,534**
2008	30	17	367	101	112	326	5	216	48	106	223	7	**1,558**
2009	29	16	352	97	107	321	5	207	46	101	214	6	**1,492**
2010	27	15	325	98	99	289	4	191	42	94	197	6	**1,378**
2011	25	14	310	85	95	275	4	181	40	89	188	6	**1,312**
2012	24	13	295	81	91	262	4	172	38	85	179	6	**1,250**

* The supply of Chemical Engineering degree graduates has been adjusted upwards from the data presented on primary degrees earlier, to take account of the output of a graduate diploma course at UL, which converts technical graduates (mainly science graduates) into Chemical Engineers, and is accredited by the Institute of Chemical Engineers.

1 The % falls are drawn from Table 4.19 where possible, and on estimates based on the data in this Table where there are gaps.
2 As many courses have more suitable applicants than there are places available, recruitment will not fall directly in line with the fall-off in applicant numbers. Degree courses more commonly have surpluses of applicants than do courses at diploma and certificate level.

Table 5.4 Diploma and Certificate Level Supply Under Supply Scenario 2

Year	Biomedical	Building Services	Civil	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
2003	11	88	472	14	376	34	188	45	103	230	0	**1,561**
2004	11	89	466	9	244	38	188	33	83	197	0	**1,358**
2005	10	85	451	9	236	37	182	32	80	190	0	**1,312**
2006	10	84	441	8	231	36	178	31	79	186	0	**1,284**
2007	10	83	440	8	230	36	178	31	78	185	0	**1,279**
2008	10	83	435	8	228	35	175	31	78	185	0	**1,268**
2009	9	78	410	8	215	33	165	29	74	175	0	**1,196**
2010	9	73	384	7	201	31	155	27	69	163	0	**1,119**
2011	9	72	378	7	198	31	153	26	67	159	0	**1,100**
2012	9	73	384	7	201	31	156	27	68	162	0	**1,118**

5.3 Balance Between Projected Supply and Projected Demand

5.3.1 Balance Between Supply and Demand for Degree Graduates

Table 5.5 sets out the balance between supply and demand projected for engineering degree graduates, based on the demand projection with the more optimistic view on software & IT services. Caution should be exercised in reading the data. Even if the views on the future turn out to be fairly accurate, minor variations in demand, changes in course provision, and changes in the disciplines attracting the most applications, could easily overturn an oversupply or undersupply of 50 or 100 graduates in any given discipline.

Table 5.5 Balance Between Supply and Demand for Degree Graduates

	Biomedical	Building Services	Civil	Chemical / Process	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
Based on Supply Scenario 1													
2003	-2	10	124	12	*	342	-12	74	9	100	100	10	767
2004	-1	-1	115	4	*	86	-13	70	5	87	74	-15	411
2005	-8	3	114	10	*	-21	-13	60	29	90	59	-31	292
2006	-10	4	112	5	*	-58	-13	56	28	88	53	-33	232
2007	-10	3	107	1	*	-94	-13	53	26	87	46	-35	171
2008	-12	4	111	-2	*	-116	-13	55	27	89	47	-37	153
2009	-15	3	86	-10	*	-158	-13	42	24	84	31	-40	34
2010	-18	2	56	-20	*	-213	-14	27	20	77	9	-42	-116
2011	-21	1	38	-27	*	-253	-14	20	18	73	-2	-43	-210
2012	-21	-1	10	-35	*	-289	-14	11	14	70	-17	-45	-317
Based on Supply Scenario 2													
2003	-2	10	124	12	*	342	-21	74	9	100	100	10	767
2004	-1	-1	115	4	*	86	-13	70	5	87	74	-15	411
2005	-9	3	114	9	*	-95	-13	52	29	85	23	-32	166
2006	-11	4	112	4	*	-130	-13	48	28	83	18	-34	109
2007	-11	3	107	0	*	-165	-13	45	26	82	12	-36	50
2008	-13	4	111	-3	*	-187	-13	47	27	84	12	-38	31
2009	-16	3	86	-11	*	-227	-13	35	24	79	-2	-41	-83
2010	-19	2	56	-21	*	-276	-14	20	20	73	-22	-43	-224
2011	-22	1	38	-28	*	-313	-14	13	18	69	-31	-44	-313
2012	-22	-1	10	-36	*	-346	-14	4	14	66	-45	-46	-416

It should be noted that an indication of an excess of supply over demand does not in itself suggest that there is a problem. Historically, a great many engineering graduates have gone directly from college into other types of work, and employers have found their numeracy, analytic skills and project management skills to give a good preparation for entry into many non-engineering occupations. Although the numbers likely to do this are not overwhelming, an oversupply of graduates in any engineering discipline should be seen in a positive light, and would be of benefit to the economy.

On the other hand, if there is a shortage the implications could be negative in terms of: constraining activity by indigenous industry; lost confidence among inward investors; and reduced capability to improve infrastructure. Thus, the table is most useful in its broad indications. The key points are as follows.

- The supply of electronic engineering and telecommunications engineering graduates is likely to exceed demand in the short term, but there is a potential for a severe shortage in the longer term. As the availability of electronic engineers is a pre-requisite for many of the industry developments envisioned, this would have negative industrial development implications. This shortage has the potential to be much worse if interest in Electronic Engineering among college applicants does not recover.

- There is a general issue across other disciplines that the balance between supply and demand is projected to tighten significantly over the period to 2012. This applies particularly to civil engineering, chemical /process engineering and electrical engineering.

- Taken in very broad terms, and aside from a significant oversupply being likely in some disciplines in the short term, there is not a major discipline-specific supply issue at degree level in other engineering disciplines. It is likely that the projected shortage of biomedical engineers will be addressed at the level of individual academic departments.

5.3.2 Balance Between Supply and Demand for Diploma and Certificate Graduates

Table 5.6 sets out the balance between supply and demand projected for engineering diploma and certificate graduates, again based on the demand projection with the more optimistic view on software & IT services.

Table 5.6 Balance Between Supply and Demand for Engineering Diploma and Certificate Graduates, by Discipline

	Biomedical	Building Services	Civil	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Telecommunications	Total
Based on Supply Scenario 1												
2003	3	33	21	*	49	8	61	10	45	127	0	357
2004	3	33	-8	*	-71	13	50	-2	45	111	-2	172
2005	2	29	-23	*	-99	12	41	-3	40	97	-2	94
2006	1	31	-6	*	-102	12	39	-5	40	94	-2	102
2007	1	32	2	*	-97	14	45	-3	43	93	-3	127
2008	0	34	5	*	-97	14	43	-2	46	92	-3	132
2009	-1	28	-35	*	-125	12	29	-5	40	78	-3	18
2010	-2	23	-61	*	-150	10	18	-8	33	61	-3	-79
2011	-3	23	-66	*	-154	11	17	-8	34	56	-4	-94
2012	-4	23	-82	*	-147	11	20	-7	36	57	-4	-97
Based on Supply Scenario 2												
2003	3	33	21	*	49	8	61	10	45	127	0	357
2004	3	33	-11	*	-163	12	46	-6	26	73	-2	11
2005	2	29	-26	*	-188	11	37	-7	22	60	-2	-62
2006	1	31	-9	*	-189	11	35	-9	23	58	-2	-50
2007	1	32	-1	*	-184	13	41	-7	26	57	-3	-25
2008	0	34	2	*	-183	13	39	-6	29	57	-3	-18
2009	-1	28	-38	*	-206	11	25	-9	24	45	-3	-124
2010	-2	23	-64	*	-226	9	15	-12	18	30	-3	-212
2011	-3	23	-69	*	-228	10	14	-12	19	25	-4	-225
2012	-4	23	-85	*	-223	10	17	-11	21	26	-4	-230

Again, this table is most useful in its broad indications. The key points are as follows.

- At both degree and diploma/certificate levels, the supply of electronic engineering and telecommunications engineering graduates is projected to exceed demand in the short term, but there is potential for a severe shortage in the longer term. As the availability of electronic engineers is a pre-requisite for many of the industry developments envisioned, the degree level shortage could have significant negative industrial development implications. This shortage at both levels has the potential to be worse if interest in electronic engineering among college applicants does not recover.

- There is potential for a shortage of graduates with diplomas and certificates in civil engineering[3].

- There is a general issue across all disciplines and levels that the balance between supply and demand for graduates is projected to tighten significantly over the period to 2012.

- Taken in very broad terms over the period addressed by the projections, and aside from a significant oversupply being likely in some disciplines in the short term, there does not appear to be a major discipline-specific supply imbalance projected at diploma level in other Engineering disciplines.

5.4 Sensitivity to Sectoral Outcomes

The main areas where demand is sensitive to particular sectoral outcomes are as follows.

- ICT industries: Demand for electronic engineering and telecommunications engineering graduates is sensitive to the future development of the ICT industries. If Ireland was to be unsuccessful in growing the design and development aspects of electronic hardware and IC design, or if the software and IT services sector failed to grow, then the gap would be much smaller, or these qualifications might remain in oversupply.

- If national economic growth stabilised at levels similar to the rest of the EU, then construction employment might fall gradually, significantly reducing demand for civil engineering graduates from the levels projected.

- Demand for chemical engineers is sensitive to pharmachem industry growth, and slower than projected growth would lead to an oversupply of graduates.
  In converse to each of the above, faster-than-projected growth would increase the shortages projected.

5.5 Immigration as a Means of Balancing Supply and Demand

The analysis of the supply of graduates does not take account of the possibility of attracting engineers and engineering technicians from other countries. It may be possible to attract significant numbers of engineers into Ireland where there is a shortfall, and where Irish employers are sufficiently interested in recruiting. Experience in two of the key areas (Electronic Engineering and Civil Engineering) shows that engineers can be attracted from overseas, even in times of strong demand in other countries. For example, a substantial part of the employment growth in the IC design sector in 1999 and 2000 was supplied by electronic engineers moving from elsewhere in Europe, including Eastern Europe and Spain. Also, engineers from the UK, and from other English-speaking countries with similar approaches to construction, bridged a significant part of the gap in supply of civil engineers in recent years. It appears likely that Ireland will be able to draw on these sources of engineers again in future.

However, for other reasons (language and cultural barriers, recruitment expenses, relocation costs etc.), the availability of engineers overseas prepared to migrate to Ireland may not always be as good as a local supply. Thus, a local shortage has possible general implications for industry competitiveness, even if it can be bridged through immigration. It may also lead to investment that would otherwise take place in Ireland, being diverted overseas.

3 For purposes of the current study, Civil Engineering includes Structural Engineering, Construction Studies and Construction

5.6 Policy Implications of Gap Analysis

The main areas where gaps in supply are projected are in electronic engineering and degree level telecommunications engineering. In these areas, the main constraint is to do with the number and quality of college applicants wishing to apply for courses. The provision of further places will only become a significant policy issue if this can be resolved.

The scope to resolve the problem at degree level through diverting students from other engineering disciplines is limited:

- The projected excess of supply over demand for the period after the recovery of the ICT markets is not large for most disciplines; and

- The area with the greatest projected excess of supply over demand is production / manufacturing engineering, which is also the area with the greatest concentration of courses not accredited by the IEI. Based on interviews with colleges, it appears that unaccredited courses tend to attract many students who would not gain admission to an accredited electronic engineering course. As the need is to recruit more top quality applicants into electronic engineering to ultimately do design and development work, diverting students from production/manufacturing engineering courses into electronic engineering courses may not contribute significant to resolving the supply problem.

Thus, the key issue is to maximise the number and quality of students applying to study engineering into the future.

6. Conclusions & Recommendations

6.1 Introduction

The report does not recommend any programme to encourage new undergraduate courses or increased numbers on existing courses. In areas where shortages are most likely to occur, the most immediate problem is of insufficient applications for courses to fill the available places with high quality applicants.

Two major factors are involved:

- demographic change, with falling numbers of school leavers leading to smaller numbers of applicants for engineering courses; and

- a recent fall in the proportion of college applicants applying to study engineering, which will have an even greater impact than demographic change on the supply of new Engineering graduates if it persists.

The lack of sufficient applications poses two threats:

- a quantitative threat: there may not be sufficient college applicants of sufficient quality for engineering courses. As a consequence, there may not be sufficient numbers of graduates, either because insufficient numbers are admitted to engineering courses, or because colleges recruit lower quality applicants who cannot reach the necessary standard; and

- a qualitative threat: a fall in the average quality of entrants may lead to a fall in the average quality of graduates.

The evidence from the UK is that both of these threats can be real and important under circumstances where numbers of applications for engineering courses are falling[1].

Also, as industry becomes more reliant on high quality engineering work for its competitiveness, it is becoming increasingly important that engineers and engineering technicians graduating from college should be of the highest possible quality. This is not just for the maintenance of high academic standards, but also for the adoption of best practices in enabling students to learn, and the provision of facilities of a high quality. It also implies a need to recruit college applicants who are sufficiently able to study engineering successfully, and indeed to maintain and increase the intake of academic high fliers.

Thus, a major part of the challenge emerging from the analysis is to:

- boost the number and quality of applicants for engineering courses; and

- make the best of the students attracted to study engineering through providing well-resourced courses using the best available approaches to learning.

Physical Sciences

While the study of the physical sciences at second level is very relevant to the supply of suitable applicants to study engineering, it has been addressed thoroughly by the recent Report of the Task Force on the Physical Sciences. The recommendations of the Task Force are important to the future supply of engineering graduates, and the recommendations of the current report have been designed to complement them. The Expert Group on Future Skills Needs reiterates its strong endorsement of the report of the Task Force.

1 See, for example, the Roberts Report "Review of the Supply of Scientists and Engineers A Summary of the Responses to the 2001 Consultation Paper", HM Treasury, November 2001. "Some universities felt that the quality of students entering science and engineering degree courses from school had declined, as well as the quality of science and engineering undergraduates emerging from them." This perspective on UK engineering education was reflected by many of the engineering academics consulted in Irish colleges for the current study.

Student Retention

Student retention is an important factor influencing the supply of engineering graduates, and it is desirable that existing retention rates should be increased. As other reports have addressed this issue for the universities and the Institutes of Technology, the recommendations of these reports are not repeated here. However, the majority of the recommendations made are intended, in part, to impact positively on retention rates, either by maximising the quality of the engineering student body, or by addressing features of the engineering student experience (part-time work and learning approaches) that tend to influence retention.

6.2 Promoting Study of Engineering to Second Level Students

There is an urgent need to boost the number of applications to study engineering. To achieve this, there is a need for a major increase in activity to promote engineering among school students.

6.2.1 STEPS Programme

There is already a programme in place designed to promote the study of engineering at third level, targeted at second level students. This is the STEPS[2] programme, which is funded jointly by the Department of Education & Science and industry, and operated by the IEI. Each year, many professional engineers and engineering academics contribute significant amounts of time to the programme.

The main activities now undertaken under STEPS are as follows.

- Visits to schools by engineers.

- The School-Industry Partnership Scheme, under which second level schools are "twinned" with Irelands leading engineering, technology & science firms for the purposes of facilitating student group visits. This part of the STEPS Programme aims to allow students to:

  - Visit engineering, technology & science firms;

  - Interact with engineers in the working environment;

  - Be given a presentation on 'Engineering as a Career'; and

  - Receive information packs.

- "Roadshows", which are promotional events, usually staged in a school or at the premises of a major participating company, aimed at the surrounding population of second level students.

- Seminars and conferences for teachers.

- Maintaining a promotional web site.

Recommendation 1: Expanding and Reviewing STEPS

There is scope for STEPS to promote entry into engineering among many more second level students.

It is recommended that the extent of existing STEPS activities should be expanded so as to reach a significantly higher proportion of second level students. This will require a significantly greater commitment of funding from industry and from the Department of Education & Science. It will also require a greater commitment of time and effort from employers of Engineers, from Engineers and Engineering academics, and from the IEI.

Recommendation 2: Reviewing STEPS

While the evidence of interviews and the industry-academic workshop is that STEPS is generally well-regarded, and should continue and expand, there has not yet been a

2 Science, Technology and Engineering Programme for Schools.

review of its operation. Such a review would represent good practice, and might present opportunities for improvement.

It is recommended that IEI should undertake a review of the operation of STEPS. Implementation of the other recommendations on STEPS presented in the current report should not be delayed for this review.

Recommendation 3: Taster Courses
One of the most commonly used approaches to promoting engineering in Ireland and in other countries is that of providing taster courses to second level students. A taster course is an in-college course, lasting anything from a few hours to a week, which includes some presentations and/or discussion about engineering as a profession, teaches some engineering content and gives participants the opportunity to undertake a basic project. It is typically provided free of charge.

There is some doubt about the likely impact of an untargeted increase in taster course activity on the number of applicants for engineering. Many of the Irish academics who run such courses mentioned cases where the courses had dissuaded students from applying for engineering[3]. Thus, while there may be careers guidance benefits, and ultimately perhaps some student retention benefits to dissuading some students from studying engineering, an untargeted programme of taster courses is unproven as a means of boosting applicant numbers.

However, there is scope to target taster courses. If they are applied to groups who are unlikely to otherwise choose engineering, but who show evidence of suitability, then the chances of dissuading anyone will be low, while the chances of persuading significant numbers in favour will be good.

The largest group of second level students meeting this criterion is that of females studying Mathematics at higher level, and particularly those also taking physical sciences or technology-related subjects. The proportion of female students taking Mathematics at higher level in the Leaving Certificate is no longer very substantially less than the proportion of males, but relatively few females apply to study engineering.

The evidence of interviews with engineering students undertaken for this study is that promotional activities, prominently including taster courses, are among the main factors that make the difference in encouraging females to apply for engineering.

It may be possible also to identify other target groups. Some engineering academics interviewed for this study indicated that, in their experience, applications from males for engineering courses tend to come from some schools rather than others. The schools where male students seldom apply for engineering courses may present an opportunity.

Taster courses are most likely to be relevant to students during transition year and senior cycle.

- *It is recommended that STEPS should become involved in engineering taster courses, through:facilitating the sharing of expertise and experience between colleges;*
- *providing support materials; and*
- *developing, in co-operation with the colleges, an overall planning framework that ensures good coverage of the key target groups.*

Recommendation 4: Research into Engineering Careers
Most engineering students consulted in the course of this study did not see engineering as the basis for a high-paying, high-flying career. They stated that information quoted in promotional material tended to reinforce this view, and that they thought this information was likely to discourage second level students from applying for engineering. There is a need for more research in Ireland to ensure that the information quoted can adequately reflect the career opportunities available, as, for example, in the UK where statistics show that engineering is among the top-paying professional careers.

3 There was also reference to a UK study which had found students were less likely to apply for Engineering after undertaking a taster course.

It is recommended that the IEI in association with Forfás should initiate an analysis of actual long term career outcomes of people with third level engineering qualifications, for potential use in future promotional activities.

6.2.2 Broader Science, Engineering and Technology Promotional Initiatives

Engineering is one of a group of scientific and technological disciplines the graduates of which are important to Irish economic development. There is little point in promoting engineering more heavily, if the only effect is to divert school leavers from, for example, computing or life sciences. Thus, it is necessary that some of the recommendations of this report should apply equally to engineering, computing, the life sciences and the physical sciences.

Recommendation 5: Marketing Resource for Third Level Colleges

Irish third level colleges do not have a long history of needing to undertake promotional activities to attract sufficient numbers of applications, of sufficient academic ability. Many of the engineering academics interviewed for the study commented on how much effort their promotional activities now take, how they think more is needed, and how there is a need to establish the activities on a more permanent and formal basis. Many also commented on the large amount of administrative work involved, and on how they do not have much expertise in marketing. It appears that the appointment of a marketing resource could address these issues, which are likely also to be relevant to Computing and some areas of science.

It is recommended that the HEA and the Department of Education & Science should consider financing a marketing resource to support the engineering, science and computing faculties and schools in each third level college.

Recommendation 6: Guidance Counsellors

It is apparent from discussions with engineering academics and engineering students that many school guidance counsellors are not well prepared to advise on engineering as a career. This is not a criticism of guidance counsellors. It is a recognition that careers counselling forms just part of a guidance counsellor's work, and that guidance counsellors have to prioritise their efforts in ways that they think will maximise the benefit that they can bring to their students. It may also reflect in part the fact that the day-to-day work of engineers and engineering technicians is not publicly visible in the same way as that of most other professions.

The best solution appears to be to package information on engineering along with information on other occupations, so as to enable a guidance counsellor to justify the investment of time required.

It is recommended that the Department of Education & Science should develop and provide a labour market in-service training programme for guidance counsellors, placing emphasis on careers in engineering, science and technology and the industries that employ graduates in these disciplines. It should develop and revise regularly a suite of materials on the labour market to support guidance work.

6.2.3 Promoting Mathematics and Physical Sciences at Second Level

Engineering students are mainly drawn from among college applicants who have had a particular interest in mathematics, the physical sciences, technical subjects and applied mathematics at second level. These subjects also provide useful grounding for those students who proceed to study engineering. Of these subjects, mathematics and the physical sciences are also particularly relevant to the study of science and computing, and so it is important to the supply of scientific and technological graduates generally that substantial numbers of second level students should pursue these subjects with enthusiasm.

Recommendation 7: Review of Mathematics

The Task Force on the Physical Sciences has recommended that a review of mathematics should be undertaken. The focus of the review as defined by the Review Group is on the high number of students receiving less than a D3 at ordinary level in the Leaving

Certificate, and on the treatment of foundation level mathematics for college entry purposes. These issues are important for Engineering, as they affect the numbers of school leavers who meet the minimum entry standards for diploma and certificate level courses in engineering, and thus impact on the number of successful college applications. A minimum of a D3 in ordinary level mathematics is required for entry into an engineering course, and students with even a high grade at foundation level do not qualify.

However, there is a further critical issue that relates to Mathematics at Leaving Certificate. It is that the number of students taking mathematics at higher level tends to limit excessively the number of students eligible to study engineering. Accredited degree courses in engineering require a minimum of a C3 in higher level mathematics. Even for unaccredited courses it is useful for students to have studied higher level mathematics. When the current mathematics curricula were put in place, the stated expectation was that the percentage of those taking Leaving Certificate Mathematics at higher level would rise to 25%. In practice it has risen to approximately 17%.

Engineering academics consulted on this issue are unanimously of the view that it would be counterproductive to lower the standard of the higher level mathematics course to make it more popular. The cost, in terms of reduced preparedness for the study of engineering, would outweigh any benefits.

Evidence presented by the Task Force on the Physical Sciences suggests that grading of higher level mathematics is more severe than for most other subjects. It suggests that Higher Level Mathematics is the fourth worst in this regard, after physics, chemistry and french. Combined with the perceived difficulty of the subject, this appears to encourage students to take a lower level option, and treat it as a spare subject.

It is recommended that the review of mathematics recommended by the Task Force on the Physical Sciences should be asked to address increasing the number of students taking Higher Level Mathematics.

The review should take account of the evidence on marking and of the recommendation of the Task Force on the Physical Sciences that problems of this nature should be resolved.

The group should consider the possibility of offering bonus CAO points for mathematics for all college courses, both to give students at all levels an incentive to treat it as one of their core six subjects, and to compensate them for the perceived heavy workload associated with taking the subject seriously[4]*.*

The review should also address the factors at primary level and at junior cycle second level that may limit the take-up of Higher Level Mathematics at Junior Cycle, thus limiting the size of the pool from which students taking Higher Level Mathematics to Leaving Certificate level can be drawn.

Recommendation 8: Common Entry Options for College Entry

Historically, entry into degree level engineering courses in Ireland was generally into a first year programme common to all branches of engineering. At the end of this "common entry" year, students chose which branch to pursue for the final three years of the course[5]. Where insufficient places were available in a branch to cater for demand, the available places were allocated competitively.

This pattern has changed, with most students now entering "denominated entry" courses, in which they choose their branch of engineering at the time of applying for the course. There are three significant drawbacks to this.

1. The evidence is that many students prefer common entry courses, at least where there is a strong likelihood that they will get their choice of place after the common year[6]. There are a number of cases where colleges operate both

4 This would be contrary to the recommendations of the Points Commission. However, the Expert Group takes the view that the question should be reopened because of the importance of Mathematics to Engineering and the other scientific and technical disciplines on which Ireland's economic success is, in large part, founded, and because the evidence suggests that the incentives inherent in the current operation of the points system may discourage second level students from studying Mathematics at higher level. The bonus scheme would not necessarily follow schemes currently operated by two colleges, which favour Higher Level Mathematics directly. For example, a small uniform bonus applied to Mathematics at both Higher Level and Ordinary Level might possibly encourage students at all levels of ability to treat Mathematics as one of their core points-scoring subjects, while minimising the risk of damage to the integrity of the points system.

5 The main undergraduate Engineering course at Trinity College Dublin had, and continues to have, a two year common programme.

6 With colleges having difficulty in filling all their places, most are likely in future to be able to avoid competitive allocation of places from common entry first year programmes.

denominated entry and common entry procedures for the same course. In these cases, CAO points are usually higher for the common entry course, and academic staff involved say that this reflects student preferences.

2. Most students are better equipped to make a good choice between branches of engineering after a year's study than they are when first applying for college. The differences between the branches are sufficiently great so that this can make the difference between success and non-completion.

3. Looking to the future, it is likely that the one of the main causes of mismatches between supply and demand for engineering graduates in particular disciplines will be the time lag between the choice of discipline and graduation. This time lag obstructs the effective working of labour market signals. For a denominated entry engineering course, the time lag will be approximately four and a half years. In contrast, the time lag will be just two thirds of that (three years) for a common entry course in which the choice of branch is made after first year.

It is recommended that colleges should move to increase the percentage of engineering degree students recruited through common entry mechanisms. The HEA should monitor trends in entry through these mechanisms.

6.3 Actions at Third Level

6.3.1 Engineering Academics as Key Influencers of Future Skills

Engineering academics are key influencers of the future supply of skills. Their views on future labour market conditions influence the views of their students, which in turn appear to have a major influence of the choices of college applicants by word of mouth. Their willingness to respond positively to skills programmes is also influenced by their views as to how well founded those programmes are, and is likely to also be influenced by their views about how fairly they are likely to be treated under the programme.

Recommendation 9: Labour Market Information for Engineering Academics

Arising from interviews with Engineering academics, it is apparent that the fact that most have not had the opportunity to see and question the detailed thinking behind Expert Group analyses and recommendations can cause problems. Under circumstances, such as at present, where the market for graduates in some Engineering disciplines is going through a difficult period, this can leave them uncertain as to the robustness of the thinking behind skills initiatives, and increase their uncertainty about likely future labour market conditions.

This is an important issue, as it is likely to affect the vision of the labour market that they communicate to their students, and as their students are likely to be among the key sources of information, and ultimate influencers of course choice, among school leavers. It is also important in that it may impact on the confidence that academics are prepared to place in future skills initiatives.

It is envisaged that the Expert Group on Future Skills Needs and Forfas will communicate a thorough and balanced analysis of the labour market position and outlook to key engineering academics.

6.3.2 Research Students

Many Irish engineering faculties are now putting a much heavier emphasis on research degrees. This is beneficial. It will increase the supply of people with research degrees suited to undertaking high level work in industry, and suited to expanding the industry research base. It will provide a stream of research outputs that may be commercialised. It also keeps more primary degree graduates within the education system, and is thus goes some way towards alleviating the current mismatch between supply and demand for engineering graduates in some disciplines.

Recommendation 10: Research Resources and Facilities

In the course of interviews for this study, many engineering departments, particularly in the universities, indicated that they were in the process of undertaking major expansions of their postgraduate research activity. Some of these face a major gap between the number of research students they can accommodate in laboratories, and the number they hope to recruit. In some cases, they are already overcrowded.

The HEA should consult with colleges about the space and other resources they need for postgraduate engineering research, with a view to providing a separate fund for investment in additional space, and upgraded space, where sufficient suitable space cannot be sourced within the college.

Recommendation 11: Funding for Postgraduate Research

The fall-off in applications for degree level courses in electronic engineering and closely related areas is giving rise to a decline in undergraduate numbers in some academic departments, but is tending to increase interest in undertaking research postgraduate studies. Apart from the beneficial effect that growth at postgraduate level will have in increasing the supply of engineers with research degrees, it has some very valuable corrective effects on the operation of colleges and on the operation of the labour market.

- It tends to maintain the funding that academic departments involved attract to their institutions, protecting them from the loss of resources (people, space, non-pay funding, promotional opportunities) that will be required again at undergraduate level once the economic situation improves.

- It gives experienced engineers and new graduates facing the impact of difficult labour market conditions the option of upgrading their skills while waiting for an upturn. This should retain more of these within the engineering profession. It should also improve general labour market conditions, and this is likely to feed back into more interest among school leavers.

It is recommended that the Government and relevant funding bodies should ensure that sufficient funding for research by engineering postgraduates is made available so as to avoid making funding an important constraint on the number of well-qualified people able to take up postgraduate research in engineering. Funding bodies should review the operation of funding cycles so as to ensure that it is possible for engineers to take up postgraduate studies as they become available for study, rather than necessarily waiting for the start of the next academic year. The HEA should monitor progress on this recommendation.

6.3.3 Undergraduate Students

Recommendation 12: Approaches to Learning in Engineering

A range of issues arose from interviews with engineering students and academic staff about approaches to learning. A great many of the students consulted would like more opportunities to apply the theory they learn as they learn it. In many cases, they are surprised and disappointed by the low level of project work.

When academic staff were questioned about international developments in engineering education, many of them spoke of their colleagues overseas moving gradually away from traditional lectures and practicals towards problem-based learning and increased amounts of project work. Both students and these academic staff felt that there was scope to improve both the quality of learning and student satisfaction by moving in this direction, without compromising the intellectual content of their courses. A move in this direction might improve the supply of engineering graduates by improving the word-of-mouth feedback that college students give to school students, and by reducing the non-completion rate. It would complement the work placements undertaken as a part of many engineering courses. The main barriers to a move in this direction appear to be a combination of inertia, the belief that it would be more resource-intensive (and thus difficult to resource), and a feeling that it might give rise to problems when undergoing IEI's accreditation process.

It is recommended that the Engineering Deans and Heads of School in third level colleges should form an ad-hoc taskforce to examine the potential benefits from, and obstacles to, moving towards a more project-based and problem-based approach to learning. A report based on this examination should be provided to the Expert Group on Future Skills Needs, the HEA and the Department of Education & Science, for consideration.

6.4 Mature Students and Lifelong Learning

Ab-initio engineering degree programmes differ from degree programmes in many other disciplines in that they do not attract many mature students. They recruit almost entirely from the school leaving population. At a time when school leaving numbers are falling, and third level colleges generally are looking to mature students to bridge the resulting fall in applicant numbers, engineering is put at a disadvantage in attracting sufficient applications.

Discussions with engineering academics suggest that the scope to attract more mature students into ab-initio engineering degrees will be limited, because the vast majority of those leaving school with sufficient academic ability and motivation to succeed in obtaining an engineering degree go directly to third level education, rather than entering the labour market. Thus, while it will be important to have systems in place to cater for those mature students interested in studying engineering at degree level, and sufficiently able and motivated to complete a course, it will be necessary to place a greater focus on other points at which mature students can be catered for.

The other key points are as follows.

- Mature entry into full time add-on diploma and degree courses. (It is common for students to graduate with an engineering diploma or certificate, and to return to college to obtain an add-on qualification after a period in the labour market.)

- Entry into national programmes to provide third level opportunities for those in employment. The main programme currently in place is the Institute Trainee Programme. Under this programme, people already in employment in engineering companies, and people recruited to take part in the programme, combine work with an engineering employer, with study, leading to the award of a national certificate. There may be scope to also put in place a programme to allow those with engineering craft qualifications to progress to third level qualifications, with exemptions consistent with their prior learning.

- In some cases, companies and third level institutions cooperate to provide courses for employees leading to a third level qualification, or leading to the award of ACCS credits that can be accumulated towards such a qualification.

- In many cases, employers support employee participation in part time programmes of education initiated and provided by individual education institutions, and leading to the award of third level qualifications or to the award of ACCS credits.

- Many companies have upskilling initiatives and patterns of career progression that do not lead to third level qualifications, but which have the effect of enabling engineering craftspeople to work in a Technician-equivalent role, or of enabling people with diploma or certificate qualifications in engineering to work in an engineer-equivalent role.

Recommendation 13: Pre-Engineering Courses

To the extent that there are people with the potential to succeed in engineering degrees as mature students, many of them have not performed to their full potential in mathematics and the physical sciences in the Leaving Certificate. Thus, there is a need for some provision to bridge this educational gap. There is at least one pre-engineering course already in place that addresses this need.

It is recommended that, where sufficient demand exists from people with suitable levels of ability and commitment, institutions including further education colleges[7] and third level colleges should run pre-engineering courses designed to bring mature students to a level in mathematics and the physical sciences equivalent to at least a higher level C3. Where such courses already exist, they should be continued.

Recommendation 14: National Programmes
Issues to do with progression for craftspeople to higher levels of qualification are being addressed in other fora. The Expert Group on Future Skills Needs believes that it is important that there should be a national framework for progression from craft level qualifications to higher level qualifications.

It is recommended that the Institutes of Technology should continue the Industry Trainee Programme and Accelerated Technician Programme where there is sufficient demand from trainees and industry.

Recommendation 15: Certification of People Up-Skilled in Companies
It is common for people working in engineering areas in industry to acquire skills informally that are equivalent to those of people at a higher level of qualification. It is also common for people to acquire skills equivalent to a substantial subset of those people at a higher level of qualification.

It is recommended that engineering departments of third level colleges, particularly of Institutes of Technology, should work with HETAC, industry and the IEI to develop more active systems of accreditation of prior and experiential learning, and also to provide tailored up-skilling opportunities to bridge existing learning and the requirements of higher levels of qualification.

6.5 Immigration

Immigration has been a key source of engineers in Ireland in recent years. The projections in this report suggest that it will be necessary in the future in electronic engineering. It may also be necessary in other Engineering disciplines. It should be noted that industry demand is often volatile. Even where there is a good long term match between supply and demand for graduates in a discipline, a short term variation in demand may lead to a short term mismatch that must be bridged by immigration.

Immigration is also potentially a means of filling places in Irish colleges with students who may later become available for recruitment by Irish industry. Engineering schools in the UK and the US rely on overseas students for a significant part of their student body. US technology industries depend to a significant extent on these students when they graduate.

Recommendation 16: Promoting Immigration by Engineers
It is likely that immigration from both within the EU and from non-EU countries will be required in the future. Eastern Europe, including some countries not scheduled for accession to the EU in the short term, is an important source of engineers in a range of disciplines. India is an important source of software engineers.

It is recommended that the Government should take into account in future immigration policies the likelihood that there will be a need for immigration by engineers from within the EU. It should also allow flexibility to introduce targeted skills initiatives.

Recommendation 17: Drawing Students from Overseas
Engineering academics in a number of Irish colleges are looking to a future in which they expect to have difficulty in filling sufficient places with Irish students, and are beginning to consider the possibility of recruiting more overseas students. One of the main issues that they say is holding them back for the present is a concern that their primary obligation is to cater for Irish students.

7 Colleges that were termed "PLC colleges" in the past are now generally termed "further education colleges".

The main potential sources of students are:

- from within the EU;
- from non-EU Eastern European countries; and
- from outside Europe, with China and a number of other Far Eastern countries being the markets most heavily tapped by US and UK universities.

For each source, Ireland's position as an English-speaking centre of technology industry, with a student lifestyle that many find attractive, is likely to be helpful in motivating students to apply to study here. From a skills supply perspective, the attraction is that many of these students might be interested in remaining in Ireland to work after graduation. This appears to be particularly likely with students from European countries.

The Higher Education Authority is nearing completion of a study examining the issues of policy around overseas students in Ireland.

The Expert Group recommends that interested bodies should take a positive action towards attracting engineering students from overseas, and that they should use the forthcoming HEA study of the issue to inform their responses. Forfas and the HEA should monitor progress in this area.

6.6 Statistics

Recommendation 18: Systems of Statistical Classification

The process of undertaking this study has demonstrated significant mismatches between the statistical classifications required for a study of this nature, and the classifications used by the Central Statistics Office and by the various agencies. It has also demonstrated significant gaps in the data collected, particularly with regard to IT-related service industries.

The Expert Group on Future Skills recommends that Forfas should initiate a review of industry data sources. This should include its own data, and that from other agencies including FAS, HEA, Enterprise Ireland and IDA Ireland, and at CSO data sources, in the context of the requirements of skills policy research, formulation, implementation and review. The review should make recommendations on industry classifications and survey coverage applicable across all relevant agencies.

Appendix A. Statistical Appendix

Table A.1 Estimates of Numbers of Primary Engineering Degree Graduates of 2000 Entering Employment in Ireland in Various Secto

Industry / Engineering Discipline	Biomedical	Building Services	Civil	Chemical / Process	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Manufacturing / Industrial	Telecommunications	Total
ICT	0	0	47	12	35	276	0	42	8	0	123	16	558
Software & IT Services	0	0	42	4	20	135	0	16	2	0	38	4	260
Electronic Hardware & IC Production	0	0	0	8	7	57	0	26	5	0	79	1	184
IC Design	0	0	0	0	7	46	0	0	0	0	5	1	59
Telecommunications Services	0	0	5	0	1	39	0	0	0	0	0	10	55
Other Fast-Growth Manufacturing	4	0	0	20	0	4	0	18	4	0	16	0	66
Medical Devices	4	0	0	0	0	2	0	16	2	0	13	0	36
Pharmaceuticals	0	0	0	20	0	2	0	3	2	0	4	0	30
Other Manufacturing	4	0	5	12	0	0	0	47	2	15	34	0	119
Aerospace	0	0	0	0	0	0	0	5	0	15	0	0	20
Food	0	0	0	0	0	0	0	5	0	0	11	0	16
Mechanical Engineering	1	0	0	0	0	0	0	14	2	0	11	0	29
Other Process Manufacturing	2	0	0	8	0	0	0	16	0	0	2	0	28
Other Manufacturing	0	0	5	4	0	0	0	7	0	0	11	0	26
Construction-Related1	1	8	196	26	0	4	0	33	1	3	13	0	285
Construction	1	0	71	0	0	2	0	5	0	0	2	0	81
Engineering Consultancy	0	8	108	26	0	2	0	21	1	3	9	0	178
Local Authority	0	0	17	0	0	0	0	7	0	0	2	0	25
Other Service	0	0	2	0	0	0	1	7	0	0	7	1	18
Financial Services	0	0	2	0	0	0	1	0	0	0	5	1	10
Transport & Logistics Services	0	0	0	0	0	0	0	7	0	0	2	0	8
Education	1	0	0	0	0	5	0	1	0	3	0	0	11
3rd Level Education	1	0	0	0	0	5	0	1	0	3	0	0	11
Other Education & Training	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Public Sector	0	2	15	0	0	11	8	12	0	0	7	0	54
Sectors with No Strong Link to Engineering	1	0	0	0	0	2	0	5	1	0	11	0	20
Total	11	9	265	71	35	301	9	164	16	21	211	17	1130

Source: Based on grossing up an analysis of employers recorded in the HEA's First Destination database for graduates of 2000.

Table A.2 Estimates of Numbers of Postgraduates Qualifying in 2000 Entering Employment in Ireland in Various Sectors

Industry	Graduate Diplomas	Taught Masters	Research Masters	PhD	Total
ICT	14	45	17	3	79
Software & IT Services	4	24	8	0	37
Electronic Hardware & IC Production	10	17	3	2	32
IC Design	0	2	3	2	7
Telecommunications Services	0	2	2	0	3
IT Services	3	19	7	0	28
Other Fast-Growth Manufacturing	11	5	0	2	18
Medical Devices	10	5	0	0	15
Pharmaceuticals	1	0	0	2	3
Other Manufacturing	1	9	5	0	15
Aerospace	0	0	0	0	0
Food	0	2	0	0	2
Mechanical Engineering	0	0	2	0	2
Other Process Manufacturing	1	2	2	0	3
Other Manufacturing	1	5	2	0	8
Construction-Related	1	17	7	2	27
Construction	0	0	2	0	2
Engineering Consultancy	1	14	5	2	22
Local Authority	0	3	0	0	3
Other Service	1	5	0	0	7
Financial Services	0	2	0	0	2
Transport & Logistics Services	1	3	0	0	5
Education	1	10	2	15	29
3rd Level Education	1	7	0	14	22
Other Education & Training	0	3	2	2	7
Other Public Sector	0	15	3	5	23
Sectors with No Strong Link to Engineering	0	9	0	0	9
Total	31	115	33	26	206

Source: Based on grossing up an analysis of employers recorded in the HEA's First Destination database for graduates of 2000.

Table A.3 Estimates of Percentages of Diploma Graduates Qualifying in 2000 Entering Employment in Ireland in Various Sectors

	Building Services	Civil	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Total Sample
Agriculture, Forestry, Fishery								10.0		1.4%
Mining						4.5%				0.5%
Food Processing, Beverages, Tobacco				1.6%						0.5%
Wood & Wood Products						4.5%				0.5%
Paper, Paper Products, Printing, Publishing,				1.6%					3.2%	0.9%
Chemicals, Rubber, Plastics, Pharmaceuticals, Healthcare		2.0%				4.5%			6.7%	2.8%
Glass, Pottery, Cement						68.2%		303%		57.0%
Engineering, Electronics & Metal Industries	75%	10.2%	66.7%	90.5%	85.7%		60.0%	26.7%	74.2%	0.5%
Transport Equipment								33%		0.5%
Electricity, Gas							20.0%			19.6%
Construction, Civil Engineering		71.4%						20.0%	3.2%	3.3%
Other Industries				1.6%		13.6%		607%	3.2%	1.4%
Civil Service, Defence		2.0%				4.5%		3.3%		1.9%
Local Government		6.1%						3.3%		
Health Boards, Hospital Services										1.4%
Education - 1st & 2nd Levels			33.3%	1.6%				3.3%		0.5%
Education - 3rd Level		2.0%								
Non-Commercial State-Sponsored										
Wholesale Distribution										
Retail Distribution								13.3%	3.2%	2.3%
Transport, Communication, Storage				1.6%	14.3%				3.2%	1.4%
Insurance, Financial, Business & Commercial Computer Services										
Professional Services, Private Practice		4.1%								0.9%
Other Services	25.0%	2.0%		1.6%			20.0%	6.7%		2.8%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

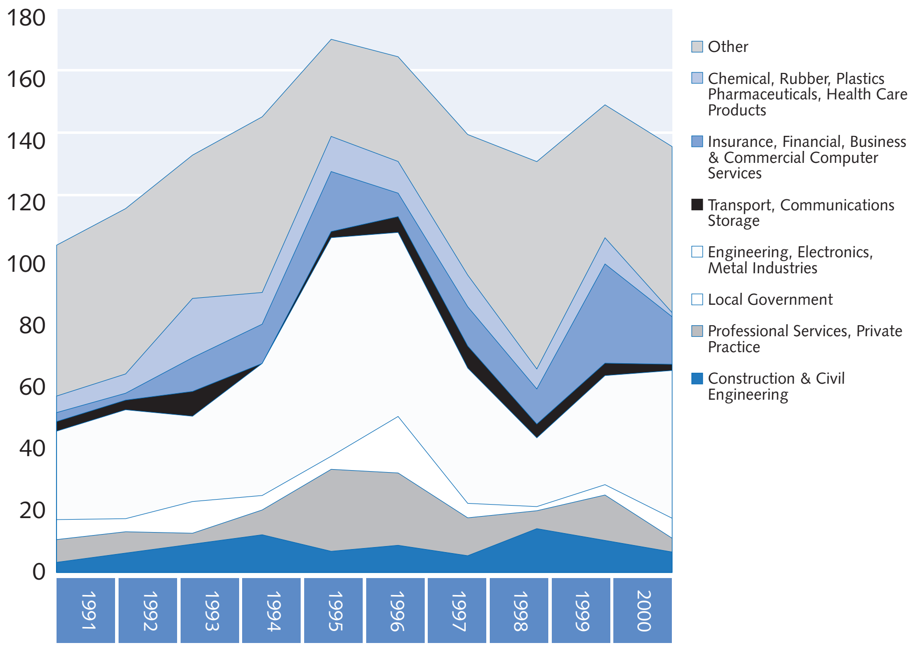
Source: Based on grossing up an analysis of employers recorded in the HEA's First Destination database for graduates of 2000.

Table A.4 Estimates of Percentages of Certificate Graduates Qualifying in 2000 Entering Employment in Ireland in Various Sectors

	Building Services	Civil	Computer	Electronic	Electrical	Mechanical	Mechatronic	Other	Production / Manufacturing	Total Sample
Agriculture, Forestry, Fishery							5.6%			0.3%
Mining				1.3%	2.6%					0.7%
Food Processing, Beverages, Tobacco					2.6%				1.5%	0.7%
Wood & Wood Products		2.4%			5.3%		22.2%		4.4%	3.6%
Paper, Paper Products, Printing, Publishing,									5.9%	1.3%
Chemicals, Rubber, Plastics, Pharmaceuticals, Healthcare		1.2%		5.0%	2.6%	25.0%	11.1%		4.4%	4.9%
Glass, Pottery, Cement					2.6%				2.9%	1.0%
Engineering, Electronics & Metal Industries	100%	3.6%		73.8%		75.0%	16.7		58.8%	47.7%
Transport Equipment					2.6%		5.6%			1.3%
Electricity, Gas				1.3%			5.6%		1.5%	0.7%
Construction, Civil Engineering		63.9%		1.3%	2.6%				1.5%	18.8%
Other Industries		4.8%		2.5%					2.9%	3.0%
Civil Service, Defence									1.5%	0.7%
Local Government		12.0%								3.3%
Health Boards, Hospital Services		1.2%								0.3%
Education - 1st & 2nd Levels				2.5%						0.7%
Education - 3rd Level									1.5%	0.3%
Non-Commercial State-Sponsored				1.3%						03.%
Wholesale Distribution		1.2%		1.3%					1.5%	10.%
Retail Distribution		1.2%		2.5%			11.1%		4.4%	2.6%
Transport, Communication, Storage				5.0%	2.6%				1.5%	2.0%
Insurance, Financial, Business & Commercial Computer Services				1.3%						0.3%
Professional Services, Private Practice		7.2%								2.0%
Other Services		1.2%		1.3%	2.6%		5.6%		5.9%	2.6%
Total	100%	100%		100%	100%	100%	100%		100%	100%

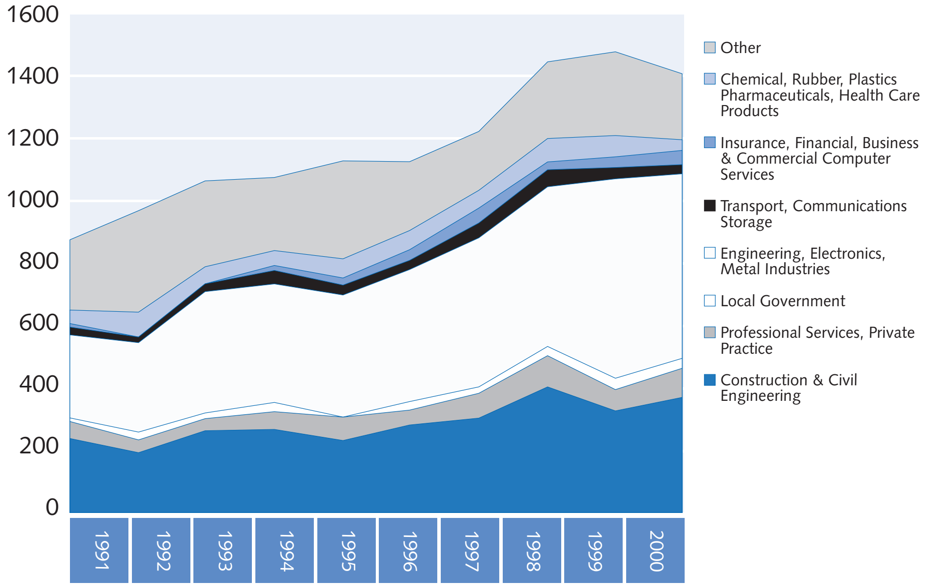
Source: Based on grossing up an analysis of employers recorded in the HEA's First Destination database for graduates of 2000.

Figure A.5 Recruitment of New Higher Degree Engineering Graduates by Irish Employers Classified by HEA Industry Sector Graduates of 91 to 00



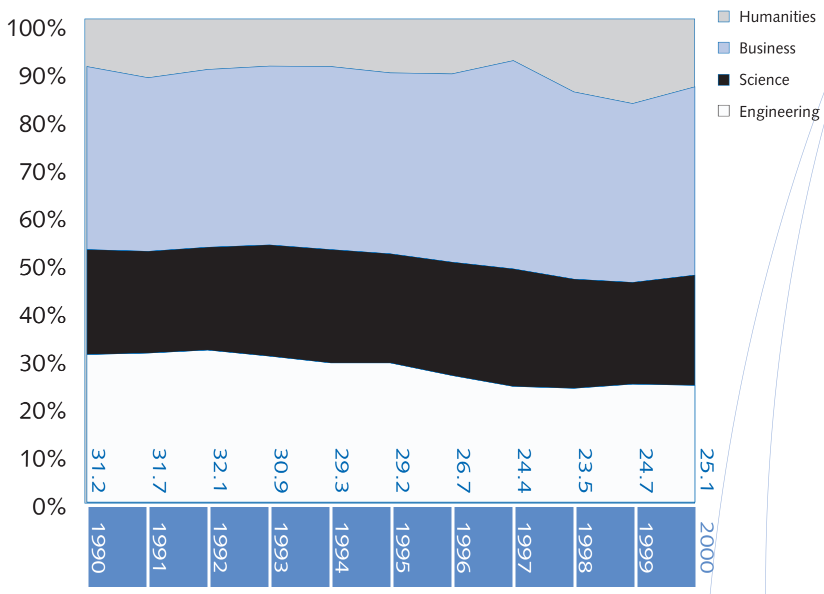
Source: Grossed up from data from First Destination of Award Recipients in Higher Education, editions from 1991 to 2000, HEA.

Figure A.6 Recruitment of New Diploma and Certificate Engineering Graduates by Irish Employers Classified by HEA Industry Sector - Graduates of 91 to 00



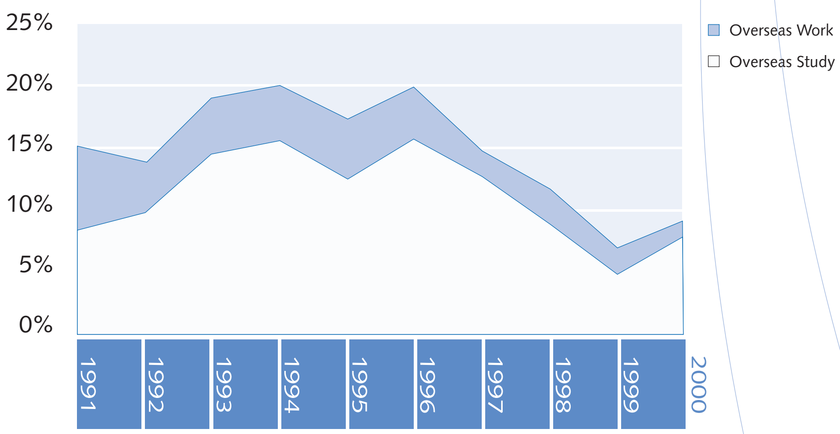
Source: Grossed up from data from First Destination of Award Recipients in Higher Education, editions from 1991 to 2000, HEA.

Figure A.7 Disciplinary Mix of Diploma & Certificate Graduates, 1982 to 2000



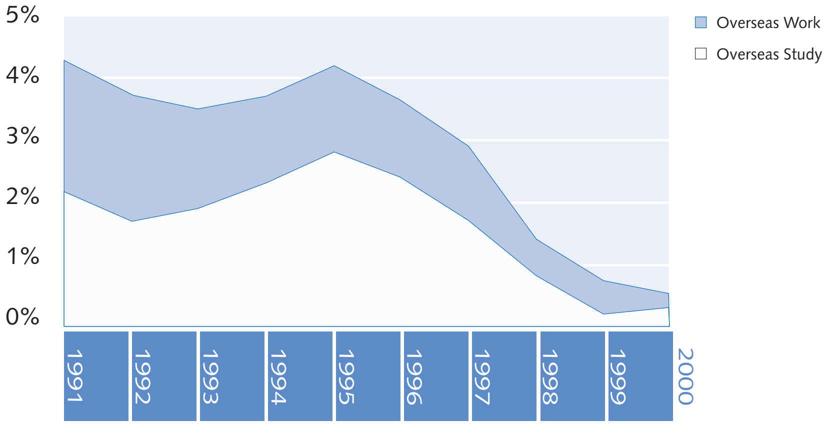
Source: Drawn from First Destination of Award Recipients in Higher Education , HEA, 1982 -2000.

Figure A.8 % of Diploma Engineering Graduates Going to Study or Work Outside Ireland



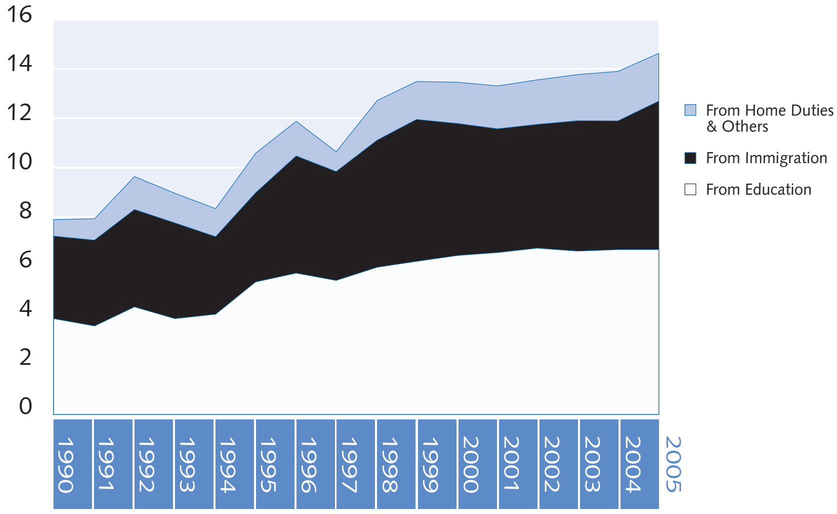
Source: First Destination of Award Recipients, various years, HEA

Figure A.9 % of Certificate Engineering Graduates Going to Study or Work Outside Ireland



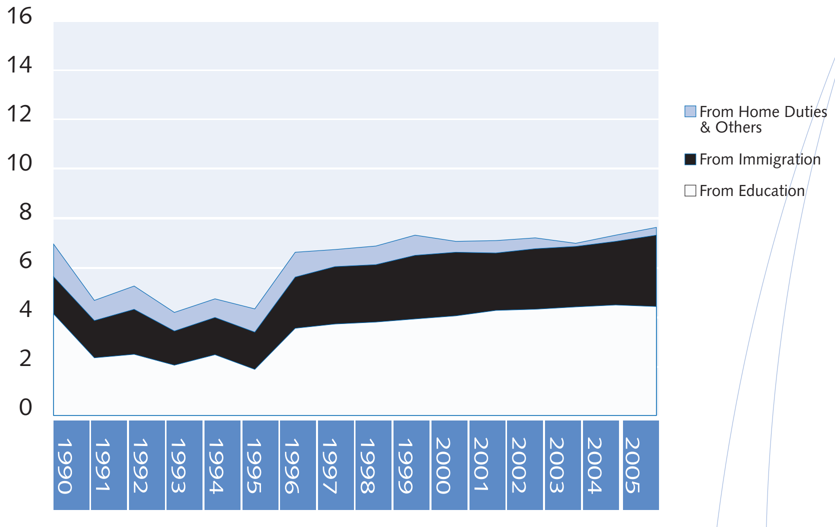
Source: First Destination of Award Recipients, various years, HEA

Figure A.10 Sources of Inflows into Professional Occupations ('000s)



Source: Results from FAS/ESRI Manpower Forecasting Studies No. 9.

Figure A.11 Sources of Inflows into Associate Professional Occupations ('000s)



Source: Results from FAS/ESRI Manpower Forecasting Studies No. 9.

Table A.12 Relationship between Change in Degree Applications for Courses and Dependence on ICT Industries for Employment

	Share of 2000 Degree Graduates Entering Irish Employment Accounted for by ICT Industries	Average Change in Degree Applications 2001-2002 for Courses in Relation to Which Responses Were Received
Civil Engineering	18%	9%
Biomedical Engineering	0%	-4%
Mechanical Engineering	25%	-7%
Manufacturing / Industrial Engineering	58%	-27%
Electronic Engineering	92%	-36%
Telecommunications Engineering	93%	-35%
Computer Engineering	100%	-37%

Figure A.13 % of Leaving Certificate Mathematics Candidates Taking Higher Level Paper

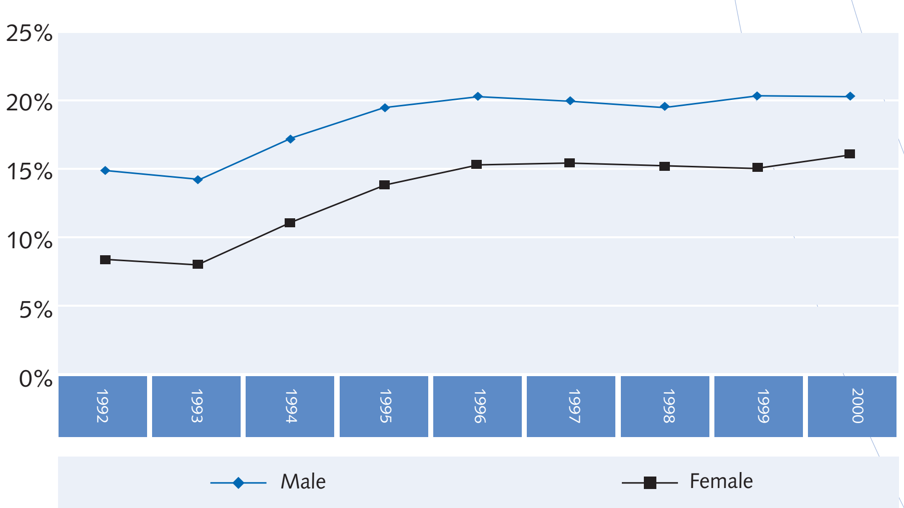


Table A.14 % of Candidates Taking Each Junior Certificate Subject*, 2000

Subject	Candidates	Subject	Candidates
English	98.3%	Home Economics	34.4%
Mathematics	97.6%	Materials Technology	25.3%
Irish	92.8%	Technical Graphics	24.4%
Geography	89.9%	German	22.4%
History	89.4%	Music	14.2%
Science	85.9%	Metalwork	13.3%
French	68.4%	Technology	5.0%
Business Studies	63.8%	Spanish	3.7%
Art, Craft & Design	34.7%		

* Only subjects with at least 1,000 examination candidates included.

Appendix B. Expert Group On Future Skills Needs List Of Members

Member	Organisation
Dr. Danny O'Hare (Chairperson)	President Emeritus, Dublin City University
David Barry Employment	Department of Enterprise Trade and
Enda Connolly	IDA Ireland
Brian Cogan	Forfás
Roger Fox	FÁS
Jack Golden Engineers of	Cement Roadstone Holdings/Institution of Ireland (CRH/IEI)
Una Halligan	Hewlett Packard
John Hayden	Higher Education Authority (HEA)
David Lowe	Goodbody Stockbrokers
Joe McCarthy	Arkaon
Kevin McCarthy	Department of Education & Science
Dr. Sean McDonagh	Skills Initiative Unit
Eugene O'Sullivan	Department of Finance
Peter Rigney	Irish Congress of Trade Unions
Dr. Catherine Kavanagh	Forfás
Aisling Penrose (Secretary)	Forfás

Appendix C. Reports Published By The Expert Group On Future Skills Needs

Report	Date of Publication
The First Report of the Expert Group on Future Skills Needs	December 1998
Responding to Ireland's Growing Skills Needs	
Business Education and Training Partnership	
Report on the Inaugural Forum, Royal Hospital Kilmainham	March 1999
The Second Report of the Expert Group on Future Skills Needs	
Responding to Ireland's Growing Skills Needs	March 2000
Business Education and Training Partnership 2nd Forum, Dublin	March 2000
Report on E-Business Skills	August 2000
Report on In-Company Training	August 2000
Benchmarking Mechanisms and Strategies to Attract Researchers to Ireland	July 2001
The Third Report of the Expert Group on Future Skills Needs	
Responding to Ireland's Growing Skills Needs	August 2001
Labour Participation Rates of the over 55s in Ireland	December 2001
National Survey of Vacancies in the Private Non-Agricultural Sector 2001/2002	March 2003
National Survey of Vacancies in the Public Sector 2001/2002	March 2003
Demand and Supply of Skills in the Food Processing Sector	April 2003

Appendix D. Steering Group List of Members

Name	Organisation
Dr. Catherine Kavanagh (Chairperson)	Forfás
Prof. Gerard Byrne	UCD
Roger Fox	FÁS
Jack Golden	Cement Roadstone Holdings/Institution of Engineers of Ireland (CRH/IEI)
Paddy Purcell	Institution of Engineers of Ireland (IEI)