ICSTI
IRELAND
Irish Council for Science, Technology and Innovation

Technology Foresight Ireland

An ICSTI Overview

Forfás

Established by the Government and Forfás to advise on Science, Technology and Innovation

Acknowledgement

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Foreword

In March 1998, Noel Treacy, T.D., Minister for Science, Technology and Commerce requested the Irish Council for Science, Technology and Innovation to develop and undertake a Technology Foresight exercise in Ireland. The Government White Paper on Science, Technology and Innovation (1996) had indicated that a Technology Foresight exercise would be undertaken in the context of the new three tier arrangements which were being put in place for the prioritisation of State investment in science and technology. The three new and inter-related infrastructural elements are: the Inter-Departmental Committee (IDC) for Science and Technology chaired by Minister Treacy; the Cabinet Sub-Committee for Science and Technology and the Irish Council for Science, Technology and Innovation (ICSTI).

It gives me great pleasure to present the findings of the first Technology Foresight exercise and to introduce this ICSTI Overview which follows from the consideration by Council of the priorities and generic issues that are highlighted in the eight Technology Foresight Panel reports.

Although this was the first time such a Technology Foresight exercise had been undertaken in Ireland, the work was completed within 12 months. This was in no small measure due to the energy, commitment and thought given to the exercise by some of Ireland's leading industrialists, scientists, engineers and public servants as well as to the leadership and guidance provided by the ICSTI Task Force[1] on Technology Foresight, chaired by Brian Sweeney. The initiative was jointly supported by the Office of Science and Technology and Forfás, who also provide Secretariat to the Council.

The timing of the initiative envisaged that the Technology Foresight outputs would provide valuable inputs to Government for the preparation of the National Development Plan, which will be submitted to the EU Commission later this year, in the context of the next round of EU Structural Funds (2000 to 2006). It is also envisaged that the Foresight outputs would guide the future allocation of Exchequer funding to science and technology in the annual budgetary exercises of the relevant Government departments.

Research, science and technology deal with developing, transferring and applying knowledge. The leit-motiv of the Technology Foresight Ireland initiative has been the focus on knowledge to underpin innovation, growth and the competitiveness of the Irish economy. All of us who participated are most anxious that the eight Panel reports and this ICSTI Overview should not be regarded as an end in themselves, but should rather mark the start of a partnership process whereby Technology Foresight insights will continue to inform national S&T policy.

Accordingly, in the coming months we shall be meeting with Government departments and agencies to consider appropriate action and responses to the recommendations of the eight individual Panel reports and also to the overall strategic issues raised in this ICSTI Overview.

Edward M. Walsh
Chairman Irish Council for Science, Technology and Innovation

April 1999

[1] See Appendix 1 for Task Force membership

Introduction

Foresight is about preparing for the future. It is about deploying resources in the best way possible – for competitive advantage, for enhanced quality of life and for sustainable development. Foresight makes possible the identification of the opportunities and challenges in the future, and what Government, scientists and engineers should be doing to meet them. In doing so, it brings together the diverse players on the national science, engineering and technology 'team'.

Like other countries which have undertaken similar exercises, Ireland has experienced the widely recognised Foresight process benefits, such as the development of better communication, interaction and mutual understanding between industry, Government departments and the scientific and engineering communities.

The main part of the Technology Foresight exercise began in March 1998 when ICSTI identified the following eight sector areas for consideration:

- Chemicals and Pharmaceuticals
- Information and Communication Technologies
- Materials and Manufacturing Processes
- Health and Life Sciences
- Natural Resources (Agri-food, Marine, Forestry)
- Energy
- Transport and Logistics
- Construction and Infrastructure

The initiative was spearheaded by eight expert Panels, representative of a broadly based input from each of these sector areas[2]. As part of the process, all the Panels undertook wide national consultation via workshops, the commissioning of contributions from international experts in specific technologies, and public contributions via press advertisements and the Foresight web page.

The time horizon for the exercise was set at 2015 and the exercise itself was completed in twelve months. The findings of the first Technology Foresight exercise are contained in the eight individual Panel reports that are being published in association with this overview.

I would like to thank most sincerely all those who committed their time, energy, expertise and experience to this exercise, either through their work on the Panels or through their contributions during the consultation stage. If we can manage to communicate even a fraction of the excitement at the possibilities opened by technological advance which we ourselves frequently felt during this exercise, I am certain we can jointly devise a more productive and fulfilling society for all of our citizens by 2015.

Brian Sweeney
Chairman ICSTI Technology Foresight Task Force

[2] See Appendix II for Technology Foresight Panel Details

Executive Summary

Technology and the Knowledge Society

The world economy is undergoing significant change, with far greater emphasis on the ability to create, store, distribute and apply knowledge. Globalisation of the world's economies has fuelled competition, and increasingly competitiveness is achieved through knowledge-based technological innovation.

Knowledge is one of the main drivers of prosperity and well being. Ireland needs to evolve rapidly to a knowledge society. Enterprises that are focused on their customers, employ educated workers, encourage innovation throughout their businesses, and know more and learn faster than their global competitors, are the most likely to succeed and grow. Societies that maximise opportunities for individuals and enterprises to develop knowledge-age skills and access knowledge-age services are the most likely to be cohesive and successful.

Knowledge societies will exploit the enormous potential of new technologies in areas such as information and communications, biotechnology, medical systems and nanotechnology. Over time such technologies and the industries they support will become increasingly important, and sectors of the economy such as manufacturing, agriculture and aquaculture will benefit from the application of knowledge-intensive production, processing and organisation.

Technology Foresight - A Way of Discussing the Future

Research, science and technology deal with creating, transferring and applying knowledge. In recent years Governments and enterprises in the major industrialised countries have been trying to *formalise* their discussion of future prospects and current choices concerning science, technology, the economy and society, in order to assist them in prioritising their investments in science, technology and knowledge.

Technology Foresight is a process for bringing together scientists, engineers, industrialists, Government officials and others to identify areas of strategic research and the emerging technologies likely to yield the greatest economic and social benefit. In the Technology Foresight process the participants work towards developing a consensus on research priorities, creating a shared vision of the future they would like to achieve. It is concerned with the role of technology in constructing a desirable but achievable long term future for the country and identifying the critical strategic decisions which must be taken now to make the achievement of this vision more probable.

The Technology Foresight initiative links investment in research, science and technology with Ireland's development as a knowledge society. Two key imperatives underline this process:

- Technology is a key driver for knowledge societies and will have wide ranging implications for the structure of society and the way we address economic, social and environmental goals
- Strategic investments in research, science and technology must be used effectively to underpin Ireland's development as a knowledge society

Technology Foresight Ireland - the process and the outputs

Noel Treacy, T.D., Minister for Science, Technology and Commerce requested ICSTI, in March 1998, to undertake a Technology Foresight exercise. The initiative was jointly supported by the Office of Science and Technology, Department of Enterprise, Trade and Employment and Forfás.

Technology Foresight Ireland was spearheaded by eight broadly based expert Panels established in March 1998, under the guidance of an ICSTI Task Force, chaired by Brian Sweeney (Chairman, Siemens Ltd Ireland). The Panels were established to cover the following sector areas:

- Chemicals and Pharmaceuticals
- Information and Communication Technologies
- Materials and Manufacturing Processes
- Health and Life Sciences
- Natural Resources (Agri-food, Marine, Forestry)
- Energy
- Transport and Logistics
- Construction and Infrastructure

The Panels, chaired by ICSTI members, were composed of representatives from industry, the higher education sector, State agencies, research institutes and Government departments - essentially the 'stakeholders'. Panel members were asked to consider the likely social, economic and market trends that would affect Ireland in the medium to long term and the developments required in science and technology to best address future needs.

An approach appropriate for a small country embarking on a Technology Foresight exercise for the first time was adopted. Building on 'best practice' elsewhere the Task Force determined that the Irish initiative should be in line with Ireland's size and economic structure and adopt a time frame to 2015.

Technology Foresight Identifies the Gap

The Technology Foresight exercise concludes that the Irish economy should be repositioned, to be widely recognised internationally as a knowledge-based economy. To do this, the knowledge framework can be visualised as a *pyramid* - where industry, the higher education sector, Government and society are the four interlinked faces forming a partnership at all levels.

The concept of excellence should permeate all the faces of the pyramid. Excellence in our education system; our enterprises, be they technology takers or technology makers; Government in its proactive management of the innovation environment; and in society, where science and technology is valued and supported for its contribution to the economy and the health and well being of citizens. The co-operative support of the various partners is needed for the development of each pyramid face and many of the Foresight recommendations, to be found in the eight Panel reports, are directed towards their continued development and expansion.

However, a gap at the *apex* of the pyramid has been identified – the need for a world class research capability of sufficient scale in a number of strategic areas within our universities and colleges, research institutes and industry. The gap identified will only be filled if the partnership of Government, industry, the higher education sector and society can combine to deliver the knowledge framework, which will in the future realise:

- Research and Technology Development (RTD) intensive and advanced technology-based indigenous and overseas companies, using high level expertise
- a vibrant, cohesive, durable and internationally recognised competitive RTD base involving industry, universities and colleges and research institutes, which provides an attractive career structure for researchers to work in Ireland
- an environment conducive to innovation
- investment in the physical and human infrastructure
- citizens well informed on scientific issues in the context of an innovation culture

Technology Foresight Ireland - Delivering the Benefits

Efforts should now be concentrated on developing the apex of the pyramid where the gap in world class research activity has been identified. Continuing the current incremental approach to Science, Technology and Innovation (STI) investment will not achieve world class research capability at the scale required. To accelerate this development, Ireland needs to take a quantum leap in investment by anticipating the areas of strategic opportunity and investing ahead of demand.

Investment must however continue for the ongoing development of all levels in the pyramid model. Continuous development of the primary and second level science curriculum and of the teaching of science is essential. Investment must also continue for the development of third level research, thus providing the high tech skills that industry needs now. To compete in the knowledge-based global economy, industry must reposition itself higher up the economic chain in terms of the innovation and value it adds to the products and services exported. Therefore, the current S&T needs of companies in terms of their capacity to use and adapt new and proven technologies must also continue to be supported.

Recommendations

Global competition and economic development will be largely driven by the unprecedented growth in knowledge in many areas of technology and particularly in the pervasive areas of Information and Communication Technologies (ICT) and biotechnologies. New sectors, firms, production and marketing methods will emerge. The evidence for this and the implications for Ireland are highlighted in the findings of the Technology Foresight Panels.

The Irish economy, if it is to continue to grow, will need to create, develop and attract firms which are research or technology-based and which can generate, apply and trade in the new technologies. The Irish economy must reposition itself from predominantly production-oriented plants to research, knowledge-based and innovation-driven firms. This will require a quantum shift in industrial policy. Firstly, it requires a vision of the type of economy and enterprises we wish to develop and secondly, it requires the supporting policies and appropriate investment to make the vision a reality.

The recommendations of the Council aim to contribute to the formulation of this vision and the policies and investment which can make it happen. The Council recommends that:

i. All Government departments and agencies utilise the Foresight findings in future planning exercises

Government departments, their agencies, other partners and the sectors themselves should take into account the Panel recommendations in order to develop the sectors involved, strengthen the national RTD base and thus underpin the long term competitiveness and productivity of the economy. In the coming months, the Council will meet with Government departments and agencies to discuss follow-on actions and responses to the recommendations of the eight Panel Reports.

ii. Ireland become a centre of excellence in ICT and biotechnology niches

There is a need for a substantial increase in national capability in niche areas of information and communication technologies and biotechnology. These are widely identified in the Panel reports as representing, for the future, the engines of growth in the global economy. They are strategic technologies for the continued development of important national sectors. In the context of the development of existing indigenous firms, the attraction of a new phase of multinational companies to Ireland and the creation of new technology-based enterprises, the Irish economy must develop a credible base of knowledge and activities in these key technologies. Competing in these technologies means competing with the best in the world. A world class research capability in selected niches of these two enabling technologies is an essential foundation for future growth.

These key technologies require new skills, and in particular the development of a cadre of world class S&T personnel. Attracting international expertise into Ireland in key technology areas will be necessary.

iii. Government policies be more proactive in the creation of an environment conducive to technological innovation and specifically in relation to regulatory and fiscal issues

Government must be strongly proactive in creating an environment conducive to innovation to ensure that the benefits from investment in strategic technology areas will not be constrained.

Policy areas of particular importance include the following:

- *regulation(s) covering new product development*
- *sustainable development*
- *fiscal policies which promote R&D and reward risk*
- *awareness activities, in the educational and industrial development systems, to promote understanding and appreciation of technological developments and to promote a culture of innovation*

iv. Government establish a Technology Foresight Fund: IR£500 million over five years

A Technology Foresight Fund should be established and run over five years - building up each year to an average commitment of IR£100 million per year.

Recent economic growth is due in large measure to the growth in exports of manufactured goods. The total value of exports grew from IR£15 billion in 1991 to IR£46 billion in 1998. Over 50 per cent of these exports arise from enterprises in the chemical and pharmaceutical, healthcare, electronics, telecommunications and other high technology sectors. Fifty companies account for half of all our exports and only 13 of the 50 do any R&D. Firms which have no strategic roots i.e. R&D function, in a location are particularly susceptible to international mobility.

Well focused and significant investment in upgrading the technological infrastructure of the economy will enable Ireland to develop world class research capability in strategic technologies for the future competitiveness of indigenous industry, facilitate the undertaking of R&D in this country by multinational companies and attract more high-tech companies to Ireland in the future.

Such a fund is necessary, if the gap at the apex, identified in the Technology Foresight findings, is to be filled. The scale is appropriate in the context of the value of the total output (now and in the future) from the sectors affected, and in the context of the potential to create new enterprises and to provide skills for 'new' industries and to increase productivity in existing industries.

Technology Foresight does not forecast the future but the process can ensure that the strategic choices made now regarding the prioritisation of national STI investment are 'future-proofed'. The Technology Foresight findings show the route to continued economic growth, wealth creation and improved standards of living.

Technology Foresight Ireland

1.1 What is Technology Foresight

Technology Foresight is the process for bringing together in partnership scientists, engineers, industrialists, Government officials and others to identify areas of strategic research and the emerging technologies likely to yield the greatest economic and social benefit and which in the long term will sustain industrial competitiveness. *(Martin, 1995)*[3]

In the Technology Foresight process the participants develop consensus on research priorities, creating a shared vision of the future they would like to achieve. The process is concerned with constructing a desirable but achievable long term future for the country and with identifying the critical strategic decisions which must be taken now to make the achievement of this vision more probable. Technology Foresight is ambitious. Ultimately, it is about creating a change in mindset regarding the way a country approaches the future.

1.2 Why Technology Foresight?

Global, national, regional and societal trends all influence the way we live and the way we do business. In the developed world, future competitiveness depends increasingly on goods and services which have a high 'knowledge content'. New technologies and people who can develop, apply and manage technology are the key to creating these more sophisticated products and businesses of the future and to improving the quality of life for the citizen.

Aligned to this are the increasing pressures on national Science, Technology and Innovation (STI) budgets, the increasing rate of change of technologies and the cost and risk of R&D activities. This means that Governments and business must concentrate available resources and focus on areas of strategic research to underpin important national sectors and areas of opportunity.

Governments and enterprises in the major industrialised countries have in recent years been trying to *formalise* their discussion of future prospects and current choices concerning science, technology, the economy and society, in order to assist them in prioritising their investments. Technology Foresight is widely recognised as a useful contributing activity to such discussions. It provides *one set* of useful inputs to the decision making process. It offers governments and firms a set of options, which can be the basis of strategic choices.

Two imperatives influenced the decision to undertake a Technology Foresight exercise in Ireland:

- Technology is a key driver for knowledge societies and will have wide ranging implications for the structure of society and the way we address economic, social and environmental goals
- The Government's strategic investments in research, science and technology must be used effectively to underpin Ireland's economic competitiveness and development as a knowledge society

[3] References see Appendix V

1.3 Technology Foresight Ireland

1.3.1 Developing the Approach

The economy of every country is unique and each Technology Foresight exercise and the results that arise from it are unique to the country in which the exercise takes place.

Japan and the US have been undertaking a range of 'futures research' activity for over 40 years. Germany, France, UK and the Netherlands have been doing so since the early 1990s. Austria and New Zealand are currently involved in Foresight projects. The Task Force, established by ICSTI to manage the initiative under Brian Sweeney, Deputy Chairman, ICSTI (Chairman, Siemens Ltd Ireland), drew extensively on the recent experience of the Netherlands, UK, Austria and New Zealand.

The Task Force developed an approach appropriate for a small country embarking on a Technology Foresight exercise for the first time. Building on 'best practice' elsewhere the Task Force determined that the Irish initiative should be in line with Ireland's size and economic structure and adopt a time frame to 2015. The process should be short, inclusive, consultative and consensual.

Technology Foresight Ireland was spearheaded by eight broadly based expert Panels established in March 1998. The Panels, chaired by ICSTI members, were composed of representatives from industry, the higher education sector, State agencies, research institutes and Government departments - essentially the 'stakeholders' - who were asked to consider the likely social, economic and market trends that would affect Ireland in the medium to long term and the developments required in science and technology to best address future needs.

The short timescale of 12 months adopted to complete the exercise recognised that the depth and detail normally associated with the outputs from a three to five year Foresight exercise could not be replicated in this first Irish exercise. But experience from elsewhere showed that the process itself in terms of consultation, consensus and commitment was in all cases of equal value to the outputs.

Each of the Panel areas was structured to cover a number of related activities and, thereby, to include a comprehensive cross-section of the entire economy.

The sector areas covered by the Technology Foresight Ireland exercise were:

- Chemicals and Pharmaceuticals
- Information and Communication Technologies
- Materials and Manufacturing Processes
- Health and Life Sciences
- Natural Resources (Agri-food, Marine, Forestry)
- Energy
- Transport and Logistics
- Construction and Infrastructure

The Technology Foresight Ireland initiative was jointly supported by the Office of Science and Technology, Department of Enterprise, Trade and Employment and Forfás.

1.3.2 The Value of the Technology Foresight Process

It was recognised that the quality and stature of the Panel members would significantly influence the outcomes of the Panel studies. The response from industry, the higher education sector, research institutes and the public sector to invitations to serve on the Panels was highly supportive, positive and enthusiastic. The participants made use of 'scenarios', or pictures of where future markets and technological opportunities might lie. Scenario-planning is a tool used in Technology Foresight exercises to test the strategies being proposed for each sector for their relative robustness in the face of any combination of future uncertainties. This approach ensured that robust and flexible strategic choices would be recommended for Ireland's technological development over the next 10 to 15 years. The use of scenario-building is an important feature of the Foresight process. It facilitates large companies, smaller enterprises, the public sector partners and researchers to break out of the constraints of thinking about the future based only on current experience and trends. The systematic process of Technology Foresight can, therefore, be of immense value in fostering a new *shared mindset* amongst the partners.

Half way through their work, the Panels publicly circulated the 'First View' (a preview of final reports) for their respective sectors. This formed the basis for numerous consultative workshops throughout the country and contributions were also invited through the press and the Technology Foresight Ireland web page. The consultation stage of the Foresight initiative is an integral and significant part of the process.

It builds consensus regarding the strategic choices being considered by each Panel and allows for a more broadly based input to the Panel's deliberations. It also ensures a quality and breadth to the debate about possible strategic choices and a strong commitment to the final outputs.

In total 180 people were directly involved as members of the eight Panels, with almost 60 per cent coming from industry. The extensive consultation phase involved a further 430 people in eight consultative workshops. Submissions were received from 115 organisations and individuals following press advertisements. The Foresight Web site recorded 3,000 visitors (66,000 hits) and over 150 contributions were registered. The level of commitment and the unstinting support for the process from the Panel members and wider public ensured that the results represent the combined wisdom and judgement of the most experienced and dedicated participants in the STI community in Ireland.

The Technology Foresight experience in other countries was that important benefits emerge from the exercise, such as better communication, interaction and mutual understanding between scientific communities, industry and Government departments. The Irish experience has been that the actual involvement in the intensive and interactive discussions about current problems and future scenarios and strategies has been of immense benefit to all participants, and will facilitate future co-operation and networking between them.

How Ireland meets technological challenges in the future must be part of national strategic planning over the medium term, involving the Government and the social partners. The Panel

reports indicate that Ireland's economic and social future will be strongly influenced by technology and, therefore, that investment in the areas recommended by these reports will

have a crucial influence on future industrial competitiveness, the quality of jobs and living standards in Ireland. This investment will also strongly influence the opportunities to develop indigenous industry and to attract overseas industry.

Technology Foresight does not forecast the future but the process can ensure that the startegic choices made now regarding the prioritisation of national S&T expenditure are 'future proofed'.

2. Findings from Technology Foresight Ireland

2.1 ICSTI Recommendations

- **ICSTI endorses the findings contained in the eight Technology Foresight Panel reports**

  For the Technology Foresight process to be a success the findings and recommendations must inform the key players in the private and public sectors

- **Government should request all its departments and agencies to fully utilise the findings of the Technology Foresight Panel reports in all future and operational matters**

2.2 Summaries of Panel Reports

Summaries of the findings of the eight Technology Foresight Panels are set out in the following pages. The summaries highlight the key technologies influencing the development of the sectors and the Panels' recommendations regarding actions needed to improve Ireland's ability to anticipate or benefit from whatever technological developments that may occur in the time horizon to 2015. In order to understand the full context of the recommendations the reader should refer to each specific Panel report.

The recommendations concern technological and related matters and are a mix of the long term and short term actions required. Some recommendations are for consideration by individual Government departments, agencies, other public and private sector bodies or by the sector itself.

Chemical and Pharmaceutical Panel Summary

Recommendations

- Establish a new Rapid Response Regulation strategy to ensure that Ireland is the most favourable location in the world in which to meet the properly stringent national and international regulatory requirements for the industry
- Introduce a research voucher (tax credit) scheme to enable firms to purchase strategic or applied research in designated Centres of Excellence or in universities and colleges (the Techmart scheme)
- Enterprise Ireland to make nurturing the growth of the indigenous chemical and pharmaceutical sector among its highest priorities (the Home Grown strategy)
- Introduce a co-ordinated awareness campaign to increase the level of understanding of the career opportunities in the chemical/pharmaceutical industry (the Hearts and Minds strategy).

Strategic Technologies

- Advanced conventional and biological synthesis
- Advanced formulation/delivery and packaging systems
- Flexible, clean and efficient processes
- Process automation and monitoring
- Information and Communications Technologies to manage the regulatory and customer Interfaces.

Enabling Policies/Mechanisms

- The Department of Environment and Local Government to establish a task force, including representatives of the relevant State agencies and the sector, to ensure that the Rapid Response Regulation strategy is enacted. It is a strongly held view of the sector that this strategy, requiring relatively small expenditure, has the potential to secure a very significant competitive advantage for Ireland
- The Department of Finance to make tax code changes to introduce the research voucher concept
- Establish centres of excellence in the following five strategic technology areas:
    - Advanced conventional and biological synthesis
    - Advanced formulation/delivery and packaging systems
    - Flexible, clean and efficient processes
    - Process automation and monitoring
    - ICTs to manage the regulatory and customer interfaces.
- Ensure third level departments which are responsive to the needs of the sector attain the highest standards in teaching and fundamental research by permitting the HEA to match the spend by the sector in those departments
- Enterprise Ireland to establish an advisory group made up of members from the sector to advise it on implementing the measures contained in the Home Grown strategy
- The sector to fund from its own resources, by an agreed contribution from the members of the sector, a nationally co-ordinated programme to implement the Hearts and Minds strategy. The Institute of Chemistry of Ireland, the sector's professional body, to act immediately to initiate this process.

Information and Communications Technology Panel Summary

Recommendations

As the pace of technological change in this area is so rapid, the recommendations focus on empowering the best people, encouraging a 'fast follower' mentality and ensuring that all citizens have the skills necessary to participate fully in the information and knowledge society.

- Introduce change at all educational levels to foster creativity and imagination from an early age, to improve the teaching of science and mathematics at all levels, and to generate a commitment by all to life-long learning
- Generate a critical mass of world class research and output in topics which are in the forefront of research at any given time. The best individual researchers will require support to establish this critical mass. Industry-Higher Education consortia should identify the relevant research topics on a regular basis
- To develop world class capabilities requires the best professional researchers encouraged by a visionary environment, with the necessary financial rewards and properly resourced with equipment and support staff.

Strategic Technologies

Areas of strategic importance, in the short term, and their technology drivers, include:

- **Networks:** high-speed, broadband, wireless, mobile; voice/data convergence; DSP; network management; switching (e.g. photonic); Internet 2
- **Systems**:distributed, parallel; engineering for reliability, predictability and security
- **Components:** integration, miniaturisation, low power consumption; novel architectures
- **User Interfaces:** multi-sensory, wearable, virtual reality; artificial intelligence; human language understanding and synthesis
- **Applications**: information access, retrieval, analysis, filtering and management; best practice in exploitation and delivery; bioinformatics; simulation and modelling; telemedicine and health informatics; distributed working; supply chain management; computer-based training.

Enabling Policies/Mechanisms

- Establishment of a Centre for Advanced Informatics. In addition, build on the existing strengths in the National Microelectronics Research Centre in a number of key areas
- Ensure more aggressive venture capital that drives rates of growth in Irish companies comparable to that of the leaders in the field
- Investment in the telecommunications infrastructure to make Ireland a 'wired country'
- Explore the opportunities to involve Irish people working abroad (the 'diaspora'), particularly in the US, in building an innovation structure around ICT
- Develop more systematic ways for obtaining and disseminating market intelligence on those areas of technology which are showing good commercial potential around the world.

Materials and Manufacturing Processes Panel Summary

Recommendations

- Manufacturing companies should develop a high value-added capability in materials-based products and related services coupled with the ability to use virtual manufacturing
- Industrial research and development spend in the sector must be increased. Additional tax incentives are needed to raise fiscal support for R&D to the levels experienced in our peer countries
- Further develop 'green' manufacturing knowledge and processes where appropriate
- World class centres of excellence in design, materials applications and related engineering competencies should be developed for the outsourcing of research by industry
- There is a need to develop a multidisciplinary approach to research and development based on the core engineering sciences. This needs to ensure that team building, communication, innovation and creativity are instilled in students throughout the entire educational system from primary, through secondary and up to tertiary level
- The Programmes in Advanced Technologies (PATs) should be refined and developed in strategic areas, such as materials and advanced manufacturing technologies, to help the implementation of these recommendations

Strategic Technologies

- Design with new and advanced materials, including bio-materials, smart materials and reusable/renewable materials
- Processing/fabrication of new and advanced materials
- Integration and miniaturisation technologies
- Exploitation of ICT, telematics and logistics, together with associated social and behavioural sciences, in order to facilitate the development of virtual enterprises

Enabling Policies/Mechanisms

- Manufacturing companies and their suppliers to invest in information and communications technologies and move towards products and services that add value
- Improve linkages between industry and third level. Industry should develop relationships with the centres of excellence in R&D and with centres of expertise in the third level sector such as the Programmes in Advanced Technologies (PATs)
- Strengthen and focus the relevant PATs to enable them to respond to the Foresight recommendations and identify areas outside of existing expertise which need to be addressed
- Ensure that industry has the appropriate long term 'green' strategy
- Introduce product design and 'green' industrial design courses at third level
- Provide focused advice on the legislative requirements for, and assistance and incentives to companies to move towards, 'green' manufacturing
- Attract product design companies to set up in Ireland and increase the expertise available in this field
- Industrial development agencies should use effective R&D and innovation strategies as a major indicator of success justifying further support.

Health and Life Sciences Panel Summary

Recommendations

- Ireland will need to invest even further in its greatest asset, that is, its population of young and well educated people, and it will need to attract the talented members of the Irish diaspora, if it is to maximise the benefits from knowledge-based industries in the coming decades
- The health and life sciences sector, which includes pharmaceuticals and healthcare, chemicals, food and drink, agriculture, forestry and fisheries, and environmental management, accounts for more than IR£10 billion of exports (more than 30 per cent of the total) and employs more than 50,000 people. For these and other reasons (e.g. tourism) Ireland is, more than most countries, a 'biological economy'
- A single complex technology, Biotechnology, is radically influencing the global development of the health and life science industries. It is predicted that the market for these industries will rise from e40 billion in 1995 to e250 billion by the year 2005 and support in the region of three million jobs in Europe. Ireland is very well placed to participate in the biotechnology revolution
- The impact of biotechnology is most obvious in pharmaceuticals, chemicals, agriculture and food. The Irish pharmaceutical industry is a vital national asset. It is dominated by multinationals and links Ireland to the international pharmaceutical industry, the industry which has led the biotechnology revolution. Nine of the top ten multinational pharmaceutical companies have major manufacturing operations in Ireland. Ireland must adapt to biotechnology as biotechnology revolutionises the global biological economy, especially the pharmaceutical, chemical and agrifood sectors
- The Irish Government should immediately invest, on a realistic scale, in a co-ordinated biotechnology programme to establish strong links between the third level colleges and industry, agriculture and the financial and services sectors. Significant components of Irish industry and agriculture will be moved up the value chain by exploiting world class R&D, much of it led by scientists and technologists recruited back to Ireland from the Irish diaspora. A world class biotechnology infrastructure, strongly rooted in Irish brain power, can and should be created in Ireland by reforming and developing the current system (pioneered by BioResearch Ireland with limited resources). The new infrastructure will ensure that world class research is carried out by world class biotechnologists and will lay the basis for Biotechnology Clustering in Ireland. If this programme is not established, Ireland will not only fail to benefit from the new biotechnology in terms of a large number of new, high quality, high added value jobs, but many existing jobs in the pharmaceutical and chemical industries, the food and drink industries and in agriculture will be jeopardised.

Strategic Technologies

- Genomics
- DNA chips, biomaterials
- Bioinformatics
- Proteomics
- Gene Chip Technology
- Knockouts & Transgenics
- Robotics
- Biosensors
- Bio-remediation

- Novel Instrumentation Technology
- Drug Delivery
- New Diagnostics

Enabling Policies/Mechanisms

The new 'Irish Biotechnology Investment Programme' requires five related strategic sub-programmes to take research from the laboratory to the market:

Irish Biotechnology Investment Programme	
Sub-Programme	**Outputs**
Biotechnology R&D Programme	Knowledge; Technology Expertise; Invention; Innovation Services; Exports; 400 biotechnologists per year
Biotechnology Translational Programme (Patenting)	Development; Patenting; Entrepreneurs
Biotechnology Start-Up Programme (Venture Capital)	50 Indigenous start up companies in 15 years; products and services
Biotechnology Inward Investment Programme (IDA Ireland)	Multinational company R&D; new 'lead' biotechnology companies
National Biotechnology Conversation	Public awareness and understanding of the role and contribution of biotechnology to socio-economic development

Natural Resources Panel Summary

The Science and Technology Foresight Report on Natural Resources covers the following three sectors:

- Agri-Food Industry
- Marine Industry
- Forestry Industry
- There is a growing need to build up the core competencies required to ensure:

- Ireland's future competitiveness in agricultural production and in the manufacture of innovative food products that meet increasingly exacting consumer requirements
- the sustainable exploration, exploitation and management of the marine resources
- the competitive production of wood and non-wood products from Irish forests together with the economic, environmental and social sustainability of the national forest estate.

With the objective of putting in place the necessary core competencies the Natural Resources Panel recommends that immediate priority be given to developing the following strategic technologies and enabling policies/mechanisms.

Agri-Food Industry

Strategic Technologies

- Agricultural production and food processing technologies and systems that meet consumer demands for guaranteed food safety, assured freshness and consistent quality. Such technologies include: ingredient technology; food microstructure, flavour and quality; minimal processing technologies; pathogen control systems, including risk analysis methodologies; high pressure technology; food irradiation; robotics and information technology
- Economically competitive and environmentally sustainable farm production and food processing technologies and systems, including reduced input farming systems; waste reduction and management technologies; environmental modelling; risk assessment methodologies and information technology
- The capacity to monitor, evaluate and harness appropriate developments in biotechnology in crops and livestock production and food processing, including: diagnostics; genetic and breeding technologies; environmental impact assessment and risk analysis methodologies
- Market intelligence involving the development of consumer behavioural models to project food demands.

Enabling Policies/Mechanisms

To establish **durable** national capabilities with the necessary critical mass in these rapidly developing technologies, the Panel recommends that the following enabling policies/mechanisms be put in place:

- There is a critical need for a national manpower programme for science and technology, including a professional career structure for researchers and mechanisms to ensure more effective research training and greater mobility of researchers

- Establishment of centres of excellence with the necessary critical mass of the next generation of scientists and technologists in areas of vital strategic importance, including biotechnology
- Grants and tax incentives for the agri-food industry need to be directed more to building the core strategic, management, marketing, scientific/technological and innovative capabilities, both in-company and through joint ventures between industry and public research and educational institutions
- Arrangements need to be put in place to ensure greater industry 'ownership' of public research programmes, with particular regard to co-operative priority-setting, more effective inter-institutional collaborative research programmes and securing a satisfactory return on investment
- Product development research should be undertaken by private companies, while public research programmes should concentrate on technology development and public good issues.

Marine Industry

Strategic Technologies

While highlighting the broad range of technologies necessary to support the development of the marine industry, the Panel recommends that priority be given to building up the following strategic technologies:

- Food processing, including food safety and quality technologies and the application of biotechnology
- Information technology, including remote sensing, geographical information systems (GIS), modelling/forecasting and data management
- Biotechnology, including disease detection and management, bio-screening of marine organisms for bio-active products and food processing
- Sustainable harvesting and production systems, including cleaner production technologies, fish-finding technology, net design and manufacture, cage and tank design
- Sensor development, including materials technology, instrumentation development and anti-fouling techniques
- Wave energy, including power take-off and control, and structural design and mooring
- Maritime transport, including inter-modal management.

Enabling Policies/Mechanisms

To establish **durable** national capabilities with the necessary critical mass in these rapidly developing technologies, the Panel recommends that the following enabling policies/mechanisms be put in place:

- The implementation of appropriate mechanisms to support critical mass, to maintain international competitiveness and to underpin continuity (at least in the medium term) of established and required cores of expertise
- Support for targeted education, training, R&D and support infrastructure

- The development of efficient mechanisms for technology transfer, leading to increased R&D applications/uptake in SMEs and more effective industry-research institute co-operation.

Forestry Industry

Strategic Technologies

To ensure the competitive production of wood and non-wood products from Irish forests and the economic, environmental and social sustainability of the national forest estate, the Panel recommends that priority be given to building up the following strategic technologies:

- Wood science, materials science and applied engineering skills
- Genetic and other biotechnologies to improve the properties of Irish timber
- Information technology and communication skills
- Environmental management skills
- Planning and appraisal models
- Advanced marketing capabilities and skills.

Enabling Policies/Mechanisms

To establish **durable** national capabilities with the necessary critical mass in these rapidly developing technologies, the Panel recommends that the following enabling policies/mechanisms be put in place:

- The consolidation of a management and co-ordinating mechanism for the application of R&D
- The development of education modules and information systems to promote awareness and skills, in the use of wood, among architects and engineers
- Investment in information technology to provide and enable effective technology transfer.

Common Strategic Technologies - Agri Food, Marine and Forestry Industries

- Capacity to monitor, evaluate and harness advances in biotechnology
- Production and processing technologies and systems that meet ever exacting consumer demands
- Competitive and sustainable production and processing technologies and systems
- Information technology and communication skills.

Enabling Policies/Mechanisms

To establish **durable** national capabilities with the necessary critical mass in these rapidly developing technologies, the Panel recommends that the following enabling policies/mechanisms be put in place:

- A national manpower programme to address the following issues:
    - building a science and technology capacity to underpin developments in the agri-food, marine and forestry industries
    - providing a professional career structure for researchers
    - ensuring mobility of science and technology personnel within and between the public and private sectors
- Centres of Excellence, involving both the public and private sectors, and with the critical mass of scientists and technologists
- More effective mechanisms for technology transfer, both in terms of R&D adaptation and transfer to end users.

Energy Panel Summary

Recommendations

- Establishment of an energy research, development and demonstration programme which is well resourced, clearly defined and of finite duration. This programme should focus on the identified key technologies.

Strategic Technologies

Technologies I and II are new technologies. Ireland has existing strengths in these technologies and for strategic energy and commercial reasons they must be developed and exploited. Technologies III and IV are existing technologies whose enhanced uptake will address some of Ireland's commitment under the Kyoto Protocol.

Technology I

New and renewable energy technologies for the electricity, thermal and transport markets, especially wave energy, hybrid energy systems, energy storage systems and alternative, environmentally friendly transport systems.

Enabling Policies

- Prepare, resource and implement a multi-annual national research, development and demonstration programme for new and renewable energy technologies
- Encourage the construction of new and renewable energy systems through an expanded renewable energy development programme and through fiscal incentives for investment in new and renewable energy technologies, skills and R&D
- Establish and support an energy emissions trading exchange. Develop validation, certification, trading and settlement systems

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Technology II

Intelligent consumer energy products

Enabling Policies

- Provide support and incentives for integration of information technology and energy services, and for new product development
- Support the development of indigenous enterprise to exploit progress on crossover technologies
- Incorporate modules on energy enterprise and technical skills into the education and vocational training systems

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Technology III

Energy efficient and renewable energy technologies in buildings.

Enabling Policies

- Revise building regulations on energy efficiency to international standard-setting levels
- Initiate a retro-fit programme for the socially disadvantaged

- Introduce personal tax relief for energy conservation activities
- Research energy use and conservation potential in buildings in the Irish environment
- Encourage the education and training sectors to act as enablers of an energy culture, through the incorporation of energy in their curricula and services' portfolios
- Ensure maximum uptake of the tax relief opportunities available for investment in solar energy technologies under the Finance Act, 1998

Technology IV

Optimise the sourcing, distribution and utilisation of energy at all levels of energy consumption.

Enabling Policies

- National coverage for the natural gas network including extension to the western seaboard to support offshore gas finds
- Upgrade the electricity infrastructure
- The liberalisation of the Irish electricity and natural gas markets must be expedited and must occur in tandem
- Industrial planning at all levels must include integrated energy planning
- Secure the early adoption and use of advanced energy technologies by enterprise through the provision of appropriate support systems
- Evaluate CHP (Combined Heat and Power) viability in all new buildings

Enabling Mechanisms

- Collaboration between Government, enterprise, State agencies, education, training and research institutions, energy suppliers and international energy players
- The Minister for Public Enterprise convene an Action Panel to secure implementation of the recommendations and report to the Government on the matter
- A fully costed, clearly defined implementation programme be designed
- The recommendations of the report be integrated into the policy and strategy statements of the relevant Government departments and State agencies.

Transport and Logistics Panel Summary

Recommendations

- Introduce greater strategic co-ordination into the whole of the Transport and Logistics sectors. Responsibility for road, sea, air and rail transport in all their aspects should be centralised in one Government department
- Integrate national/regional planning powers to one national authority
- Undertake more research into all aspects of transport and logistics - technical, economic and social
- Promote Ireland as an international centre of excellence for transport and logistics systems
- Begin planning now for the problems of urban congestion by 2015
- Establish a forum for debating and discussing issues critical to the development of the Transport and Logistics sectors.

Strategic Technologies

- Intermodality of transport systems
- Telematics for transport systems
- Road design and maintenance technology
- Demand management
- Land use development

Enabling Policies/Mechanisms

- Appointment of a Minister for Transport, incorporating Logistics
- Establish a Government/Business Forum for National Transport and Logistics
- The Transport and Logistics industry to establish an umbrella body to discuss all issues critical to the development of the sector
- Ensure that at least one global player in transport and logistics systems establish its European operations centre in Ireland.

Construction and Infrastructure Panel Summary

Recommendations

- **Change the Culture of Construction:**
  Change the external and internal perception, culture and practices of construction and infrastructure such that they are more appropriate to their national and European role
- **Information and Communication Technology:**
  Introduce customised and integrated information technology throughout the construction process
- **Science, Technology and Innovation Centre:**
  Establish a permanent centre/focus for access and transfer of new and best practice technologies, with a strong element of industrial ownership
- **Improve Competitiveness:**
  Improve competitiveness of the process so that customer and society's expectations for efficiency, quality, performance and life-cycle value are satisfied
- **Increase Tradeability:**
  Develop and sustain the tradeability of knowledge based and niche elements of construction
- **Sustainable Development:**
  Progressively improve the contribution to the inherent sustainability of the construction process and the built environment. Develop associated technologies, skills and practices
- **Materials Technology:**
  Track and optimise the benefits to construction and infrastructure from advances in materials technology.

Strategic Technologies

There are issues and forces that are technology driven and those that are technology dependent. The technology driven are:

- The potential of ICT to influence and change the way the construction industry will be structured and operate in 2015 and the type of infrastructure it will be producing
- Developments in materials technology will have the potential for a new generation of smart materials and components based on new sciences such as biotechnology
- Developments in manufacturing technology will stimulate prefabrication, use of robotics, mechanisation and tool technology

The technology dependent forces are:

- The sustainability of the construction process and of the built environment
- The health, safety and environmental friendliness of the process
- The increasing competitiveness of the industry

Enabling Policies/Mechanisms

These policies/mechanisms are grouped under economic, operational, social and technological. Significant examples are as follows:

Economic: Provide for the consequences of reduced growth rates between now and 2015 and for the replacement of EU Structural Funds with private finance as envisaged in the Public Private Partnership. In view of the mobility of capital for infrastructural projects provision of a more efficient planning and regulatory process is necessary.

Operational: An attitude of excellence and quality must be fostered throughout the process and the progressive integration of the various participants will contribute to this policy. Higher standards of quality and consumer protection will require registration of the principal participants. Continuing education and life long learning will be necessary ingredients.

Social: Insufficient appreciation of the role of construction in underpinning social and economic life needs correction. The provision of affordable housing, particularly in urban centres, is urgently needed together with an efficient public transport system. Employment conditions and a career framework need to be improved to attract better qualified personnel into the industry.

Technological: Extend the status that currently applies to manufacturing industry to the wider construction industry in terms of grant aid and research and development assistance.

Support the implementation of the recommendations of the Strategic Review of the Construction Industry. Give priority to opening a dialogue with the Department of the Environment and Local Government and the Forum for the Construction Industry.

2.3 Key Strategic Technologies

The following section presents, in matrix format, an overview of the strategic technologies, underpinning the industrial sectors represented by the eight Technology Foresight Panels.

Strategic Technologies – Examples Identified by the Panels	
Panels	**Strategic Technologies**
Chemicals and Pharmaceuticals	**Advanced, conventional and biological synthesis** including enantioselective synthesis, microbial transformations, biocatalysis. **Advanced formulation/delivery and packaging systems** including smart drug delivery technologies to improve compliance and therapeutic benefits for patients, use of smart packaging for speciality chemicals to permit safe and efficient use by the customer and safe and efficient disposal. **Flexible, clean and efficient processes** including novel manufacturing technologies to exploit renewable feedstocks and minimise energy usage, waste and flexible process technologies that can be rapidly re-engineered for product localisation. **Process automation and monitoring** including use of process control sensors to build quality into the manufacturing process, thereby improving regulatory compliance and reducing costs. **ICTs to manage the regulatory and customer interfaces** including use of ICT to affect real-time interactive regulation and to reduce time to market without lowering of regulatory standards; use of ICT to establish a long term/life-long relationship between the GP and patient and to provide specifically tailored health care programmes.
Information & Communication Technologies (ICT)	**Networks:** High-speed, broadband, wireless, mobile; voice-data convergence; digital signal processing (DSP); network management; switching (e.g. photonic); Internet 2. **Systems:** Distributed, parallel; engineering for reliability, predictability and security. **Components:** integration, miniaturisation, low-power consumption; novel architectures. **User Interfaces:**Multi-sensory, wearable; virtual reality; artificial intelligence; human language understanding and synthesis. **Applications**: Best practice in exploitation and delivery; bioinformatics, telemedicine, health informatics; simulation and modelling; distributed working; supply chain management.
Materials & Manufacturing Processes	**Design with new and advanced materials** including bio-materials, smart materials and reusable/renewable materials. Examples include increased use of aluminium in cars, improved design, drug delivery systems activated by pH/temperature etc.

Materials & Manufacturing Processes cont'd	**Processing/fabrication of new and advanced materials** including exotic metals to prevent corrosion in chemical industry, new polymers to prevent contamination in food/healthcare sector, repair of turbines for aircraft. **Integration and miniaturisation technologies** including digital cameras - electronics and materials for the manufacture of screen-integrated circuits, medical devices, sensors. **Exploitation of ICT and logistics,** together with associated social and behavioural sciences, in order to facilitate the development of virtual enterprises.
Health & Life Sciences	**Biotechnologies,** affecting biomedical science, agriculture, fisheries, forestry, food, environmental regulation and management, instrumentation, information technology: Genomics, New Diagnostics, Gene chip technology, Drug Delivery, Bioinformatics, Biosensors, Knockouts & transgenics, Biomaterials, Combinatorial chemistry, Bioremediation Robotics, Proteomics, Novel Instrumentation technology.
Natural Resources	**Agri Food Industry** **Food Safety, Quality Production and Processing Systems** including ingredient technology; food micro-structure, flavour and quality; minimal processing technologies; pathogen control systems including risk analysis methodologies; high pressure technology; food irradiation; robotics, information technology. **Sustainable and Competitive Production and Processing Systems** including reduced input farming systems, waste reduction and management technologies, environmental modelling, risk analysis methodologies, information technology. **Application of Biotechnology in Crops, Animal Production and Food Processing** including diagnostics, genetic and breeding technologies, environmental impact assessment, risk analysis methodologies. **Market Intelligence** involving the development of consumer behavioural models to project future food demands. **Marine Industry** **Food Processing** including food safety and quality technologies, biotechnology. **Information Technology** including remote sensing and modelling/forecasting, data management. **Biotechnology** including disease detection, bio-screening marine organism, food processing (as above).

Natural Resources cont'd	**Sustainable Harvesting and Production Systems** including fish finding technologies, net design and manufacture, cage and tank design, clean production technologies. **Sensor Development** including materials technology, instrumentation development, anti-fouling techniques. **Wave Energy** including power take-off and control, structural design and mooring. **Marine Transport** including intermodal management. **Forestry** **Production of Competitive Wood and Non-Wood Products** including wood/material science, applied engineering, genetic and other technologies, information technology, communication skills. **Sustainable Forestry Development** including environmental management systems, planning and appraisal models, information technology. **Advanced Marketing Capabilities** including information technology systems.
Energy	**Use of new and renewable energy sources** including ocean wave technology, hybrid energy systems, energy storage systems, alternative environmentally friendly transport systems such as fuel cells. **Intelligent consumer energy products** including photosensitive lighting technology, motion and heat detector technologies, technologies to produce the intelligent home of tomorrow. **Energy efficiency and renewable energy technologies in buildings** including passive and active solar heating systems, daylighting systems, natural cooling systems, building management systems. **Technologies aimed at optimising the sourcing, distribution and utilisation of energy** including co-generation technology, condensing boilers, variable speed drivers, energy efficient lighting, heat pumps, combined heat and power (CHP).
Transport & Logistics	**Intermodality of Transport Systems** including research into the development of models for the sharing of space in all modes of transportation of people and goods. **Road Maintenance Technology** including research into materials and design for improved performance. **Demand Management of all modes of Transportation** including research into real-time optimisation systems for the transport of people and goods.

Transport & Logistics cont'd	**Telematics Technology** for advanced traveller information and transport systems such as route guidance, vehicle tracking, intelligent transport systems (ITS). **Land Use Development** including research into both social and environmental dimensions such as service and transport demands.
Construction & Infrastructure	**Use of ICT** throughout the construction process including developing customised electronic data interchange (EDI), customised capability for planning, architectural and engineering design including the use of virtual reality, customised systems for project cost management, customised systems for contracting. **Developments in materials technology** including smart multi-functional materials (e.g. multi functional façade elements), components based on new sciences such as biotechnology supported by IT. **Developments in manufacturing technology** including prefabrication technology, use of robotics, mechanisation, tool technology. **Sustainability of the construction process by use of technologies** including low energy consumption technology, waste management and disposal technologies, recycling and deconstruction technologies, repair, maintenance and restoration technologies.

Note: This is not an exhaustive table of the strategic/emerging technologies as identified by the Panels. It is necessary to refer to the Panel reports for a complete listing.

3. Building on Technology Foresight Ireland - an ICSTI Overview

3.1 Introduction

The Technology Foresight Panel reports contain recommendations on the areas in which Ireland should develop its technological capabilities to prepare for the challenges ahead. By definition they are a contribution to future planning by public and private sector organisations. However, the work of the Panels also points to the need for a wider vision of how Ireland should develop as a knowledge-based society in the coming decade. Indeed, without such a vision, and the policies to achieve it, the recommendations of the individual panels will have a sub-optimal impact on our national development.

3.2 Ireland: A Vision of Technological Excellence

ICSTI's vision of the knowledge-driven Ireland in 2015 is of an economy founded on high value-added products and services and a society supportive of the benefits of scientific and technological developments.

Ireland in 2015: The Knowledge Society
• **A significant proportion of industry has become technology-based, and robust in the face of international market developments**
• **An export trade in R&D and technology services in certain niches has developed**
• **Ireland has developed a substantial number of large and small indigenous technology companies that are internationally competitive**
• **Ireland has become a sought after location for advanced technology firms to perform R&D, interact with the Irish STI system and produce and export innovative goods and services**
• **Industry, universities, colleges and State institutes constitute a vibrant research partnership, particularly in the key enabling technologies**
• **Access to the best international knowledge has become widespread, as has collaboration with the research base in Europe and the US especially through the diaspora**
• **The Irish labour market can now meet the high tech expertise needs of the productive sectors**
• **Higher standards of living are being enjoyed by ever increasing numbers of people**
• **Irish researchers have become world renowned in niche technological areas**
• **Attractive employment opportunities now exist for researchers in science and engineering disciplines; and leading Irish researchers around the world have been encouraged to return**
• **Venture capital has become more widely available to technological innovators**
• **Ireland's infrastructure, particularly in telecommunications and transport, has come into line with the needs of an advanced technology economy**
• **Irish society has become fully aware of the economic and societal benefits of scientific and technological development**

3.3 Overview: The Current Industrial Environment

Ireland has built a strong reputation as a location for high quality manufacturing and internationally traded services. This has been achieved because of a mix of attractive fiscal arrangements, a plentiful supply of skilled and adaptable labour, the recent emergence of technology entrepreneurs, English as the main spoken language and access to European markets.

However, the underlying base driving output and exports is quite narrow and the long term performance of industry in Ireland continues to be hampered by a weak commitment to technological innovation. Exports grew from IR£15 billion in 1991 to IR£46 billion in 1998. Half of our exports are accounted for by 50 companies, of which only 13 do any research and development.

In terms of technological capabilities, companies can be described as belonging to one of four different types[4], namely:

- Research performers operating with a specific R&D budget and typically having a formal R&D department
- Technological competents performing some element of product and process development
- Minimum capability companies adopting and implementing package solutions
- Low technology companies with no meaningful technological capability

Most companies in Ireland fall into the lower two categories. In fact, there are only 500 from a total of 4,000 companies in manufacturing and internationally traded services (with >10 employees) in the country which can be described as ‘research performers’ spending at least IR£100,000 per annum on R&D. Even within that group, the top 50 R&D spending companies – those spending a minimum of IR£1 million each per annum on R&D – account for two thirds of business sector R&D activity. Only one in five foreign owned companies can be described as a ‘research performer’.

R&D, as a percentage of sales, trails behind other countries, particularly in high-tech sectors such as pharmaceuticals and office and computing machinery. Indigenous industry needs to build on national strengths in software and electronics and transform its approach to innovation. There is a low level of patenting by Irish-based companies in general and particularly in the US market.

Irish industry must position itself higher up the economic chain in terms of the innovation, including R&D, and the value it adds to the products and services exported. This competitiveness shift is necessitated by the globalisation of markets and firms, the challenges faced by traditional cost-based industries, economic and monetary union, the progress towards greater tax harmonisation in Europe, and improving quality of labour supply and more cost effective manufacturing and exporting systems, particularly in Eastern Europe. The repositioning will also have to be underpinned by Government policy action in related areas as set out in the following section.

[4] 'Staircase' model presented by the Tierney report 'Making Knowledge Work for Us'.

3.4 Critical Success Factors and the Policies to be Pursued

A strong culture of innovation is an essential source of industrial competitiveness. Ireland must constantly seek to improve the capability and performance of its industrial base to cope with increasing global technology-based competition. To do this, Ireland will have to put in place a durable science and technology infrastructure which will create new, technology-based indigenous firms, establish an internationally competitive research base in universities, colleges and institutes, attract the R&D activities of MNEs to locate in Ireland and provide the physical infrastructure and environment to promote innovation. A number of issues transcend the sectoral concerns outlined in the Foresight Panel reports; they are common to all or a wide span of the Panel reports, and have been identified by ICSTI as being central to Ireland's future success and will require action from Government in the associated policy areas.

3.4.1 Human Capital

To achieve the vision described in Section 3.2, and to ensure that the Foresight Panel recommendations are capable of being fully implemented, Ireland needs to develop a population characterised as follows:

The Population in 2015
• **Well educated across a range of disciplines and comfortable with science**
• **A broad base of numerate citizens**
• **Entrepreneurial and adaptable, including a basic technical competence**
• **Cross-disciplinary capabilities, including environmental understanding**
• **Innovation management capability**
• **Professionals with high-level specialities**
• **World class R&D expertise in companies and research centres**

A high skill base is an essential foundation for the knowledge-based economy. This means investment in people and science in primary, secondary and third level education and subsequently in the workplace through continuous professional development in the context of a 'life-long learning' approach. Flexible, highly trained and technically capable staff is a key component of agile, competitive and successful companies. The Irish workforce must in future be able to balance traditional literary and verbal skills with an equal competence in science and technology.

Science and technology subjects must be an integral part of the curriculum at all levels from primary through to third level. At primary level, ICSTI in a recent Statement has welcomed the new science curriculum and wishes to see its implementation speeded up. Pupils should have a good grounding in maths at primary level and most pupils should acquire an ability in physics and chemistry at second level. In recent years, there has been a decline in the number of second level pupils (mostly male) studying the basic sciences. Pressures in relation to subject, college and career choices, compounded by examination and assessment policies as well as inadequate teaching resources, have militated against science.

The falling numbers taking physics and chemistry is potentially the biggest long term threat to Ireland's ability to develop as a knowledge-based society.

STI-related education at third level is now starting to respond well to the demands of the economy, providing the necessary numbers of well rounded and suitably qualified individuals, notably in sectors such as electronics, software and pharmaceuticals.

However, there is a fourth level, involving world class research and technology development capabilities, which is seriously deficient. The low levels of funding for research in the third level sector, the absence of real career opportunities in research, the pressure on universities and colleges to accommodate increased undergraduate numbers during the last decade have all impeded the development of this fourth level.

ICSTI Recommendations

- **The Department of Education and Science should press ahead quickly with the introduction of the primary school science curriculum.**
- **The Department of Education and Science should continue to benchmark the performance of Irish school children in mathematics and science against international norms with the objective of positioning Ireland in the top quartile in any such exercise.**
- **The Department of Education and Science should establish a specialised 'Centre for the Teaching of Science' to support the teaching of science at second level.**
- **The Department of Education and Science should build on its recent third level research initiative[5] which aims to develop and enhance the research capacity in the higher education sector.**

In order to provide a cohort of STI personnel to support Ireland's future prosperity, the education system must prepare now. The strongly inter-dependent education levels should emphasise the STI related elements illustrated on the next diagram.

The Department of Education and Science's recently announced Programme for Research in third level institutions provides necessary capital investment in research facilities and encourages a more focused approach to research in the universities and colleges. This initiative is strongly welcomed. To complement this important initiative, it is now necessary to develop a national focus on technology areas of strategic importance. A quantum leap is required in our approach to investment in strategic technology areas. Proposals to put in place a layer of world class researchers in key strategic technologies are addressed in the following sections.

[5] Allied to the recommendations above, ICSTI will be making a separate Statement on the issues surrounding the selection of science subjects and the teaching of science in schools.

3.4.2 World Class in Strategic Technologies

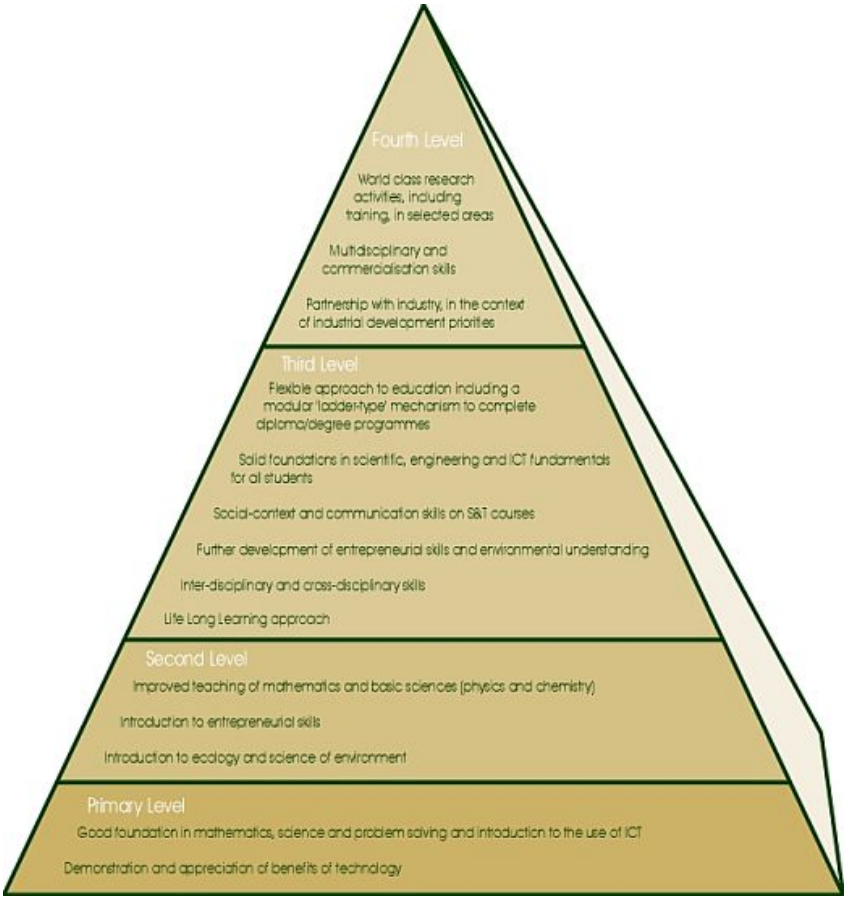
There are two strategic technology areas where a significantly strengthened national capability would contribute to improved innovation across all sectors of the economy: information and communication technologies (ICT) and biotechnology.

a. Information and Communications Technologies

Capabilities in information and communication technologies must be developed in order that Irish society can participate in economic, cultural and educational activities and that Irish business can take advantage of the opportunities arising in this field.

Information and communication technologies impact on society and the economy in a number of different ways:

STI Emphasis in Education and Training



- ICT is an underlying and necessary technology for society in general and for business in particular. For example, in the US at present, equipment used for processing and transmitting information amounts to 12 per cent of the capital stock. This is about the same proportion as the railroads represented at their peak during the late nineteenth century[6]. All of the Foresight Panels referred to the contribution which ICT was expected to make to their sectors

[6] National Co-ordination Office for Computing, Arlington, USA.

- ICT also functions as an enabler/facilitator for industry, for example, in electronic commerce, logistics and telematics
- Looking outward, organisations will increasingly use ICT to link their stock of tacit knowledge to that of other organisations so as to develop cross-discipline solutions in areas of emergent need e.g. in bio-informatics, smart products, supply chain management
- In recent times the ICT sector has been the engine of growth for all developed countries. Ireland has been particularly successful in this area both in attracting foreign direct investment and in developing a select number of companies with a global reach. Currently 40 per cent of all Irish exports come from the ICT sector and employment in this sector is forecast to double by 2003

If Ireland is to compete in an era of rapid development of ICT products and services, appropriate state-of-the-art infrastructure must be put in place. Furthermore, if Ireland is to fully meet the future societal and economic challenges posed by the rapid developments in ICT, a number of general capabilities will be required.

ICT by 2015: General Capability Requirements

- **General computer and IT competence from an early age**
- **A top cadre of computer graduates and research expertise**
- **Cross-disciplinary and multidisciplinary skills (e.g. computing/biotechnology/management)**
- **Systems modelling skills**

Raising the levels of IT and computer literacy in the population should be a top priority action. The high potential for job creation in this area provides an opportunity to tackle the existing situation where significant numbers of young people are excluded from the job market because of lack of training and skills. The extremely high cost of research into future technological developments will place a premium on sophisticated modelling and simulation systems, which can substantially reduce the risks involved. There is an opportunity for skills to be developed in this area and tradeable services commercialised. For the foreseeable future the need for top class electronic engineers and computer scientists will continue and the enhancement of mathematical and fundamental engineering principles will be critical to maintaining Ireland's position as a global player in these industries.

ICT and the Value Chain

In today's global economy, manufacturing enterprises should be viewed in the context of their contribution to the total value chain. Successful manufacturing companies need sophisticated inbound (supply chain management) logistics, and outbound (distribution and active warehousing) logistics systems. Such systems are based on distributed ERP and PDM software, whose functionality is now converging. In addition to logistics, ICT can facilitate customer-driven design at the beginning of the value chain, and improved customer service at the end. Ireland can help to offset its location disadvantage with superior value chain and logistical performance.

Government-supported Programmes in Advanced Technology in the areas of software, power electronics, optoelectronics and telecommunications, as well as the National Microelectronics Research Centre, carry out research and provide postgraduate opportunities in the ICT field. However, the level of existing funding for these organisations does not permit them to generate the scale and activity necessary to build up and maintain world class centres of expertise. Whether from public or private or both sources, support at a higher order of magnitude is needed. In the context of Ireland's ambition to become a knowledge-based and technology driven economy an infrastructure, which develops and transcends what is already in place, *must* be developed.

ICSTI Recommendation

- **The Department of Enterprise, Trade and Employment should commit to establishing Ireland as a centre for world class research excellence in the strategic niche area of telematics and communication technologies.**

b. Biotechnology

In seeking to establish a dynamic, competitive, knowledge-based economy - characterised by a high skill base and high added value - biotechnology is going to reveal more knowledge in the coming decades than all other technologies combined. This was emphasised in the central role assigned to biotechnology by the Health & Life Sciences, Chemical & Pharmaceutical, and Natural Resources Panel reports.

Biological and chemical industries account for a high proportion of Irish high technology jobs and exports. The sectors most obviously affected by biotechnology are pharmaceuticals, chemicals, agri-food and medical devices. These industries have contributed significantly to industrial development in Ireland in the last 20 years and have the potential to continue to do so. And these industries are being revolutionised world wide by biotechnology. In addition to helping enterprises in the agri-food, pharmaceutical, chemical and medical devices sectors to anchor themselves more firmly in the Irish economy, a biotechnology capability will strengthen the flow of biotechnology start-up companies, which at the moment is small but steady.

Biotechnology went through a development phase in the 1980s, mainly in the US, and is now going into a huge expansion driven by genomics, DNA chips, combinatorial chemistry, phage display libraries, the polymerase chain reaction, robotics and many other high impact technologies which are now producing incredible amounts of data. Biotechnology may well play as pivotal a role in social and industrial advancement over the next 10 to 20 years as did physics and chemistry in the post-World War II period. With its strong base in the relevant industrial sectors and with its existing, though small, research capabilities in some aspects of biotechnology, Ireland is in a good position to participate in the next phase of the biotechnological revolution.

Biotechnology by 2015: General Capability Requirements

- **Graduates with core scientific capabilities, but also with sufficient entrepreneurial and managerial capabilities to harness and communicate the potential of this technology and the pace of developments within it.**
- **Research capabilities of international/world class standing with associated multi-disciplinary and commercialisation skills.**

The capabilities will be aimed at harnessing international biotechnology developments, enhancing the competitiveness of indigenous industry and increasing the attractiveness of Ireland as a location for international biotechnology-based businesses and providing the impetus for Irish indigenous start-ups with global potential.

The rapid pace of development in biotechnology will require continuous development in the quality of graduates. In many areas of biotechnology cross-disciplinary interaction is well developed but industry's plea for improved communication, teamwork and networking skills among graduates needs more action.

ICSTI draws particular attention to the recommendation of the Health and Life Sciences Panel regarding the introduction of a national Biotechnology Investment Programme embracing research and commercialisation, more start-up companies, enhancing the competitiveness of

indigenous industry, greater involvement of multinational companies in R&D in Ireland, and increased public awareness and knowledge of biotechnology. The Programme's objective would be to establish a number of research teams in niche areas of biotechnology at a scale and competence to achieve international recognition.

The Government currently funds a biotechnology programme - BioResearch Ireland - which has successfully commercialised some of its own R&D and also interacts with industry (R&D, training). BioResearch Ireland plays an important role in integrating the various elements of industry and the third level sector and focuses the latter on industrial development. In addition, other State organisations, universities and colleges carry out research in aspects of biotechnology. However, support for this technology must be greater in scale and scope in order to underpin the biotechnology industry in Ireland and realise some of the opportunities which this technology will bring. Achieving this will require a large and sustained investment in human and financial resources by Government, through the third level sector and State research institutes, and by industry. Furthermore, as biotechnology becomes increasingly reliant on ICT (particularly in areas such as genomics with its vast data management needs) the quantity and quality of human resources committed to this sector will determine Ireland's relative success or failure in it.

To foster a successful biotechnology sector in Ireland there is a need for the citizen to be comfortable with the use of biotechnology and accepting of its benefits. The sector must establish the objective facts and address public fears surrounding certain applications of the technologies such as the genetic modification of foodstuffs. A number of European countries (the Netherlands, Finland, Portugal, Italy and Belgium) as well as the US have accepted genetically modified food and plants, while others, including Ireland, have not. To date, public debate in Ireland on the safety or ethics of some new product developments in biotechnology has been highly confrontational and has not assisted either policy makers or the general public in making informed decisions.

In this context, the *Hearts and Minds* programme suggested by the Chemical and Pharmaceutical Panel and the *National Conversation on Biotechnology* suggested by the Health and Life Sciences Panel are very practical suggestions whereby both scientists and the general public might increase their mutual understanding of their respective goals and fears.

Related to this issue is the need for Government to operate a regulatory regime, which protects consumers and allows the industry to prosper.

ICSTI Recommendation

- **The Department of Enterprise, Trade and Employment should commit to establishing Ireland as a centre for world class research excellence in strategic niche areas of biological sciences[7].**

[7] Outlines in Appendix III are criteria wich could usefully be applied to the establishment of centres of excellence, which would contribute to the development of world class research and technology development capability.

3.4.3 Management of Innovation

If the repositioning of Irish industry in terms of technological innovation, founded on a vibrant RTD base, is to be realised, then the management of the innovation process is critical. If industry and researchers in universities, colleges and research institutes are ultimately to translate their research, knowledge and technological expertise into marketable innovations and greater wealth the challenge is to introduce and optimise the research outputs for use in Irish enterprises.

There is a clear requirement for the development and dissemination of 'best practice' techniques in the management of the innovation process in order to give Irish industry an internationally competitive advantage. Such techniques would improve the ability of the wider research community to diffuse their research outputs and would improve the ability of firms to efficiently commercialise existing technology and to source new knowledge and technologies. In the context of the latter, an important issue in the development of indigenous companies is their access to strategic intelligence regarding technological developments in their market sectors. This issue has two elements – firstly, the ability of industry and the science and technology community to monitor, screen and adopt new technologies and secondly, the understanding of the socio-economic influences that dictate consumer acceptance of the use of technology in the production cycle.

In the context of a knowledge society, the development of a national capability in innovation management would strengthen our industrial competitiveness. One possible approach to the provision of this infrastructural service is along the lines of the Centre for Innovation in Product Development at the Massachusetts Institute of Technology (MIT). The Centre, which is publicly funded and s*upported by major companies on a partnership basis,* transfers best practice to companies and provides product development methodologies, tools and enabling technologies.

ICSTI Recommendations

- **The Department of Enterprise, Trade & Employment and its agencies should develop a national mechanism in the area of Innovation Management that would support companies, universities, colleges and research institutes in the commercialisation of their research.**
- **The Departments of Enterprise, Trade & Employment and Agriculture & Food and their agencies should investigate how best to meet the strategic technology and market intelligence needs of Irish companies.**

3.4.4 Sustainable Development

Sustainable development has been defined[8] as

'development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs'

The concept of sustainability runs through the whole Technology Foresight process - by envisioning different futures it attempts to make existing and intended policy more robust across a range of possible outcomes, and thus make Ireland's economic development more sustainable.

Most Irish enterprises are still at the stage of merely complying with environmental regulations. It is a matter of some concern that the current low level of 'ownership' of environmental concern by Irish enterprises has resulted in products and services which are not future-proof against a sudden shift in market sentiment, based on broad environmental considerations. A number of EU countries and business sectors have actively embraced environmental sustainability and have deployed technology to redesign their processes and products so as to minimise their environmental impact.

It is inevitable that ecological and environmental considerations will increasingly inform and modify areas as diverse as our school curricula, our production, manufacturing and building processes, our use of natural resources, transport and energy. All future technological development will have to contribute to the critical societal requirement of achieving greater competitive and environmental sustainability. Indeed, technologies which actively contribute to that objective will confer an advantage on their developers. Significant market opportunities will arise for Irish enterprises that proactively operate on ecological and environmental principles.

Furthermore, a great deal more discussion is required between Government, consumers and producers in Ireland in order to develop a shared understanding of the trade off involved in real, effective environmental policies. For example, the Energy Panel flagged the need for Irish society to make hard choices if it is to meet its Kyoto obligations on greenhouse gas emissions in the medium term. In the longer term, post 2010, both the cost and scarcity of oil will enforce even harder choices.

ICSTI Recommendations

The Departments of Enterprise, Trade & Employment; Environment & Local Government and Public Enterprise should undertake an awareness and information campaign directed at enterprises which:

- **facilitates an informed debate on the economic, societal and environmental issues surrounding sustainable development.**
- **highlights the market opportunities and potential competitive advantage to be gained by being 'first mover' in this area.**

[8] Department of the Environment (1997) Suatainable Development: A Strategy for Ireland.

3.4.5 Regulatory Policy

Scientific and technological advances often increase the complexity of products, shorten the time to market and may lead to new impacts on consumers. There is need for a firm and transparent regulatory policy by Government if industry's products are to be acceptable to the buying public. However, avoidable delays in the regulatory process that increase the time taken to introduce new products to market, with the risk of making them uncompetitive, must be addressed. Industry, particularly in the pharmaceutical area and in life sciences generally, would accept more stringent scrutiny of new products if accompanied by a reduction in the time taken for such scrutiny.

A new approach to regulation is required. A worst case scenario to 2015 would envisage the introduction of new broad ranging legislation to make business products, processes and services more 'society-friendly' without adequate resources for the regulatory bodies charged with policing this legislation. The resulting delays would mean new project/product activities of highly regulated industries, as diverse as construction and pharmaceuticals, would be rendered uncompetitive.

In this context, the recommendation from the Chemical and Pharmaceutical Panel 'that Ireland should become a world leader in rapid-response regulation' should be further explored. Using the analogy of basing US Customs officials in Dublin and Shannon, the Panel recommends that the Government should encourage the US Food and Drugs Administration (FDA) to set up an office in Ireland in strategic partnership with the Irish Medicines Board. Within this partnership new 'rapid-response' regulatory procedures for product testing would be developed. A parallel is already underway in the regulation of the construction/infrastructural area where advanced planning permissions on pre-approved sites allow for the accelerated implementation of new projects. In the case of the aforementioned FDA analogy, such early approval mechanisms have the potential to secure, for a relatively small investment, a very significant competitive advantage for Ireland.

Finally, on the issue of recognising and policing the intellectual rights which protect and encourage research and innovation, Ireland's relaxed approach in the past, for example to software piracy, is changing and improvements are in train. An internationally competitive, efficient and properly resourced IPR protection system is essential to the development of an innovation culture.

ICSTI Recommendations

- **Establish an inter-departmental Task Force to determine how best to implement the 'rapid-response regulation' recommendation of the Chemical & Pharmaceutical Panel.**
- **The Department of Enterprise, Trade and Employment be given all the support necessary to sustain and accelerate its current efforts regarding the development of an efficient and effective IPR protection system.**

3.4.6 Investment Environment for R&D

A paradox exists whereby Ireland's low rate of tax on profits in manufacturing and in internationally traded services – which has been so successful in building up Ireland's wealth creation capacity – might in turn prove a deterrent to locating research facilities here. If costs per research project in Ireland and in a high tax country[9] were broadly similar, and if research was being undertaken anyway, a business might choose to locate its R&D in the high tax country where it would provide a larger taxation shield to profits.

With industry becoming increasingly knowledge-based it will be important to tackle the present financial disincentive to locating R&D facilities in Ireland and to performing R&D in Ireland. At present 200 out of 1,000 multinationals located in Ireland undertake some R&D in Ireland, and IDA Ireland policy is to seek to increase this proportion. However, the majority of foreign-owned multinationals choose to locate their R&D facilities outside the country. While most indigenous firms carry out their R&D in Ireland, there are some indications that indigenous firms are beginning to locate their R&D functions abroad for tax reasons.

ICSTI Recommendation

- **Fiscal incentives, perhaps in the form of research vouchers or tax credits, be developed to attract and retain R&D facilities in Ireland.**

This is in line with ICSTI's previous Statement on Innovation in Enterprise.

[9] Corporation profits tax is 10/12.5 per cent in Ireland compared to 38 per cent in Germany and 35 per ecnt in the US.

3.5 The Road to 2015

In previous sections, a vision of Ireland as a knowledge-based society has been described and has been linked to Ireland's current economic, industrial and STI structure. The partners to this vision education, industry, Government and society – and their current role and potential contribution to industrial competitiveness can be illustrated by reference to the four inter-linked faces of a *pyramid.* The pyramid demonstrates the irresistible upward progression in partnership towards a knowledge-based, technologically innovative and competitive economy and society.

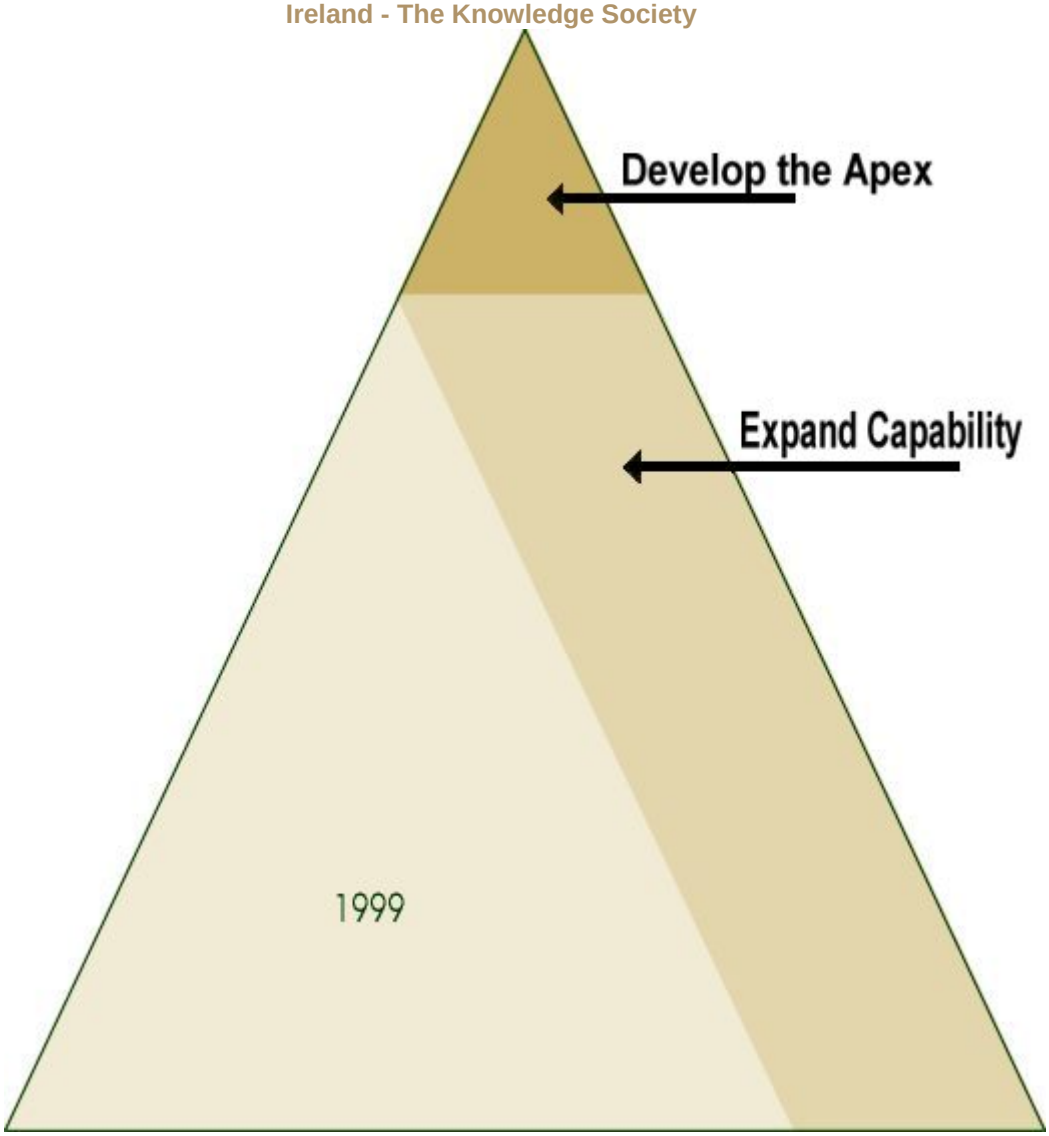
However, a gap at the *apex* of the pyramid has been identified – the need for a world class research capability of sufficient scale within our universities and colleges, research institutes and industry. The gap will only be filled if the partnership of Government, industry, the higher education sector and society can combine to deliver the necessary knowledge framework.

ICSTI urges Government to direct and focus S&T and related Government policies to aggressively stimulate the environment at the apex of the pyramid. Strategic investments now will ensure the accelerated development of the apex, by stimulating:

- RTD intensive and advanced technology-based indigenous and overseas companies, using high level expertise
- A vibrant, cohesive, durable and internationally recognised competitive RTD base involving industry, third level colleges and research institutes, which provides an attractive career structure for researchers to work in Ireland
- An environment conducive to innovation
- Investment in the physical and human infrastructure
- Citizens well informed on scientific issues in the context of an innovation culture.

By focusing on the two areas of ICT and biotechnology, there is enormous potential to signal to industries and researchers world wide that Ireland is prepared to provide an environment supportive of and conducive to the undertaking of world class research in niche strategic areas. In part, the additional capabilities needed for this development reside in graduates of Irish institutions who have gone abroad to work in Europe and the US. Many of these people have developed specialities which would be needed to provide the initial momentum and scale to the development of niche ICT and biotechnology areas.

The apex is, to some extent, reliant on the existing strengths at the various levels below it in industry, third level colleges and State institutes. All of these levels must continue to be developed. However, it is not enough merely to allow each level to develop organically through the normal, incremental spill over from the previous level.



The accelerated development of the apex, by strategic investments now, will create a positive influence on the other layers in the pyramid. Such explicit action will send out a strong signal about Ireland's economic intentions and determination to achieve the vision of research excellence and technologically innovative companies in a knowledge-based economy.

Government must invest in educational and industrial capabilities ahead of developments to take advantages of the opportunities which the new technologies will provide. The Council believes that Ireland's current economic performance and underlying strengths provide the ideal platform to launch Ireland as a recognised location for technological excellence in selected niches.

ICSTI Recommendations

- **The Department of Enterprise, Trade and Employment should establish a Technology Foresight Fund to support the recommendations in the Technology Foresight Panel reports relating to research excellence, particularly the development of world class capabilities in niche areas of ICT and biotechnology**
- **An average of IR£100 million per year over 5 years is required to put this new level of research competence in place in Ireland. This investment should be a priority in STI proposals under the new National Development Plan**
- **Mechanisms need to be developed to ensure that this investment results in the optimum implementation of the Foresight recommendations.**

Recent economic growth is due in large measure to the growth in exports of manufactured goods. The total value of exports grew from IR£15 billion in 1991 to IR£46 billion in 1998. Over 50 per cent of these exports arise from enterprises in the chemical and pharmaceutical, healthcare, electronics, telecommunications and other high technology sectors. Fifty companies account for half of all our exports and only 13 of the 50 do any R&D. Firms which have no strategic roots e.g. R&D function, in a location are particularly susceptible to international mobility.

Well focused and significant investment in upgrading the technological infrastructure of the economy will enable Ireland to develop world class research capability in strategic technologies for the future competitiveness of indigenous industry, facilitate the undertaking of R&D in this country by multinational companies and attract more high-tech companies to Ireland in the future.This is effectively an investment plan to develop world class research capability in strategic technologies for the future competitiveness of indigenous industry, to facilitate the undertaking of R&D in this country by multinational companies and to attract more high-tech companies to Ireland in the future.

This amount is *necessary,* if the gap at the apex, identified in the Technology Foresight findings, is to be filled. The scale is *appropriate* in the context of the value of the total output (now and in the future) from the sectors affected, and in the context of the potential to create new enterprises and to provide skills for ‘new’ industries and to increase productivity in existing industries.

4. The Next Stage

4.1 Technology Foresight in the Future

In the coming months ICSTI will be meeting with Government departments and agencies to consider appropriate action and responses to the recommendations of the eight individual Panel reports and also to the overall strategic issues raised in this ICSTI overview.

Technology Foresight by its nature is an ongoing process, as technology itself continues to advance and change. Thus, there is a need to consider how the Technology Foresight Ireland process might be further developed, so that the insights, benefits, momentum, networks and synergies created by this initial Foresight exercise can be maintained and enhanced.

There is a continuous need to develop and harness the science base to ensure Ireland's long term competitiveness. As a complement to that, there is a continuous need to encourage business to further develop and maintain partnerships with the science base. The process benefits derived from the Technology Foresight exercise make a significant contribution to that partnership.

4.2 Monitoring and Evaluation

Technology Foresight Ireland was completed within 12 months – a remarkably short period of time by international standards. If the process is to be effective it will require ongoing monitoring and evaluation of outcomes.

Evaluation in turn will require the initial selection of appropriate baseline indicators and the benchmarking of Ireland's relative progress towards or away from such indicators.

All this will require a substantial commitment of resources and in particular it will require intellectual resources in the form of concentrated, imaginative thought. However, participants in this Technology Foresight exercise are convinced that the process has a valuable contribution to make to an intelligent debate regarding the harnessing of technology benefits and the allocation of resources for the development and application of science and technology in the future and for the support of excellence in the science and industrial base.

Appendix I - ICSTI Task Force Members

Brian Sweeney, Chairman	Deputy Chairman Group Chairman	ICSTI Siemens Ireland
Paul Holden	Managing Director	Redacteurs Documentation Ltd
Dr. Donald Fitzmaurice	Chemistry Department	NUI - Dublin
Professor Jane Grimson	Dean of Engineering	Trinity College Dublin
Dr. Liam Downey	Director General	Teagasc
Professor Michael Ryan	Head, Computer Science Department	Dublin City University
Professor David McConnell	Professor of Genetics	Trinity College Dublin
Dr. Brendan Goldsmith	President	Dublin Institute of Technology
Pierce T. Piggott	for Sean McDonogh, Director	Piggott Construction Engineering Ltd Director Institute of Technology, Dundalk)
Professor Susan McKenna Lawlor	Department of Experimental Physics	St Patricks College, Maynooth
Deirdre O'Higgins	Office of Science and Technology	Department of Enterprise, Trade & Employment
Helena Acheson,	Secretary, STI Division	Forfás

Appendix II - Technology Foresight Panels

Chemical and Pharmaceutical Panel Members	
Dr. Donald Fitzmaurice, Chairman	Irish Council for Science, Technology and Innovation
Dr. Henry Doran, Deputy Chairman	Schering-Plough (Avondale) Company
Dr. Bernard Bolger	Loctite (Ireland) Limited
Dr. Kieran Brady	Swords Laboratories
Dr. Donal Coveney	Chamfield Limited
Dr. Alva DeVoy	Ulster Bank Investment Managers
Dr. Dermot Diamond	Dublin City University
Dr. Declan Gilheany	NUI - Dublin
Joseph Harford	Yamanouchi Ireland Company Limited
Professor Frank Hegarty	NUI - Dublin
Pat MacGovern	IDA Ireland
Dr. Anita Maguire	NUI - Cork
Matt Moran	Irish Pharmaceutical and Chemical Manufacturing Association (IBEC)
Dr. Tom O'Ceallaigh	Merck, Sharp and Dohme (Ireland)
Jim O'Daly	Newport Synthesis Limited
Dr. Padraig O'Murchu	Intel Ireland Limited
Dr. Joe Rowley	AGB Scientific Limited
Dr. Robert Rutledge	Henkel Ireland Limited
Dr. Fionnuala Walsh	Eli Lilly SA
Dr. Eamonn Kinsella Secretary	The CIRCA Group Europe Limited

Construction and Infrastructure Panel Members	
Pierce Pigott, Chairman**(s)*	Pierce Pigott Consulting Engineer
Dr. Sean McDonagh, Deputy Chairman*	Dundalk Institute of Technology
Aidan Burke *(s)*	Executive, Construction Industry Federation
Frank Coffey *(+)*	County Engineer, South Dublin County Council
Roger Dunwoody	Director, Dunwoody and Dobson
Barry English	Director, Wintrop Engineering
Leo Harmon (Alternate Charlie Cullen)	Architect Director, Ascon Limited
Billy Houlihan	Cork County Council
Neil Kerrigan *(s)*	Head of Division, Enterprise Ireland
Professor Owen Lewis	NUI - Dublin
John Nash	Technical Director, Aeroboard Ltd, CRH Group
Professor Philip O'Kane *(s)*	NUI - Cork
Nick Ryan	Senior Adviser, Department of Environment and Local Government
Ian Roberts	Director, Arup and Partners
Con Sheehan	Project Manager, ESB International
Conor Skeehan *(s)*	Director, CAAS
James Smyth (Alternate Vincent Traynor, Partner)	Principal, James Smyth Architects
Fergus Whelan	Industrial Officer, ICTU
Brian Woods	Partner, McArdle McSweeney Associates
Seán Dunleavy, Secretary	Seán Dunleavy Associates

** Due to pressure of business, Dr. Sean McDonagh invited the Vice Chairman, Mr Pierce Pigott to assume the Chairmanship of the Panel, with Dr. McDonagh as Vice Chairman. This was effective from the fifth Meeting on 26th August 1998.*

(+) Resigned in October 1998

(s) Member Scenario Sub-Group

Energy Panel Members	
Colum MacDonnell, Chairman	Chief Executive, Irish Exporters Association
Dr. Eamon McKeogh, Deputy Chairman	NUI - Cork & Renewable Energy Information Office
Michael Forde	Managing Director, Irish Shell
Rosemary Steen	Assistant Director, IBEC
Pat Mercer	Managing Director, Flogas
Jim O'Brien	Group Technical Advisor, CRH plc
John Fingleton	Managing Director, Fingleton, White & Co
Sean Noone	Managing Director, SELC Ireland
Owen Wilson	Manager of Corporate Safety & Environment, ESB
Sadhbh O'Neill	Acting Co-ordinator, Earthwatch
Charles Shier	Commercial Manager, Peat Energy Division, Bord na Móna
Rory O'Grady	Gas Utilisation Manager, Bord Gais
Denis Blanch	Branch Secretary, Irish Congress of Trade Unions
David Taylor	Director, Irish Energy Centre
Professor J. Owen Lewis	Energy Research Group, NUI - Dublin
Fergus Cahill	Ireland Representative, Philips Petroleum
Niall Ó Donnchú, Secretary	Department of Public Enterprise

Health and Life Sciences Panel Members	
Professor David McConnell, Chairman	Chairman Genetics Department, TCD
Dr. Mike Comer, Deputy Chairman	Caramed Ltd
Dr. Brian Brady	Schering Plough (Avondale Company)
Dr. Gerry Byrne	Jacobs International
Professor Martin Clynesr	National Cell & Tissue Culture Centre, DCU
Dr. Margaret Creedon	Abbott Laboratories
Noel Crimin	Organon Teknika
Dr. Dan Donnelly	Guinness Ireland Group Ltd - Diageo
Dr. Liam Donnelly	Teagasc
Dr. Jane Farrar	Genetics Department, TCD
Dr. Desmond Fitzgerald	Royal College of Surgeons Ireland
Professor Tim Foster	Microbiology Department, TCD
Dr. Ann Francis	Quest International Ireland Ltd
Dr. Frank Hallinan	Irish Medicines Board
Denis Hayes	Avonmore Waterford Group plc
Dr. Tony Kavanagh	Genetics Department, TCD
Dr. Cormac Kilty	Biotrin Holdings
Pat MacGovern	IDA Ireland
Dr. Barry McCleary	Megazyme International Ireland Ltd
Matt Moran	IBEC
Dr. Dan O'Mahony	Elan Corporation
Dr. Luke O'Neill	Biochemistry Department, TCD
Dr. Patrick O'Reilly	Monsanto
Dr. Thomas Quigley	Food Safety Authority of Ireland
Dr. Mark Rogers	Zoology Department, NUI - Dublin
Dr. Douwe van Sinderen	Microbiology Department, NUI - Cork
Dr. Owen Smith	St. James's Hospital, National Childrens' Hospital
Professor Brian Walker	Biochemistry Department, QUB
Dr. Patrick Wall	Food Safety Authority of Ireland
Dr. Jim Walsh	Trinity Biotech
Professor Philip Walton	Physics Department, NUI - Galway
Dr. Fiona Shalloe, Secretary	National Pharmaceutical Biotechnology Centre, TCD

Information and Communication Technologies Panel Members		
Paul Holden Chairman	Managing Director	Redacteurs Documentation Ltd
Frank Turpin, Deputy Chairman	Academic Relations Manager	Intel Ireland Ltd
Frank Boland	Professor	TCD
Eamon Cahill	Consultant	Irish Productivity Centre
Jennifer Condon	Director	National Software Directorate
Joe Curtis	Director	Teltec Ireland PAT
Hilary Doyle	Company Secretary	Siemens Nixdorf Ireland
Edwina Fitzmaurice	General Manager	Scottish Amicable
David MacDonald	Chief Executive Officer	I.T.P.
Tony McGuire	Managing Director	System Dynamics Ltd
Susan McKenna Lawlor	Professor	NUI - Maynooth
Danny McLoughlin	Managing Director	Visibility Software
Denis Molumby	Executive	IDA Ireland
Jim Mountjoy	Managing Director	Euristix
Barry Murphy	Manager	Cullinane Group Ireland
Pat O'Connor	Managing Director	IISL Ltd (IBM sub.)
Diarmuid O'Colmain	General Manager	Ericsson Ltd
Michael Ryan	Professor	Dublin City University
Frank Ryan	Manager, Electronics	IDA Ireland
John Sterne	Managing Director	Newsmail
George Young	Director	Commergy Ltd
Martin Hynes, Secretary	STI Division	Forfás

Materials and Manufacturing Processes Panel Members		
Professor Jane Grimson, Chairperson	Dean of Engineering	Trinity College Dublin
Dr. David Melody, Deputy Chairman	Vice President, R&D	Loctite Ireland Ltd
Paul Blackie	Lecturer	Athlone Institute of Technology
Professor Werner Blau	Head, Department of Physics	Trinity College Dublin
Professor Gerry Byrne	Head, Department of Mechanical Engineering	NUI - Dublin
Dr. Eamonn Cahill	Consultant	Irish Productivity Centre
Niall Carroll	Managing Director	ACT Venture Capital Ltd
Garrett Dee	R&D Manager	Reagecon Ltd
Dr. Joseph Dowling	Technology Development Manager	Bausch & Lomb Ireland
Dermot Keena	Advanced Manufacturing Technologies Manager	Motorola BV
Dr. Ardawan Lalui	R&D Director	Vitalograph (Ireland) Ltd
Jim Lawler	Director	AMT Ireland
Professor Pat Mallon	Head, Department of Mechanical and Aeronautical Engineering	University of Limerick
Professor John Monaghan	Head, Department Mechanical and Manufacturing Engineering	Trinity College Dublin
Dr. Eamonn Murphy	Research Director AMT Ireland	University of Limerick
Paul O'Brien	Managing Director	Raychem International
Eoin O'Driscoll	Vice President, International Operations	Ascend Communications
Dr. Barry O'Connor	Lecturer	NUI - Cork
Brian O'Grady	Managing Director	BSM Ireland
Matt Russell	Head, Department of Manufacturing Engineering	Dublin Institute of Technology
Eamonn Sheehy	Business Development Manager - Healthcare	IDA Ireland
Dr. Joe Healy, Secretary	Technical Operations Manager	Materials Ireland

Natural Resources Panel Members		
Dr. Liam Downey, Chairman	Director	Teagasc
Pat Ridge, Deputy Chairman	Chairman	Bord Iascaigh Mhara
Noel Cawley	Managing Director	The Irish Dairy Board Co-operative
Frank Convery	Director, Environmental Institute	NUI - Dublin
Matt Dempsey	Editor and Chief Executive	The Farmers Journal
Liam Donnelly	Director of Operations	Teagasc
Michael Feeney	Manager, Food, Timber and Consumer Products	Enterprise Ireland
Gerald Fitzgerald	Professor of Food Microbiology	NUI - Cork
Jim Flanagan	Chief Inspector	Dept. of Agriculture and Food
Paddy Glennon		Glennon Bros Timber Ltd
Professor Michael Guiry	Professor of Botany	National University of Ireland, Galway
Peter Heffernan	Chief Executive Officer	Marine Institute
Pat Keogh	Chief Executive	Bord Iascaigh Mhara
Martin Lowery	Chief Executive	Coillte Teoranta
Michael Duffy	Chief Executive	An Bord Bia
Denis Lucey	Chief Executive	Dairygold Co-operative Society
Fergal Mulloy	Director	COFORD
Larry Murrin	Lecturer	Dawn Farm Foods Ltd
John O'Callaghan	General Manager	Kerry Agri-Business
Dennis O'Connor	Head, Business Strategy, Consumer Foods Group	AWG
Maire Mulcahy	Professor of Zoology	NUI - Cork
Paddy O'Keeffe	Chairman	FBD Insurance Ltd
Joe Sreenan	Head, Animal Reproduction Department	Teagasc
Dr. Patrick Wall	Chief Executive	Food Safety Authority of Ireland
Brian Wickham	Chief Executive	Irish Cattle Breeding Federation
Owen Sweeney, Secretary		The Circa Group Europe Limited

Transport and Logistics Panel Members		
Dr. Brendan Goldsmith, Chairman	President	Dublin Institute Technology
Eamon Moran, Deputy Chairman	General Manager	Aer Rianta
Peter Rigney	Industrial Officer	ICTU
John Dunne	CEO	South Dublin Chamber of Commerce
Eoghan Hynes (Snr)	Managing Director	Hytherm Navan
Christopher McNulty	Director, Education and Training	Chartered Institute of Transport
Paul Keely	Operations Manager	Bus Eireann
Brendan Lynch	Manager - Logistics	Telecom Eireann
Dr. Stefan Bungart	Director General	National Institute for Transport & Logistics
Professor Simon Perry	Head of Department	Department of Civil, Structural and Environmental Engineering, TCD
Dr. Margaret O'Mahony	Project Manager	Department of Civil, Structural and Environmental Engineering, TCD
Declan Allen	Lecturer	Dublin Institute of Technology
Maria Kyne	Research Fellow	The Centre for Project Management (University of Limerick)
Aine O'Donoghue	Managing Director	Taylor NelsonSofres & MRBI
Karen Gannon	Assistant Director	Transport Policy, IBEC
Gerry Glynn, Secretary		Gerard Glynn Associates

Appendix III - ICSTI Criteria for establishment of RTD 'Centres' of Excellence

Research Excellence

"The science and technological infrastructure in Ireland, by international standards, is second-rate.....There are no world class universities (an Oxford, an MIT, a Pasteur Institute) or relevant Centres of Excellence which the sector can call on if new technologies have to be developed and implemented. This is compounded further by university-industry co-operation being superficial, short term and underfunded"

Chemical and Pharmaceutical Panel

Ireland, with a few exceptions, has no recognised Centres of Research Excellence i.e. research groups which are recognised as being 'world class' in their field in terms of scientific excellence and scale. At the same time Ireland possesses a diaspora of well educated and highly experienced graduates in a number of fields, notably in information and communications technologies and in biotechnology, who will return if the circumstances are attractive and who could contribute to the development of our national research capability.

There is no one formula which can apply to the establishment of these ‘centres’, but their design must allow them to be responsive to the policy objective(s) for which they are established. The research groups could be established as physical or virtual ‘centres’, company/research body partnerships or sectoral networks.

Whatever physical form such ‘centres’ might take, to be successful they must:

- Develop world class RTD capability
- Operate at critical mass
- Be dedicated to particular technology areas
- Be strategically, operationally and financially effective partnerships between the public research community and industry with strong Government involvement
- Develop linkages with other national research activities and provide access to international sources of technology
- Be effective in the management, commercialisation and transfer of technology

Because of its size, Ireland must avoid fragmentation of its research effort and be selective in its research focus. Nevertheless, it is vital that ‘centres’ should be of an international standard, show world leadership in niche areas and network into best practice in other areas.

‘Centres’ should be established, directed, managed and funded on a partnership basis between Government and industry and possibly in collaboration with other world class centres. Government would provide continuity and pressure towards undertaking public good research through the involvement of universities and institutes, while indigenous and multinational industry would provide market relevance and commercialisation if the R&D were successful.

‘Centres’ should develop collaborative relationships with similar international institutions and experts to promote transfer of expertise and technology into Ireland.

The ‘centres’ should be strongly networked to related research or teaching in other Irish institutions. The essential dynamic of this relationship would be the flow of feedstock between the ‘centres’ and these institutions.

Successful implementation can only be achieved if Government is prepared to be courageous in the face of the scale and level of scientific excellence that such an approach necessitates. To attract the necessary calibre of researchers and to maintain the dynamism of these ‘centres’, contracts cannot be limited by the norms currently applied under public sector remuneration guidelines.

Appendix IV – Glossary

CHP	Combined Heat and Power
EI	Enterprise Ireland
ERP	Enterprise IrelandEnterprise Resource Planning
HEA	Higher Education Authority
IBEC	Irish Business and Employers Confederation
ICSTI	Irish Council for Science, Technology and Innovation
ICT	Information and Communication Technologies
IDA	Industrial Development Authority
IDC	Inter-Departmental Committee
IPR	Intellectual Property Rights
IT	Information Technology
MIT	Massachusetts Institute of Technology
MNEs	Multi-National Enterprises
OECD	Organisation for Economic Co-operation and Development
PATs	Programme(s) in Advanced Technology
PDM	Product Data Management
R&D	Research & Development
RTD	Research and Technology Development
RTI	Research, Technology and Innovation
S&T	Science & Technology
SMEs	Small and Medium sized Enterprises
STI	Science, Technology and Innovation

Appendix V – References

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