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TECHNOLOGY CAPABILITY

PREPARED FOR MATRIX BY

PA Consulting Group

THE NORTHERN IRELAND SCIENCE INDUSTRY PANEL

MATRIX is key to the development of Northern Ireland's future knowledge-based economy and will play a key advisory role in the formulation of R&D and Innovation policies.

A key objective for MATRIX is the successful development and implementation of HORIZON it's flagship programme tasked with carrying out focussed foresight exercises.

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EXECUTIVE SUMMARY

PART 1 INTRODUCTION

This document presents the findings and conclusions of PA Consulting Groups (PA) Technology Capabilities Study for Northern Ireland (NI), undertaken on behalf of MATRIX, the NI Science Industry Panel, which provides expert advice to the Department of Enterprise Trade and Industry (DETI).

Its aim is to identify and qualify NI existing research and technology strengths in terms of scientific capability and the potential for exploitation across six sector-based technology areas.

The sectors[1] selected reflect the UK Technology Strategy that was launched by the UK Department of Trade and Industry, and consider the specifics of the NI economy in terms of:

1. Advanced Manufacturing;
2. Advanced Materials;
3. Sustainable Production and Consumption (including energy technologies)[2];
4. Life Sciences;
5. Information and Communications Technology (ICT); and
6. Electronics and Photonics.

PART 2 THE APPROACH

In mapping and measuring the capability identified and accessing in this exercise, two factors have been considered, those of 'Scientific Capability' and 'Exploitation Capability'. The matrix, which these two elements create, is shown overleaf. The ideal scenario for all capability is to exist in the upper right hand quadrant, i.e. where strong scientific capability is effectively exploited for economic gain. But in practice this is not always the case. The potential influence of this capability in the NI economy is represented by the size of the squares[3] and the timescales to the realisation of this impact is depicted by their colouration.

To achieve this for each of the sectors, three distinct phases of work were undertaken by PA between April and September 2007, and these are briefly summarised.

The first phase was the identification of capability[4], and consisted of a variety of interviews with companies, universities and other relevant public and private sector bodies throughout NI. Due to the size and scale of the undertaking it was impossible to rely solely on such first-hand information, and as such, a major source of further input was the company information contained within a variety of databases held and maintained by DETI. These were thus amalgamated and validated to provide many of the figures contained in this report;

The second phase was to benchmark the capability influencing factors (e.g. percentage of revenue spent on R&D) against other comparable regions and countries. This enabled the relative sizing of the capability and allowed an extrapolation of how this capability was likely to develop in the future, assuming that the reference conditions remain the same.

1. The classification of companies in each sector is relatively subjective as companies can be classified in many ways. However; the view of this report is that the capability is essential to be captured.
2. Energy technologies have been included in the Sustainable Production and Consumption sector in relation to the activities carried out in those sectors.
3. This involves subjective judgement as it is not possible to accurately predict market size. However, based on the roadmaps presented in Chapter 10 of this report, an attempt is made to gauge impact in the NI economy.
4. As such, the report only reflects existing capability within NI and can be classified as a 'NOW SIGHT' perspective of Northern Ireland. Additionally, the identification process takes limited consideration of scale. Once the capability does exist, the scaling question becomes one of funding or focus. The assessment of scientific capability in academe is based on RAE 2001 data.

FIGURE 1: THE MATRIX OF CAPABILITY

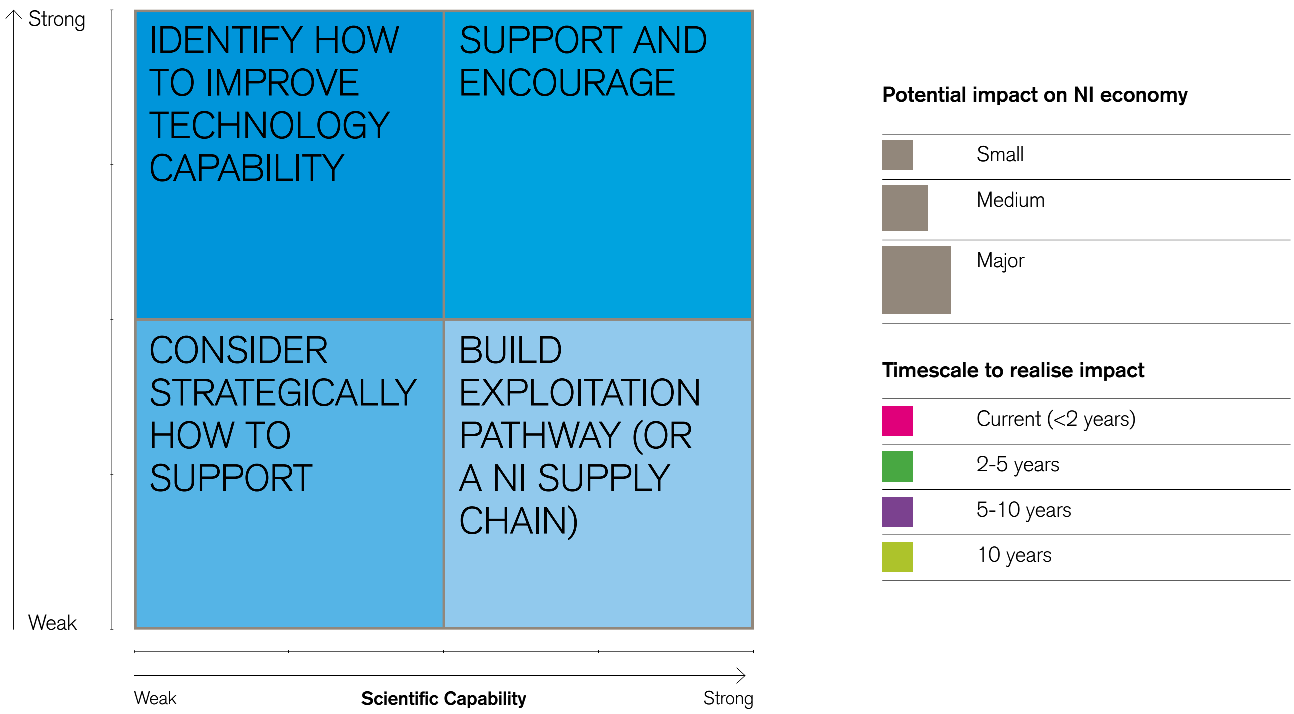
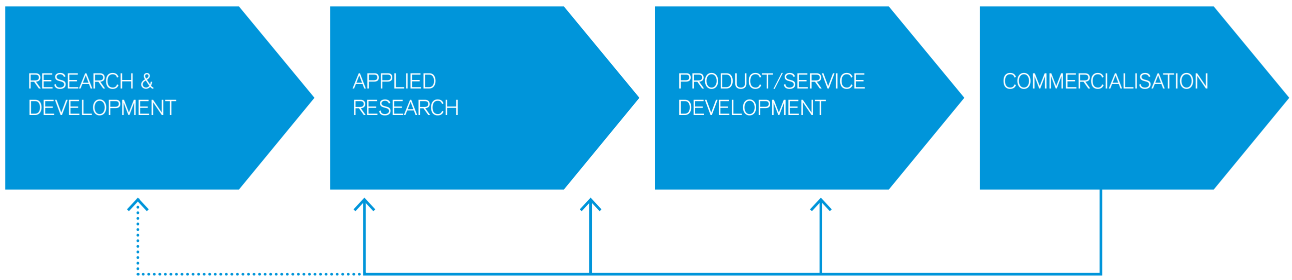


FIGURE 2: THE INTERACTIVE MODEL OF INNOVATION USED IN THIS REPORT



The final phase was to combine the results of these two previous phases into this final report, and from them to derive a set of conclusions that identify both areas where NI has definite capability and leadership opportunities, and reflect the views of industry on the conditions that will positively contribute to the maximisation of this potential.

Definitions of Research and Development
This report assumed an interactive model of innovation in terms of how R&D links to market commercialisation of products and services. The model selected is outlined in Figure 2.

Whilst the historical model of innovation in economies suggests that the more R&D that is conducted the more innovation in products/services is occurring[5], this report assumes a higher degree of interactive innovation. This suggests that innovation is due to the outcomes of an interactive process in which many actors are working together and therefore does not happen from left to right in Figure 1 but happens outside of this cycle[6]. Hence, the starting point does not have to be academia but rather the impulses and ideas tend to come from existing production or the specific markets[7] with no specific interaction amongst players and ideas being refined and generated at all stages of the overall process. This implies that basic research and development is not always the sole initiator and in fact value is not maximised until the commercialisation stage. This report takes this view because, unlike academic reviews, it only considers the economic application of any ideas or investments which implies the implementation of changes in production or the introduction of new products/services to the market.

In this report, all definitions are seen from the interactive perspective and the key feature is not how individual actors perform but rather how these same actors interact with each other to create greater economic impact. The only aim therefore is to see all activities in the context of increasing competitiveness and rapid technological change that underpins such competitiveness.

5. This is called a Linear Model of Innovation
6. Nelson and Winter 1992
7. Halvorsen and Lancave 1998

PART 3 TECHNOLOGY CAPABILITY FINDINGS

A General Sector Trends

Before assessing each of the sectors in turn, it is of benefit to contextualise them against each other in the NI context. The following figure presents the Gross Value Added (GVA) contribution of each of the sectors to the NI economy, and shows that Advanced Manufacturing and Sustainable Production and Consumption are the most important sectors to the NI economy in this regard.

A second commonly used measure of importance is that of employment, and the following figure shows that as with GVA, Advanced Manufacturing and Sustainable Production and Consumption continue to dominate, with a combined level of employment of some 64%.

Figures 5 and 6 depict the trends in both employment and turnover within each sector over a three-year timeframe (2003-2005) and show that in all instances there has been growth in this period.

In summarising the economy of NI at this time, 2005 saw an estimated rate of growth of some 3.2%, which is almost twice that of the UK average and it is anticipated that this will continue for 2006 and 2007.

FIGURE 3: GVA BY SECTOR IN NI

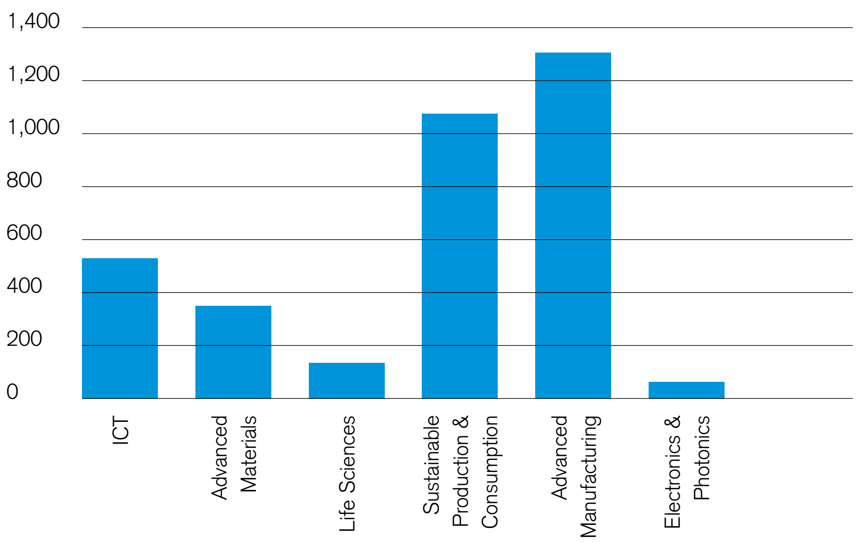


FIGURE 4: EMPLOYMENT BY SECTOR IN NI

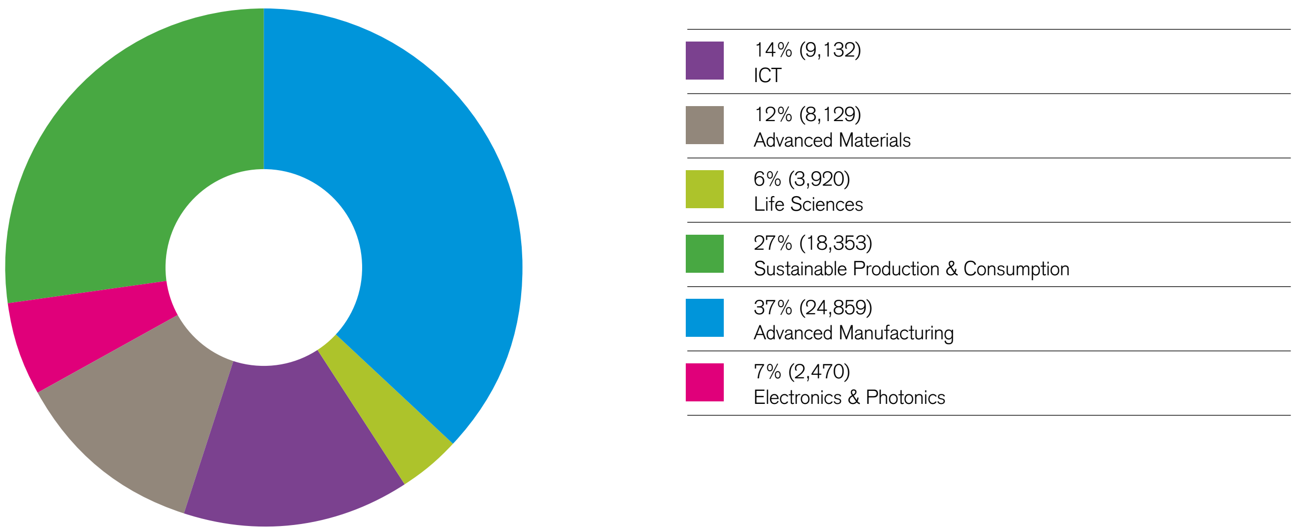


FIGURE 5: EMPLOYMENT GROWTH BY SECTOR

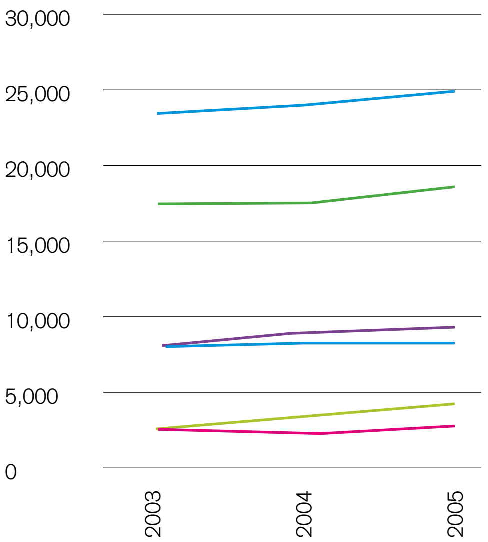
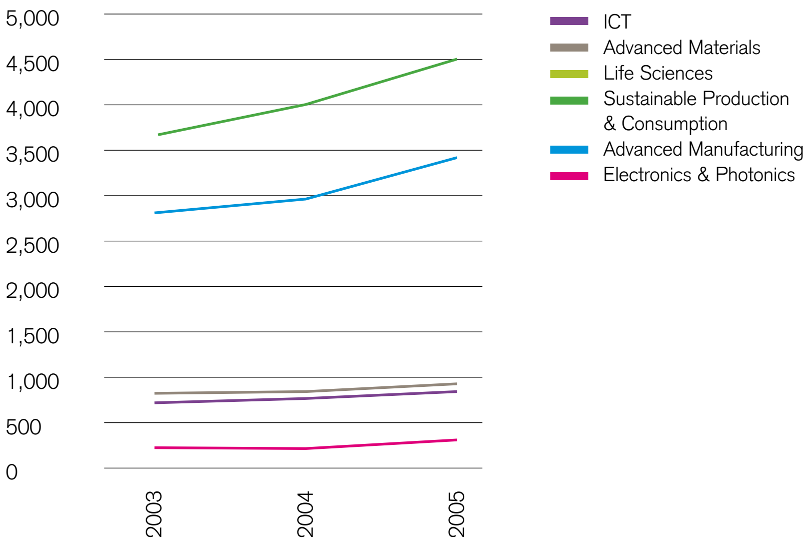


FIGURE 6: TURNOVER GROWTH BY SECTOR



ADVANCED MANUFACTURING

B The sector analysis
Advanced Manufacturing

The first sector addressed is that of Advanced Manufacturing. This is described as the transformation of raw materials into either finished goods for sale, or the intermediate processes related to the production or finishing of semi-manufactured items with specific emphasis on using advanced engineering techniques. Advanced engineering techniques include Computer Aided Design and Computer Aided Manufacturing software, computer-driven machining and process control mechanisms. In general, this sector experiences rapidly changing conditions related to workforce, process and technology in the context of an increasingly dynamic, competitive and global market environment. The nature of the activity remains resource-intensive and under increasing cost pressures.

In the context of NI, this is perhaps the most disparate sector, both in terms of size and speciality. It consists of some 139 companies that employ in the region of 25,000 employees with a combined turnover of £3,404 million. Concerning R&D, 79 companies have identifiable programmes in place, and together there are 808 staff directly engaged in such activities.

Advanced Manufacturing has always been of significant importance in NI, and this will continue to be the case in the future. Whilst the levels of employment are much lower than in the past, and potentially may even continue to decline further in the future, advanced manufacturing effectively enables the services sector.

At the present time, this sector can be characterised as having:

- Strong supply chain management;
- Strong links with universities in specific instances;
- Strong UK branding;
- High levels of responsiveness and flexibility;
- Low employee turnover; and
- High levels of government support.

It is also the case that there are specific concerns in this sector related to:

- Low levels of productivity (NI has the lowest productivity of any of the UK regions);
- Supply chain price sensitivity;
- Diminishing competitive position due to rising costs; and
- A continued need to increase productivity.

The following figure graphically summarises Advanced Manufacturing capability in NI. Reflecting the diverse nature of this sector, there is a variety of very different capabilities.

Due to the immense diversity of the sector, Figure 7 does not provide sufficient understanding of the capability in the sector. Although these capabilities look strong (and they are in leading NI companies), the analysis demonstrates that there are sectoral splits in Advanced Manufacturing. The traditional industries are suffering and newer industries are demonstrating leadership and growing capability. Therefore, although Advanced Manufacturing in NI is declining overall, this decline is in the traditional manufacturing sectors. In the newer sub-sectors of Advanced Manufacturing, there is growth at a rate exceeding the UK average and these are where newer technologies are deployed. This is demonstrated in Figure 8.

In summarising the Advanced Manufacturing sector in NI at this time, the following key points can be made:

- Whilst traditional manufacturing has declined in NI as it has declined throughout the UK, the extent of the decline overall has not been as great as may be perceived. There have been losses in the most traditional types of manufacturing in NI (e.g. textiles and shipbuilding) but there remains a significant growing capability in newer sub-sectors;
- Future growth in this sector will be based around more highly skilled production processes, and a move to excellence in Advanced Engineering focussing on design, development and validation in collaboration with customers nationally and internationally;

- There remain important capabilities in NI with regards to construction, packaging, advanced materials and computational science that are not being fully exploited locally;
- There is a need for increased spending in innovation and technology in the broadest sense.

Advanced Manufacturing Conclusions
Through discussion with industry leaders it is clear that for the Advanced Manufacturing sector to remain viable in the future there is a need to change its profile, as most companies active in this sector at this time are working in areas of cost sensitivity. The few larger companies in this sector (e.g. Bombardier, FG Wilson, Thales) are addressing these issues through the adoption and development of highly competitive capabilities in lean manufacturing, design and the utilisation of Advanced Materials and associated manufacturing techniques, leveraging where appropriate the capabilities of the local universities to assist them.

A transition from traditional to Advanced Manufacturing means a move away from a sector that competes on cost to one that has leading innovation and technological strengths embedded within the supply chain. Building on the capability that exists and managing this transition is likely to have the following implications for the sector;

- Move away from mass production to semi-customisation, which in turn will result in lower volume, higher margin products that are less price-sensitive;
- Move away from centralised production locations to distributed production sites and a move away from clean room environments to less costly bases of production;
- Move away from centralised business control of production towards collaboration between production units. This will include the adoption of outsourcing where appropriate;
- The adoption of Advanced Manufacturing techniques (product design, advanced engineering, lifecycle analysis etc);
- The sub-division of the sector into smaller, distributed specialised companies that work in various supply chain networks were their core competencies are of value;
- The ability to engage in new manufacturing supply chains a shift towards the employment of an extremely adaptive workforce that continually learns new skills;

FIGURE 7: ADVANCED MANUFACTURING CAPABILITY IN NORTHERN IRELAND

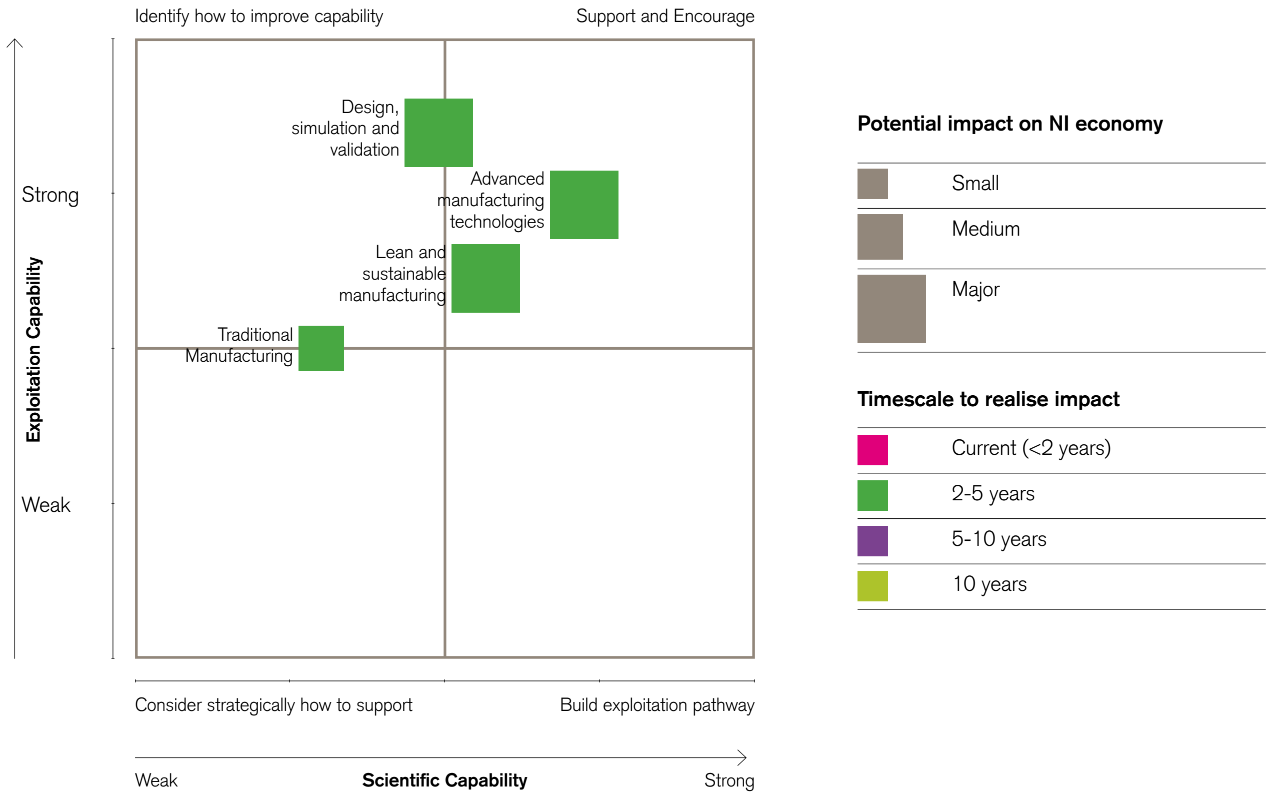


FIGURE 8: NORTHERN IRELAND ADVANCED MANUFACTURING BY SUB-SECTOR

ADVANCED MATERIALS

B The sector analysis
Advanced Materials

The sector is defined as the generation and application of knowledge relating to the composition, structure and properties of materials and their use in specific applications. As such, advances in this sector are viewed as the key enablers for product development and innovation in most sectors.

Advanced Materials is a sector of strength in NI. Some 55 companies operate within it, with a collective turnover of £867 million and an employment level of in excess of 7,000. Of these 55 companies, 33 have an identifiable R&D programme, with a combined spend of £4.2 million. As one would expect, this sector also has the closest affiliation with university and research organisations as materials knowledge is rarely solely possessed by one institution.

Within NI there is very definite and highly competitive capability in this sector. Whilst certain companies already exploit this capability quite well, given the multi-disciplinary nature of Advanced Materials, it is also important to recognise that further exploitation potential exists across a variety of sectors including Agri-food, Transport, Life Sciences and ICT.

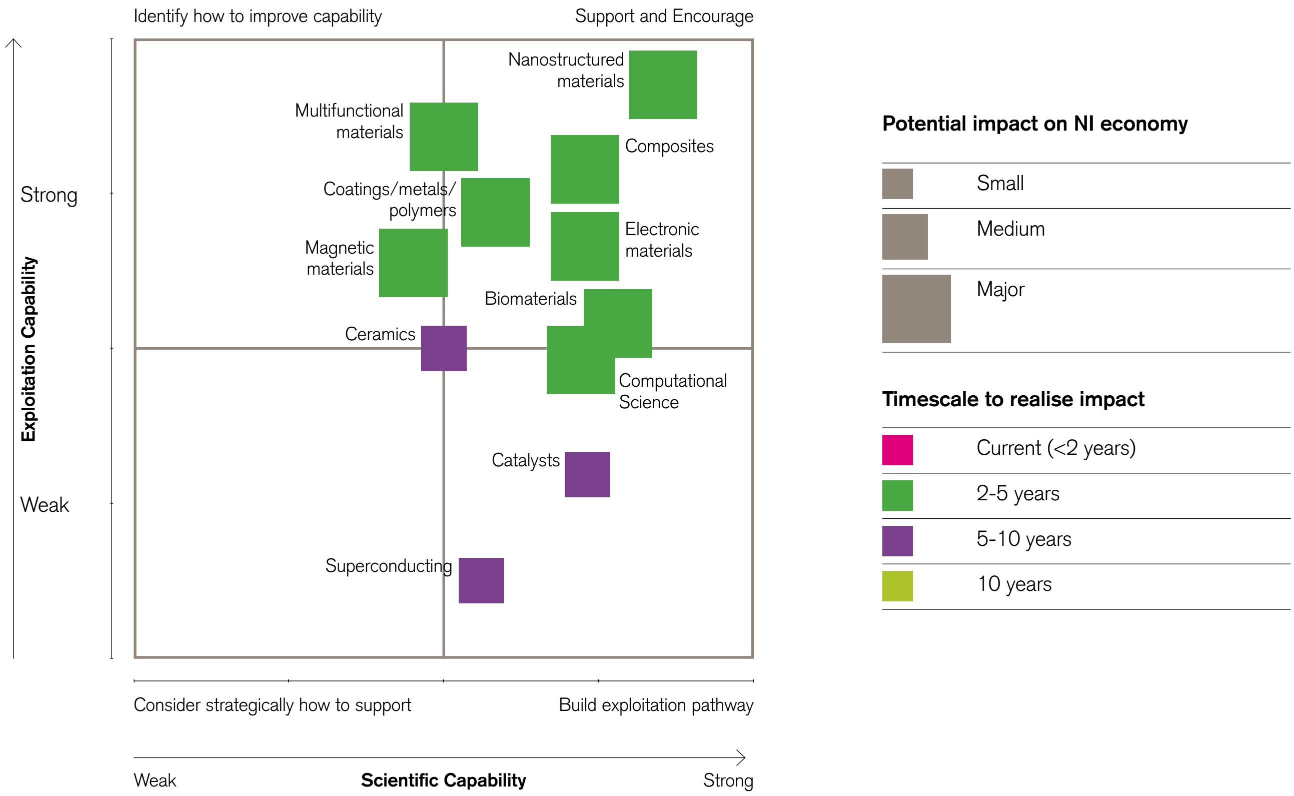
The following figure categorises the key Advanced Materials capabilities within NI at this time and shows that there again is quite a breadth of capability.

In summarising this sector, the following is noted:

- NI has strong capability in this sector and that there are productive links between industry and academia;
- There is a strong multi-disciplinary nature to the teams operating in this sector which ensures that both scientific and industry issues are adequately understood and addressed. For example combining mechanical, chemical and biological sciences;
- The productive linking of industry and academia is undertaken in this sector with a strong customer focus;
- Computational Science is an integral aspect of all Advanced Materials. Through the use of simulation and modelling techniques, it is possible to understand and predict how materials will behave in specific applications and this reduces cost, lead-time and enhances product performance. This links Advanced Materials to Advanced Manufacturing and NI has clear strengths in this space (alongside Bioinformatics in Life Sciences);
- From the analysis, it is evident that NI has international standard capability in most of the sub-fields of Advanced Materials including polymers, metals and biomaterials. However, the same analysis indicates that the quantity of this R&D is not sufficient for the range and size of sectors within NI and for critical mass globally;
- There however remains some capability that could be better exploited, specifically concerning the Built Environment, Biomaterials (Life Sciences) and the development of Computational Science as a key component of the Advanced Materials sector.

Advanced Materials Conclusions
The analysis of the NI industrial and academic strengths, alongside the existing global centres of strength in Advanced Materials, shows that a rich focus area for NI is the convergence between traditional material sectors and a focus on the inter-disciplinary and multi-disciplinary areas of Advanced Materials (specifically biomaterials, nanostructured materials, multi-functional materials and composites). In this space aided by computational science, NI is demonstrating some key capability on a scale that makes it viable for company growth and the creation of a niche leadership focus within the UK to underpin the future development of the Life Sciences, Advanced Manufacturing, Agrifood and ICT sectors in NI.

FIGURE 9: ADVANCED MATERIALS CAPABILITY IN NORTHERN IRELAND



SUSTAINABLE PRODUCTION & CONSUMPTION

B The sector analysis
Sustainable Production & Consumption

The Sustainable Production & Consumption (SP&C) sector covers energy, construction, agriculture and food, including the impact and relationship that these have with environmental technologies and energy. As indicated in Figure 2 above, this sector is the second-largest employer in NI at this time, with 82 companies with a combined turnover of £4,500 million employing some 18,300 people. Of these companies, 28 have identifiable R&D budgets and collectively employ 153 staff in R&D-related activities.

- Energy as a key differentiator in company and country competitiveness;
- Fundamental shifts in energy understanding, consumption and security[8];
- Fundamental shifts in understanding CO2 emissions and global warming;
- Construction industry changes been brought about by standards, legislation and increased competition;
- Newer technologies being applied to construction are fundamentally changing the shape of the industry;
- Changes in the construction industry brought about by materials, new regulations and emerging affordable housing concepts;
- Critical global events (World Trade Organisation (WTO) are aspiring to remove all agriculture exports subsidies by 2013);
- CAP Reform;
- Critical sector events (food prices are changing, customer viewpoints on nutrition and cheaper imports from third world countries);
- Fundamental shifts in global patterns - availability of land for farming, water scarcity, water purity, urbanisation and migration;
- Land usage including soil erosion, land degradation and competition of natural resources between energy and food;
- Shifts in dietary patterns of entire populations from grain-based diets to meat and dairy products;
- Emerging pressure on the sector concerning Carbon Footprints (from the Retail Side), new directives (Water Frameworks, Nitrates), energy costs and emerging constraints on items such as Phosphates. These are sure to increase the cost base within the sector. Whilst this will impact agriculture and food first, it will also impact energy and construction.

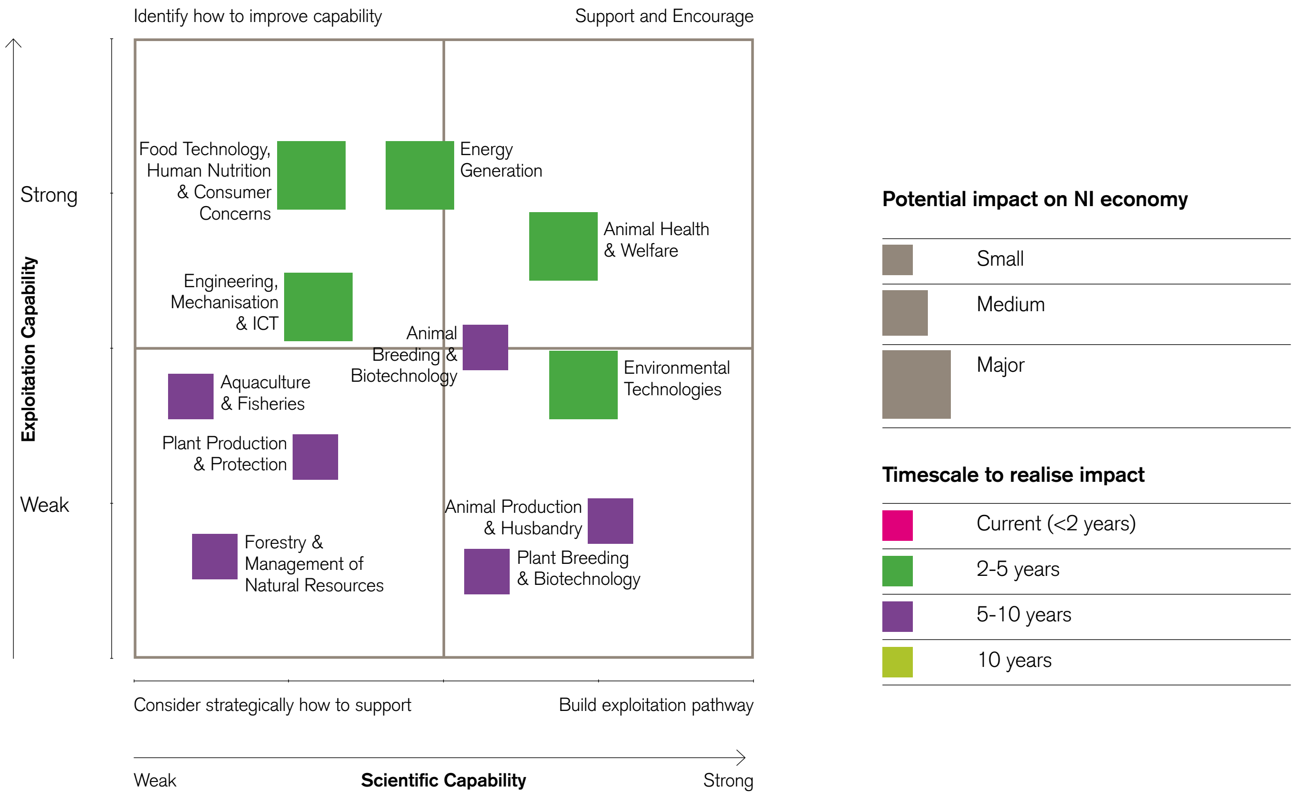
In the NI SP&C private sector there are two predominant company types - those that supply the local market with produce (e.g. bakeries and smaller food companies) and those that are focused on export-related markets (e.g. large scale poultry firms). These large-scale producers find themselves under continual pressure concerning their margins and as such, their focus remains on cost reduction and improved efficiency with the resultant effect that the level of investment made in R&D is low in comparison to turnover. Complementary to this, however, is the NI public sector capability in this sector as the AgriFood and Bioscience Institute (AFBI) is the largest such science and technology organisation in NI. They employ approximately 800 people, have an annual budget of £40 million and have core competencies in plant science, veterinary science, agriculture, food and environmental science, and economics.

The following table presents a summary of the capability of NI in this sector and shows that there are two quite distinct aspects to it. The first of these is the strong exploitation capability that exists with regards to technology in the poultry and dairy processing sectors in particular, and it is these capabilities that have immediate short-term economic benefits in terms of employment and revenue, and are focused on contributing to the continued viability of the companies. The second set of capabilities is more science focused and includes veterinary science, animal health, plant science, food safety and food nutrition. There also exists the complementary capabilities from other sectors (e.g. Advanced Materials), that despite its potential benefits, remains under exploited.

Although the sector has traditional strengths, it is currently in a situation whereby its margins

8. The European Union has agreed a commitment to use biofuel in 10% of road transport fuels by 2020. The European Commission is also pursuing a target of 20% of renewables in overall consumption by 2020.

FIGURE 10: SUSTAINABLE PRODUCTION AND CONSUMPTION CAPABILITY IN NI



are threatened. Across the sector, there remains a level of fragmentation that hinders a better exploitation of capability into new markets.

Sustainable Production and Consumption Conclusions

The NI sustainable production and consumption sector has a wide range of capabilities that have evolved over the past 30 years. However, industry leaders feel that in order for this capability to continue to develop in the future the following needs to be considered:

- There is a need for increased collaboration between NI food companies and research institutes and with other regions and countries in order to maximise the impact and benefit of knowledge transfer;
- The competitive scientific capability that exists with regards to animal and plant genetics, breeding and energy needs be exploited in the contexts of new foods and knowledge-based food enterprises;
- The need for and benefit of fundamental research in this sector should be better communicated and aligned with industrial needs;
- The capabilities of the AFBI and the universities could be better exploited by adopting a more multi-disciplinary approach, and AFBI plays a key role within this development;
- Complementary capabilities outside the sector such as Advanced Materials (biomaterials and nanotechnology), Computational Science (Bioinfomatics), Life Sciences (Human Genomics, Study of Diet and Humans, Nutrigenomics) and Proteins (Dairy and Beef) could be exploited for the future of the industry;
- In the energy and alternatives field, NI has a leadership position in understanding how to reduce carbon emissions, reduce energy costs and recycle waste for the entire sector. These initiatives should be further exploited to provide a clear picture of Environmental Technologies in the NI context.

LIFE SCIENCES

B The sector analysis
Life Sciences

Life Sciences is the general term used to encompass the fields of biotechnology, pharmaceuticals, biomedical technologies, life application technologies, nutriceuticals and biomedical devices. In essence, it combines all elements of biology, chemistry and technology that contribute to the discovery and development of products for the healthcare and wellbeing of humans and animals.

The Life Sciences sector in NI consists of approximately 60 companies that had in 2005 a combined turnover of some £290 million and employ in the order of 4,000 staff. Twenty-eight of these companies have an identifiable R&D capability, and spent in 2005 some £33 million and directly employed some 600 staff in R&D.

The private sector shows clear capability with regards to pharmaceuticals, medical devices and diagnostics, medical disposals, biotechnology and clinical trials. The public sector is driven by DHSSPS and covers a number of aspects of both healthcare and community/social care. The academic sector has significant capability with regards to vision, immunology, drug formations and associated technologies, system biology, bioimaging, epidemiology and tissue engineering, although this tends to be predominantly fundamental in nature and thus is exploited in a limited manner Figure 10 categorises the capability of NI in Life Sciences and reflects that there is a very significant and impressive capability across the private, public and academic sectors, and graphically depicts the significant under-exploitation of strong scientific capability in a number of fields.

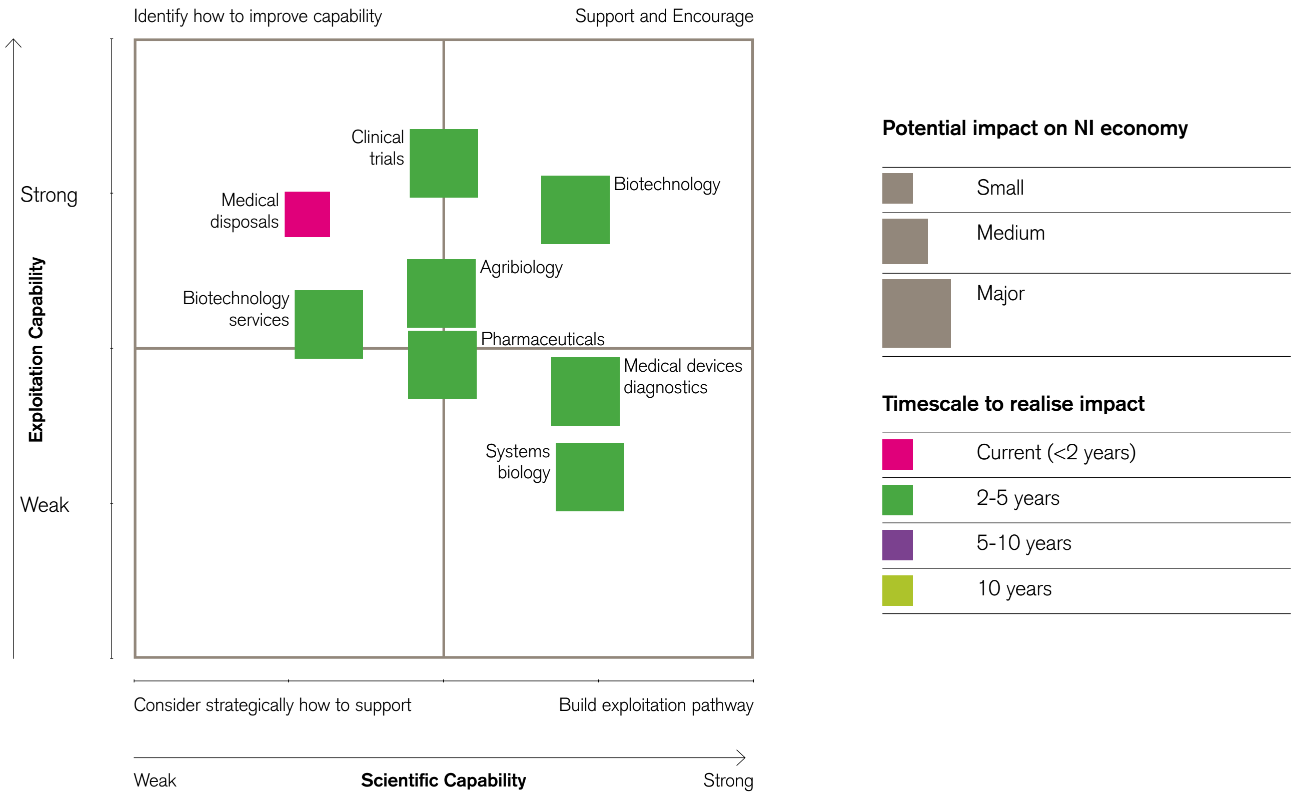
Life Sciences Conclusions
The capability in NI Life Sciences is significant, but fragmented within and between the public, private and academic sectors. The net influence of this is that the potential of the capability cannot be fully exploited. There is limited recognition of the complementary capability of Life Sciences to other sectors such as Agri-food and ICT.

There is little exploitation within Life Sciences of the relevant capabilities that exist within other sectors such as Advanced Materials and Advanced Manufacturing. In some instances, the competitive capability that exists is small in scale and as such, the scope for maximising further development may be limited. The major actors in this sector do not communicate or interact in any meaningful way, undermining the potential for exploitation of capability in other parts of this sector[9].

In order for this sector to progress there is a need to address the fragmentation issue. Better cooperation of the private with the academic sector would alleviate this but there appears to be a mismatch of thoughts and expectations on such co-operation.

9. There are naturally examples of improved connection such as the McRobert award to Randox which was based on NITC and EEECS contributions, however the point in general still stands.

FIGURE 11: LIFESCIENCES CAPABILITY IN NI



ICT

B The sector analysis
Information Communications Technology

Information Communications Technology (ICT) can be defined as the combination of manufacturing and service industries that support the capture, transmission and display of data and information.

In the context of NI, the ICT sector employees almost 11,000 people spread over some 750 companies with a turnover of £833 million, indicating that the majority of companies remain relatively small and predominantly supplying the local market. Growth in this sector has largely been achieved through a combination of cost competitiveness and an emerging business policy environment. A cluster[10] is not developed effectively in NI and this positions it behind the model adopted by countries such as Sweden, the US, Israel and other UK regions, and only slightly ahead of emerging Eastern European countries and India.

The private sector is dominated by the Telecommunications (53%) and Software (34.3%) sub-sections of ICT. Significantly, in this ever-developing section, only 1.9% of turnover is devoted to R&D activities, with 95% of this expenditure allocated to software development. It is also interesting to note that the sector is characterised by a small number of large Multi-National Companies (MNCs) that invest a disproportionately small amount on R&D, and a few mid-tear indigenous companies that together account for some 70% of R&D expenditure.

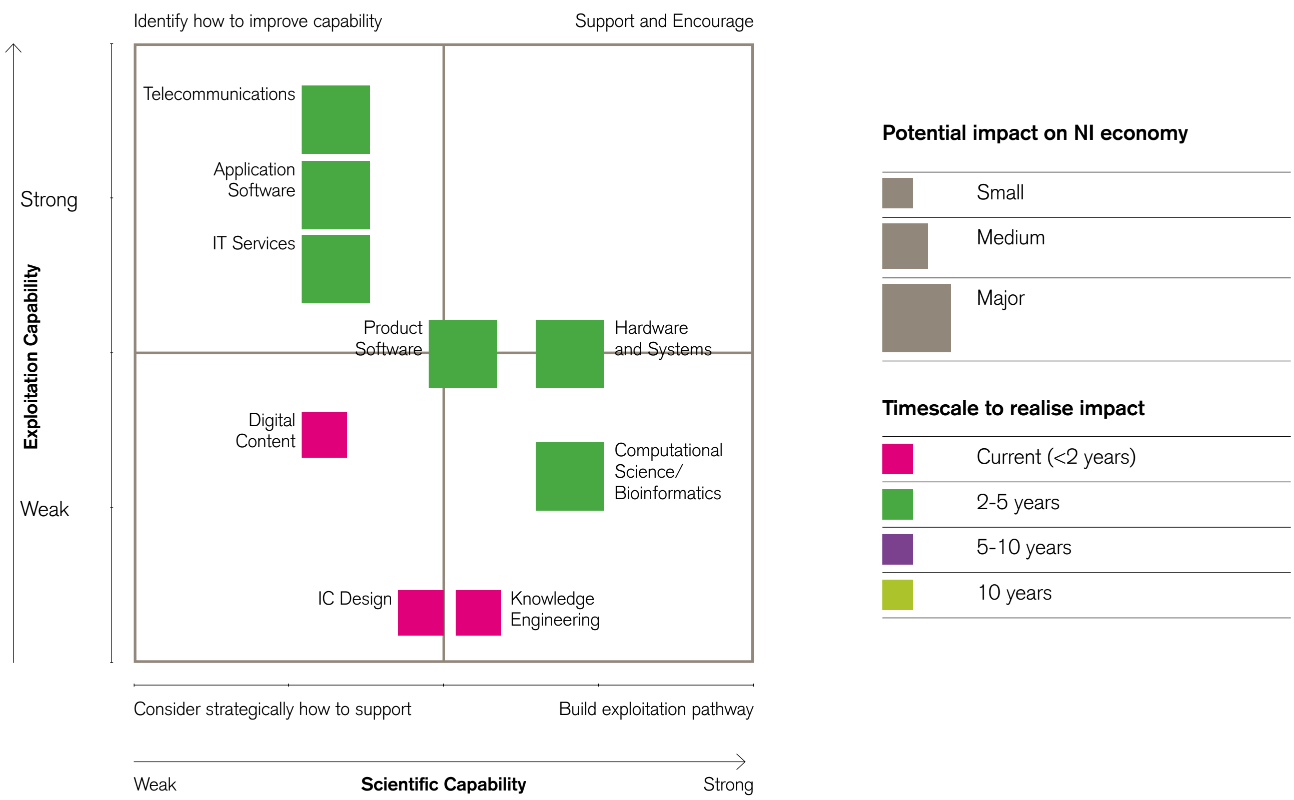
The following figure depicts the capability that currently exists in the NI ICT sector and shows that some capabilities are being well exploited (e.g. nearshoring, product software and application software), but other such as Computational Science and Knowledge Engineering are much less well exploited. It also shows that there is very limited scientific capability in the hardware and systems aspects of ICT in NI.

ICT Sector Conclusions
The sector shows strong exploitation capability in application development but this lacks significant scientific backing. This can be seen in terms of Software Development techniques or the evolution of new business models that are required to deliver Software Package solutions. The ability to understand the models of Software Package solutions will be essential in the future as the amplification of profit enabled by this market is significant. There appears to be significant disconnects between education, skills and exploitation requirements at this time.

As there is not an effective ICT cluster in NI at this time, the development of such a cluster is considered to be a key strategic focus. Additionally, the scientific capability of note that exists in NI is relatively new (e.g. ECIT[11]), and there is a need to align this capability with industry to ensure that it can be exploited to its maximum potential. ICT in NI shall always be a net importer of capability and as such growth of the sector must be based on collaboration with other centres - an integral aspect of ICT clustering. Now the NI ICT environment appears to be in transition as it is losing its low cost competitive position and as such must build upon its technical expertise to ensure that value for money continues to be achievable.

10. The definition and concept of cluster is explained later in this summary.
11. As in all instances, some of the existing ECIT capability was pre-existing within QUB however ECIT was the key manifestation of the development of critical mass in this capability.

FIGURE 12: ICT CAPABILITY IN NI



ELECTRONICS & PHOTONICS

B The sector analysis
Electronics & Photonics

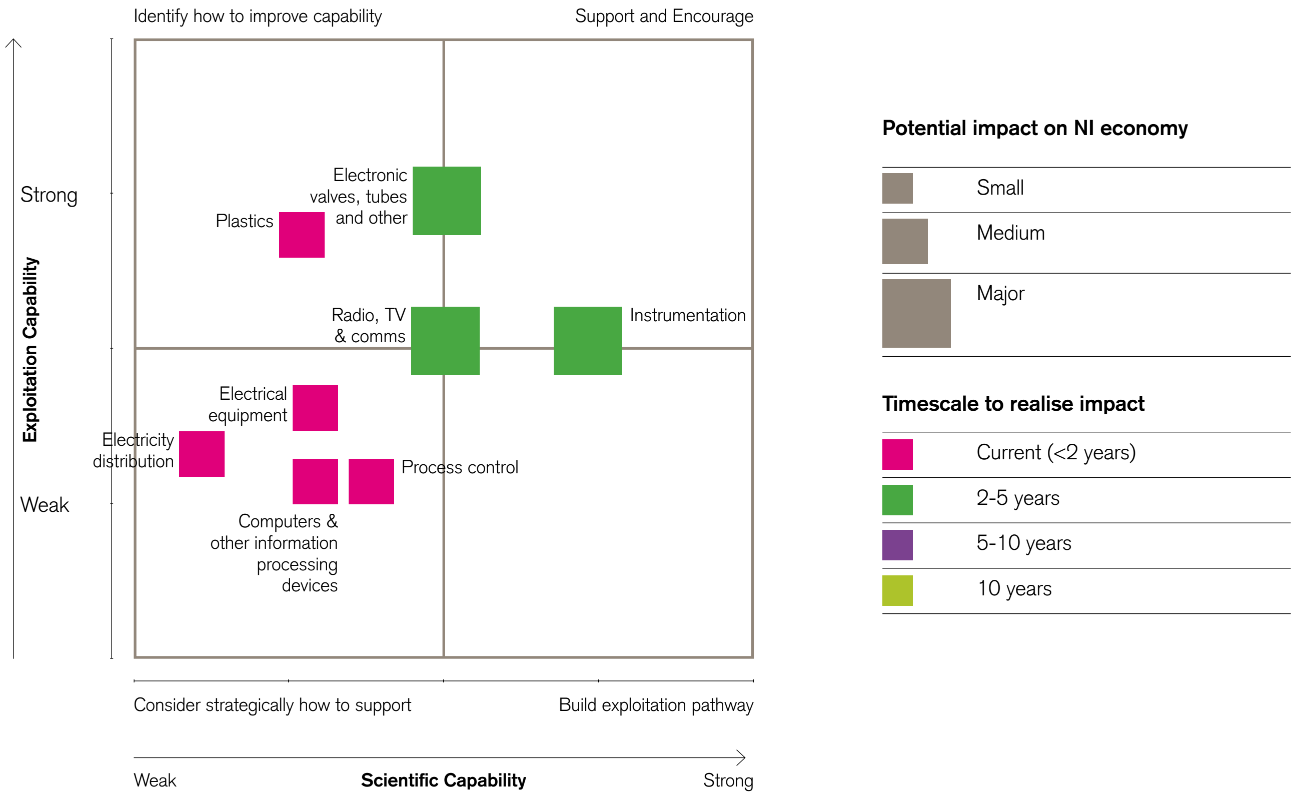
Electronics consists of the development and manufacture of electronic components, integrated circuits and electronic systems, whilst Photonics is defined as the transmission, control and detection of light (photons), and is often referred to as fibre optics or optoelectronics. The sector as a whole has suffered from the fact that most of the integration technologies are specific to the devices they have been customised for. The market for these devices has not been large enough to justify the investment needed to develop large-scale integration technologies that in turn would significantly reduce costs.

The NI Electronics and Photonics private sector comprises of approximately 35 companies that have a collective turnover of £506 million and employ 3,114 people. Of these companies, 23 have an identifiable R&D capability, spending a combined total of £14.1 million, and employing over 300 staff directly on R&D. The sector is characterised by a small number of large companies and large number of indigenous SMEs that tend to focus on niche sectors such as sound compression, ceramic/tantalum capacitors etc.

Electronics and Photonics Conclusions
Electronics and Photonics in itself does not have a strong exploitation capability but its potential lies in exploitation via other sectors. The upper end of capability in this sector is driven by SME companies. However, in NI, these exist primarily by underpinning other sectors channels to markets - Advanced Manufacturing, ICT, Lifesciences etc.

There remains opportunity to advance the sector and it is proposed that the capabilities in the sector are further integrated into Advanced Materials or ICT to provide critical mass and impetus.

FIGURE 13: ELECTRONICS AND PHOTONICS CAPABILITY IN NI



PART 3 BENCHMARKING

In order to gauge the current position of NI with regard to its technology capability, it is important to benchmark it against other regions in the UK and the rest of Europe. Technology indicators measure capability at an aggregate level to allow tracking of changes over time, to inform policymaking and to ensure that these indicators actually drive economic development[12]. In the past 10 years, all developed economies have become interested in tracking their capability for technology and innovations. There is significant development in this area with the development of the European Innovation Scoreboard[13], the UNIDO (United Nations Industrial Development Scoreboard), OECD and UK regional comparators.

Technology Capabilities are the result of knowledge produced by scientific and applied research that culminated in new processes, designs, products and consumer goods. From all the indicators of technology measurement, it is clear that this is a complex process that is difficult to measure but it is worthwhile noting that the bottom line of capability exploitation is reflected in economic measures such as employment, exports and productivity.

In comparing NI, it is important to look at two groupings of indicators for comparison and these are:

- **Regional orientation**
  This evaluates NI regionally at a UK and European level in terms of High Technology Employment, Investment in R&D (Business Expenditure in R&D, Government Expenditure in R&D and Higher Education Expenditure in R&D), Private R&D Funding, Competitiveness, Education and an analysis of the industry present in NI.
- **Technological scoring**
  In Technological scoring, a NI perspective on scoring was derived based on UK scorings that were adapted for the NI position within the UK. These analyses compared NI to global players such as Finland, Sweden, Denmark, Japan etc and looked at two categories;

  Environment
  The assessment of the degree to which the environment in NI is conducive to the development and use of technology - Markets, Regulatory, Infrastructure etc.

  Readiness
  The assessment of the capability of business, government and individuals to leverage the use of technology - Business Readiness, Government Readiness etc.

The analysis of the benchmarking indicates the following key points:

- NI does possess the key drivers for innovation in terms of the quality of science and engineering graduates, the provision of tertiary education and lifelong learning and the quality of youth education. It is worth noting that NI is among other 'small nations' in leading the field in this space - Sweden, Finland, Denmark and is ahead of the large players - US, Japan and India.
- NI has the key tenets of a good intellectual infrastructure. The laws and guidelines pertaining to Intellectual Property creation and transfer are clear and known. The political certainty has increased this standing.
- NI also creates knowledge but does not exploit this knowledge for full economic gain locally. NI does not match the percentage of GERD/HERD from the leading or emerging leaders - however the quality of outcomes where spending has been made has been positive. Therefore, NI needs to scale up investment whilst keeping the same quality level. However, BERD in NI is very low by European comparisons and this would simultaneously need to be addressed. The share of High Technology R&D is relatively low in NI.

12. OCED 2000/2002
13. www.cordis.lu/itt

The university system is doing most of the high technology R&D and attracting significant players internationally. However the exploitation conduit needs to be further examined.

- NI needs a broader innovation system that supports new and existing companies using the latest technologies. The exploitation of knowledge, once created, is the most significant aspect of focus in NI (irrespective of where the knowledge is created). This tends to be sub-divided between the SME sector and the FDI sector. The number of NI SMEs innovating in-house, or co-operating with each other, scores poorly at a national and European level. The focus of NI SMEs tends to be on cost reduction only. From the sectors analysed above, there is limited focus on innovation in SMEs. The top 10 in all sectors tend to account for most of the identifiable innovation in that sector.
- NI needs a significant cultural shift with regards to high technology and how new capabilities resulting from it can be exploited. NI is lagging most other European regions in high technology classified employment. There is typically, where R&D drives the new products or processes of a company and creates the growth in employment, revenue and profit.

Benchmarking Conclusions

In conclusion, the NI benchmarking exercise shows that the eco-system for scientific capability and the innovation it brings is currently fragmented. The overall net effect is that NI is trailing the rest of Western Europe, the US and Eastern countries in terms of the overall technology innovation performance. However, the basic building blocks necessary to build a platform for rapid improvement are already in place in terms of extensive highly competitive capability in R&D, excellent schooling and overall intellectual infrastructure. It is the ‘connectedness’ between these aspects appears to be the most critical missing item.

PART 4 THE FRAMEWORK CONDITIONS FOR TECHNOLOGY IN NI

In this report, the focus is clearly on the Technology Capabilities work and on specific aspects of science and technology as they relate to different sectors. However, as outlined earlier, it has become important to recognise the framework conditions that characterise the NI economy. Framework conditions are the elements that make an environment conducive for the research, development and uptake of new technologies. They are not technology-based but refer to general issues such as incentives, funding, skills etc. Throughout all interviews and workshops conducted, a number of deficiencies in framework conditions were continuously raised.

The SME environment in Northern Ireland

The industrial landscape in NI is characterised by the predominance of SME companies. Whilst employment and GVA predominance resides with the large Foreign Direct Investment (FDI) players, SME companies show a high degree of technology capability and exploitation in a number of the key sectors - specifically Life Science, ICT and Advanced Materials where start-ups and spin-offs are using competitive technology capability and seeking market exploitation.

The SME section of the evaluated sectors shows the variation between the innovative companies and the traditional companies. Innovative companies are showing growth (irrespective of sector) in terms of 20 - 50% per annum with increasing spend on developing technology capability. This is in comparison to traditional companies that are showing no employment growth and in fact a certain amount of decline, although this varies by sector. In some sectors, companies indicated that there was no real decision to grow (Sustainable Production and Consumption). In other sectors, aggressive growth targets were outlined and planning was underway to achieve this growth. Our evaluation of this is that these issues are heavily sector dependent and fundamentally linked to the technological aspect of the sector.

There are some general parameters however, that cause a degree of concern for NI SMEs. These parameters are:

- **Customers and markets**

A large number of SMEs in NI rely on few customers for business, creating cost pressure and dependence. This tends to drive the core business and leaves no time or capacity for the development of other capabilities or markets. This is generally because the SMEs are serving the intermediates in the market.

However, the dependence on the local market is reduced for the more dynamic companies who immediately look to the rest of the UK, the Republic of Ireland and other international markets. These companies tend to seek markets outside of NI to stimulate growth. The view expressed was that the local market did not always provide the 'quality of demand' that they required[14];

All SMEs encountered are very focussed on responsiveness to customer needs, product quality and the development of an excellent reputation. Companies in the Advanced Manufacturing, ICT and Advanced Materials space were very specific on the need to look at product design, quality, cost, price and responsiveness. However, all of these encountered a 'scaling issue' with specific reference to international markets;

- **Collaborations**

SMEs in NI tend to have relatively low amounts of collaborations. In this study, it was noted that their independence is considered an asset. However, prudent selection of partners can produce significant market amplification, particularly in new markets. But this was not always well understood. In certain sectors - Life Sciences, Advanced Materials ICT - collaborations were noted to be significantly higher;

- **Skills and Training**

The ratio of technologists within the SME sector is approximately the same as in the rest of the UK or Republic of Ireland[15]. However, in the key sectors of ICT, Life Sciences, Advanced Materials and Advanced Manufacturing, most, if not all, companies reported difficulties in recruiting the quantity and quality of skills, even in categories that they currently employ. This extends across the skills continuum from the technologists and higher professions to skilled technician resources. SMEs struggle to develop their own skills - they are short of time and other resources and tend to focus on recruiting the 'finished product'. This is of course different from FDI, where their critical mass allows for time and resources to develop skills.

- **Funding**

All SMEs noted the lack of a full spectrum of financing (limited Venture Capitalists[16], limited Banking resources etc) and that innovation costs are high with long pay-back periods. This funding gap is seen as a major inhibitor to success. Above all, the lack of innovation capacity was deemed most critical. Most SMEs are seeking more 'space' to be innovative but needed to mind the day-to-day business. This is also related to funding.

- **Government Supports**

Linked to the previous point, it is also evident that SMEs in NI are not always fully aware of the full range of Government funding and supports available to them. Most funding seems to come from local government funding (InvestNI) with some smaller participation in EU funding schemes. Whilst established manufacturing firms appear to receive funding however, Advanced Materials or newer companies explained some difficulties. It is difficult to analyse the cause of this but it

14. All ICT Companies and Advanced Materials companies interviewed perceived the 'global market' to be there market. In some other sectors, the focus is more local.
15. Expert Skills Group (Republic of Ireland)
16. Where VCs do exist, they focus on later stage funding.

could be a lack of awareness on their behalf or perhaps some issues relating to the form of funding;

The FDI sector
The FDI sector in NI is significant in terms of technology capability and capacity. Companies such as Seagate Technology, DuPont, Bombardier Aerospace, Caterpillar, Allstate (Northbrook), Liberty Mutual, Daewoo, BT, Halifax and Prudential and HCL are the big players in the 640 externally-owned companies in NI. The employment numbers of skills and capable resources are significant - 74,000 by 2005 numbers. More importantly, these companies are bringing and developing significant skills to NI. It must be recognised that the efforts to cultivate these industries is very different from those that are required for the SME sectors outlined above.

- **Broadening the scope of FDI for NI**

The scope of efforts to attract FDI must encompass all economic sectors. The tendency in the past has been to focus on infrastructure and on efficiency-seeking FDI in manufacturing. In the future, more and more FDI will be market seeking investment in service sectors as well as investment in offshore or near shore services[17]. This is consistent with the NI Corporate Plan which seeks greater selectivity and focus in sectors beyond infrastructure and manufacturing;

- **Tackling FDI macroeconomic issues**

The requirements for efficiency-seeking investment in manufacturing are increasingly well understood - low factor costs, a flexible labour market, a small regulatory burden, efficient infrastructure and customs. Less obvious factors include easy access to a competitive supplier base and business service providers. A similar analysis applies to Nearshoring capabilities as these are also becoming smarter as the investors learn lessons from previous endeavours.

Despite some negative viewpoints, FDI remains a very strong proposition. FDI flows to and from OECD countries increased significantly in 2006, outflows by 29% to $1.12 billion and inflows by 22% to $910 billion. These are the second highest levels in the history of OECD, exceeded only in the boom year 2000. Hence, although there may be negativity surrounding FDI and its direction, the facts indicate that the FDI global market remains buoyant albeit very focussed on what it requires from specific sectors.

As an example to NI, it is important to note some of the developments in FDI across the developed world. Despite high cost, Sweden has seen FDI inflows more than double to $28 billion in 2006. This increase reflects corporate takeovers to some extent, although it also reflects the ability of new companies to invest in markets where technology capability is deemed to be high and where substantive innovation is available.

FDI Conclusions
Going forward, the battle for FDI will increasingly be fought at the microeconomic level sector by sector (Advanced Materials, Advanced Manufacturing, Life Sciences). Of course, foreign investors will continue to insist on basic political and macroeconomic stability, but this should become less important as a differentiating factor. Investors will look increasingly at microeconomic conditions, and what they look for will vary significantly from one sector to another.

Education and Skills development/ continued support
The NI education system is unique within the UK in that it has its own curriculum regulations and school funding as well as unique arrangements for Further and Higher Education. However, the challenges facing the education of Science, Technology, Engineering and Mathematics (STEM) and related subjects (which are critical to the fostering of innovation capabilities) at all levels are similar to the rest of the UK.

Science and Technology is a fast moving area. Smaller countries show that they can rapidly manage the variations in the area by changing directions or emphasis in relatively short periods of time. Throughout this study, it was apparent that most people felt that STEM in NI could be more coherently managed, offering advantages on the rest of the UK.

Currently, NI remains in a slightly better situation than the UK in terms of post- 16 uptake in science subjects, and has a strong participation and achievement in education overall. This is reflected strongly in the Benchmarking conducted in Chapter 8. Participation of 16-17 year olds in full time education and training is high at around 78% as compared to only 67% in England, and these rates have shown a steady increase in recent years. GCSE and A-level results are traditionally higher in NI than the national UK average. However, in the uptake of science and engineering, NI follows similar trends to the UK. At A-level, NI consistently enters a slightly higher proportion of its students for science subjects than in the UK as a whole, but patterns of low and declining entries in the HE and FE physical sciences are the same.

NI and the skills that enable technology exploitation
In the Benchmarking section, the point was made that while NI continues to have high rates of participation in higher education, student migration away from NI continues to persist, with up to 30% of NI students moving away to take their degree and not returning. Often the cap on higher education places in NI is blamed for this but the evidence presents a more complex picture:

- The students who leave tend, on average, to be better qualified in terms of 'A' level scores than those that remain in Northern Ireland;

17. There are a number of Horizon panels looking at this currently.

- The vast majority of those that leave do so to secure their first choice course as decided upon during the application process;
- Those students who leave NI tend to be drawn much more heavily from the higher socio-economic groups; and
- The proportion of NI students who study in GB and return after graduation has stayed more or less constant since 1996/97.
- Whilst there is emerging evidence that the proportion of NI students leaving the region is declining, the 'brain drain' problem is still significant. Because these students' departure from NI appears to be more out of choice as opposed to being a result of necessity brought about by an inability to secure a place in a NI university, this situation poses particular challenges for the economy.

Technology Transfer in NI

The key finding in this report is that NI has scientific capability but also has an inability to transfer or exploit new ideas and approaches within industry[18]. This can be rectified in a variety of ways, including the application of greater creativity to business planning, the use of design, the promotion of innovative business practices (especially in smaller SMEs) and through the establishment of cross-sectoral business networks and clusters for firms of all sizes through which to transfer and disseminate knowledge, experience and best practice.

Central to a truly innovative economy is a strong and commercially-focused R&D base and the successful exploitation of internationally competitive science and technology by industries focused on future business trends. However, R&D is only one aspect, and increasingly, innovation is no longer seen as the preserve of a small elite of companies working in high-technology sectors and investing in costly R&D programmes. The innovation agenda is relevant for all NI firms irrespective of industrial sector or size.

In an increasingly competitive global economy, the application of innovation has become a necessary precondition for competitive performance. NI can no longer compete on low wages and costs. Identification and differentiation of regional innovation and R&D capabilities is the basis for economic growth, particularly for small regional economies such as NI that are endeavouring to become more knowledge-based.

This report supports the view that a market failure exists in relation to the level of R&D in Northern Ireland. Underinvestment in R&D and innovation is due to the inherent risk in R&D and the fact that there is a reluctance to take such risks in NI. A degree of intervention is thus required to realise the knowledge spillovers that stem from R&D and innovation, thereby resulting in benefits to the economy as a whole[19].

Throughout this study on capabilities, most stakeholders recognised that improving and enhancing NI's overall innovation and R&D performance will lead to increased productivity and prosperity, moving the NI economy up the value-added chain. Failure to do so will, at best, result in moderate economic performance and failure to secure the goal of closing the productivity gap with the rest of the UK at a faster rate that is currently being observed. In order to accomplish this, some significant 'framework' issues appear to need to be addressed:

- The proportion of NI firms engaged in innovation needs to increase significantly;
- Although NI's innovation propensity is similar to that of the UK, it is currently ranked eleventh of the twelve UK regions in terms of BERD. A significant step change is required for NI to close the gap;
- NI HERD, at 0.6% of GVA, is above the UK average of 0.4%. It is apparent from all sectors however, that businesses are not making adequate use of the R&D being carried out within the HE sector. NI businesses (FDI and SME) need to become more proactive in exploiting the HE R&D base and in working with HE institutions in more and better collaborative R&D. The ratio of HERD to BERD and the model outlined in Figure 13 suggests that NI's innovation system is essentially supply-driven. This means that Scientific Capability is being created before the exploitation channels do exist or can exist. Hence, NI must develop the demand side of its innovation system.
- Most companies and institutions visited outlined high costs as being a primary barrier to investing more in innovation or R&D. Many smaller firms trading in more traditional sectors in NI (e.g. SP&C), do not see innovation-related activity as an intrinsic aspect of their business planning. In order to facilitate this, greater awareness of the availability of innovation and R&D support programmes (in addition to existing Tax Credits) and their potential benefit is important to develop. For SMEs, some form of tax-incentivised investment funding, of a private equity nature, would also be useful;
- In many sectors, outside of the top 10 - 15 companies, businesses are often unwilling or unable to carry out effective future planning through horizon scanning 'Foresight' activities. Companies should continue to be encouraged to recognise that forward planning and horizon scanning is necessary if they are to be in a position to exploit new business opportunities as they arise. It could be useful to structure this by sector;
- In the skills sector there is an open acknowledgement from industry that

18. There are examples where this connectivity has occurred - Kainos, Andor etc. and these reflect the ability of the universities to transfer knowledge. In the future a greater scale of similar examples will be required. The Connected collaboration programme (2007) and others noted further in this document appear to be key steps in achieving this).
19. Search for Spillovers - The RTD Centres of Excellence

a broader range of skills is required to encourage innovative thinking as a core skill. Although believed to be an inherent skill, this is a learned management skill reflecting a comprehensive understanding of innovation or enterprise. NI firms tend to under-invest in relevant staff training and offer too few staff development opportunities in terms of innovation and R&D (it is unclear if there is a career path for researchers within Northern Ireland).

Education and Skills Conclusions

It is fully acknowledged that many of these issues are not new and there are already a number of initiatives aimed at addressing many of them. These changes include curriculum changes and the implementation of the NI Skills Strategy. However, it is also recognised that the development of innovation skills in NI businesses will continue to be a key challenge to be overcome in progressing NI's future knowledge economy and that businesses themselves must lead in the development of these skills through closer association with the education and vocational training sectors.

The interaction between NI business and the HE-FE sector has grown significantly during the past decade[20], but it is clear from the capabilities mapping that there remains room for improvement. The universities in particular have made noteworthy efforts to open their R&D pipelines to commercial exploitation opportunities. This is demonstrated in the Advanced Materials and ICT sectors in particular. Business, on the other hand, needs to do more to engage with the HE community in a more proactive fashion in order to 'pull' through more and better commercially realisable R&D.

Finally, the absorptive capacity (i.e. the ability of a firm to internalise external knowledge) is also highly important in determining whether an establishment engages in R&D spending. It appears that the lower levels of absorptive capacity within NI actually increase the costs of collaborative technology partnerships between the universities and the companies involved. This 'disconnect' needs to be openly addressed as it is a clear market failing.

20. Search for Spillovers - The RTD Centres of Excellence

PART 5 CONCLUSIONS

In this review, we consider both scientific and exploitation capability as they relate to the overall technology capability within NI. It is therefore important to note that, whilst scientific technology capability is the knowledge, skills and experience are necessary in companies to produce, innovate and organise this knowledge into meaningful outputs (exploitation).

The role of technology capability in economic or industrial growth has been recognised for a significant period of time[21]. The OECD, through a number of reports, has demonstrated that over 50% of growth in advanced countries is derived from technology capability and the resultant innovations[22]. Furthermore, industrial development is the process of building technological capabilities through learning and then translating that learning into product/ process innovations that create employment and income in the course of continuous technological change.

In this report, it has been important to place a broad definition on Technology Capabilities. Technology Capability is the ability to make effective use of scientific knowledge in production, engineering and innovation in order to create and sustain competitiveness in price, quality and market. This capability therefore allows companies to assimilate, use and adapt new or existing scientific capability. It also allows companies to create new technologies and to develop new products/processes as markets change. This becomes very important in the context of NI.

In this analysis of NI, we have developed a model for understanding capability in the NI context. This model was evolved over the course of the study due to the fact that it is now believed that there is a key mismatch within the NI industrial landscape. This mismatch exists in principle between the knowledge creators (universities and some individual companies) and the exploiters (majority of companies in each sector). This model is demonstrated in Figure 14.

Figure 14 outlines the twin pillars of the MATRIX work. Industrial growth (on the right hand side) is developed through the Foresight panels that determine high technology or medium low technology selection areas for the specific sectors in Northern Ireland. The selection of specific technologies is dependent on the analysis of what the sector needs, the existing capabilities within the sector and where new markets can be identified. Clearly this foresight produces the need to derive new industrial policies or to revamp existing ones. This capability study has looked to identify the domestic Technology Capability by sector. In addition, it has determined issues concerning technology transfer within NI, the overall innovation learning process and how policies at the technology/skills areas impact on NI (the left hand side of the figure above). These has been crystallised by the benchmarking exercises also. The focus of the conclusions of this report are on NI Technology Capability only, it does acknowledges the other issues within the overall infrastructure in Northern Ireland.

NI Domestic Technology Capabilities

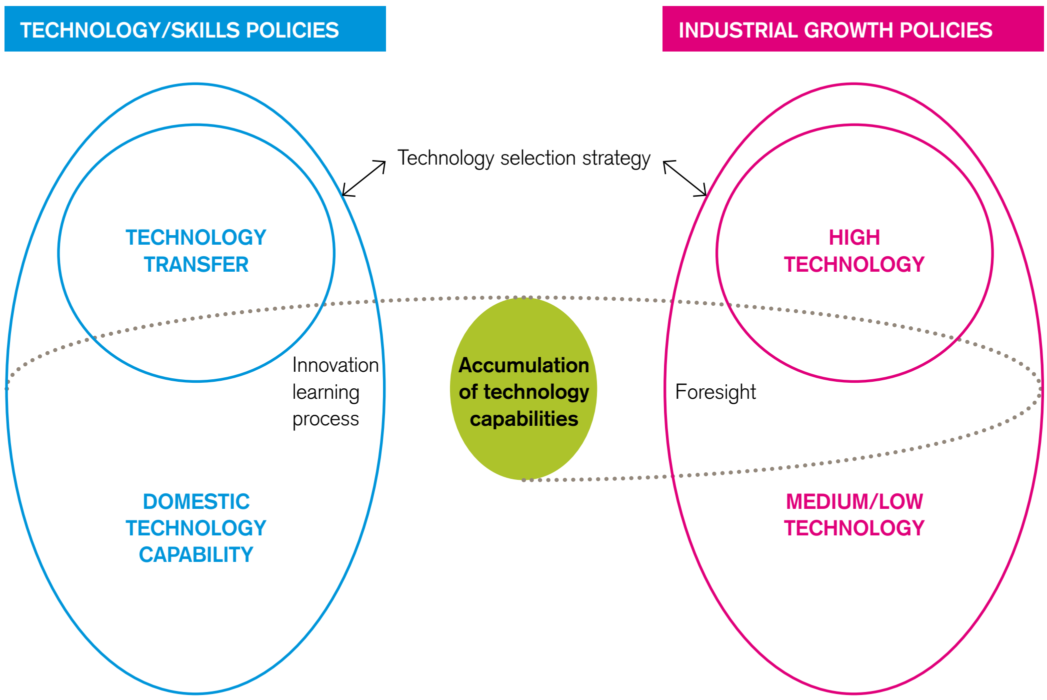
The findings with regards to the Technology Capabilities in NI indicate a dichotomy. Normally, in economic development, the exploitation capability exceeds the scientific capability significantly. This tends to be driven by the factors of relatively low cost, incentives etc. As employment rises and economic costs increase there is the pressures to rise up the value chain - in other terms develop scientific capabilities beyond the cost-dependent activities normally conducted. This requires an emphasis on science, technology and higher degrees of innovation using the platforms of exploitation that are already in existence (i.e. access to markets, market understandings etc). The key aspect of this however is that the overall direction of the science and technology capability building is related to the existing exploitation base thereby ensuring a high degree of overlap between the new emerging Technology Capability and the legacy exploitation capability. This provides an accelerator mechanism to exploit the deeper Technology Capability.

In NI there is a relatively distinct decoupling between the scientific capability that has been developed and the exploitation of this capability. There are of course instances where this is not the case, but in general, the areas of overlap are much less where the breath of areas of highly competitive capability is greater than expected. This appears to indicate effectively two different systems in operation at different paces. Without a tighter coupling, both aspects are in danger as scientific capability without a chance of exploitation is vulnerable and exploitation without scientific capability is always subject to market costs and market rules.

Finally, irrespective of the findings from the Horizon Foresight panels, it is evident that in all sectors, NI will be a 'net importer' of scientific capability. The expression 'net importer' implies that the region will need to be able to absorb developments in these sectors and apply them to companies within NI, as it will not have the capacity to develop these fundamental understandings itself. This will mean that commercial intelligence is required to secure relevant and appropriate knowledge from outside the region and that this knowledge will need to be translated into relevant sector solutions for the region using knowledge of the existing value chain in the region. This knowledge will also have to be 'packaged' differently depending on the size of industry with emerging sectors (Life Sciences) requiring different SME support than established sectors (Aerospace and Food). In this space between fundamental research and markets, NI will need to have a multi-disciplinary excellence to create and sustain successful companies in the selected sectors. The expression 'net importer' should not be misunderstood. To import,

21. Solow 1956
22. OCED/Grossman 1991

FIGURE 14: THE ANALYTICAL FRAMEWORK FOR TECHNOLOGY CAPABILITY, TECHNOLOGY LEARNING AND INDUSTRIAL GROWTH INNORTHERN IRELAND



implies the ability to fully comprehend what is being imported and relies on a deep local capability in fundamental science and advanced technology. Once knowledge is imported, it can then be adapted for exploitation through international markets.

The technology capability in Northern Ireland
NI does possess competitive technology capability but this is not always integrated and this is demonstrated in Table 1.

From the analysis of Table 1, the key sectors with deep technology strengths in NI are Advanced Manufacturing, Advanced Materials and Life Sciences. ICT and Sustainable Production and Consumption (which includes Energy) are generally strong in terms of employment and hence exploitation. However, the linkages between scientific capability and exploitation capability are relatively weak in these sectors;

The developments in Advanced Materials support and enable the efforts of Life Sciences and Advanced Manufacturing. The linkages are most apparent in the newer inter-disciplinary areas of Advanced Materials - Biomaterials, Nanostructured Materials, and Multi-functional Materials.

Across ICT, Life Sciences, Advanced Manufacturing and Advanced Materials the predominance of Computational Science - in multiple guises - is very important and of growing relevance.

In Life Sciences, the biomedical capability allied to Clinical Trials enables NI to further develop this sector in specific directions. This same capability, if transferred to the SP&C sector, would also enhance the Agri-food business, when coupled with the traditional animal and plant capability in that sector.

From the analysis of these sectors, it appears that it would be preferable to map the capability in Electronics and Photonics into the Embedded Systems capability in the ICT sector. The overlap is significant based on existing capability.

It is also evident that the exploitation capability in SP&C requires the capability from Advanced Materials (packaging), ICT (toolsets) and Life Sciences (Biomedical) to make further directions into the existing and future direction of that sector.

The coupling of the Advanced Manufacturing sector with the Advanced Materials sector will be of great significance in the further development of both sectors within NI and the integration of the strengths in Life Sciences with Advanced Manufacturing and Advanced Materials will support the further development of medical devices and diagnostics.

There are gaps within these capabilities. The gaps appear in terms of Scientific Capability (as in ICT for example) and in Exploitation Capability (as in Life Sciences, Advanced Materials etc). In many cases however, the overlapping of capability between sectors is seen as critical in the development of the new products and solutions for the economy. The application of Life Sciences techniques, Advanced Materials and ICT solutions to Agrifood are an example of this, as is the combination of Advanced Materials and Advanced Manufacturing.

The Horizon panels will need to evaluate these issues in further detail to ascertain where exactly the overlaps and relevant focus needs to be.

TABLE 1 SUMMARY OF CAPABILITY IN NI[23]

SECTOR	TECHNOLOGY CAPABILITY STRENGTHS	EXPLOITATION CAPABILITY STRENGTHS
Advanced Manufacturing	Advanced Materials in multi-disciplinary areas - Composites, Multi-functional Materials, BioMaterials, and Nanostructured Materials Polymers, Metallics Computational Science Design, Simulation and Validation	Advanced Manufacturing Capabilities using Composites, Multi-functional Materials, BioMaterials, and Nanostructured Materials Computational Science Design, Simulation and Validation
Advanced Materials	Nanostructured Materials, Composites, Multi-functional Materials, Catalysts, BioMaterials, Computational Science	Nanostructured Materials, Composites, Multi-functional Materials, Magnetic Materials, Composites, Computational Science
SP&C	Animal Welfare Animal Breeding and Biotechnology Plant Breeding and Biotechnology Environmental Technologies	Animal Welfare Animal Breeding and Biotechnology Plant Breeding and Biotechnology Food technology Engineering, Mechanisation and ICT Energy Creation
Life Sciences	Medical Devices and Diagnostics Biomedical Science Biotechnology Computational Science (Systems Biology)	Medical Devices and Diagnostics Biomedical Science Computational Science (Systems Biology) AgriBiology Biotechnology Services Clinical Trials Pharmaceuticals
ICT	H/W & Systems (ECIT) Computational Science Knowledge Engineering	H/W and Systems Computational Science Telecommunications Application Software Product Software
Electronics and Photonics	Instrumentation	Plastics Electronic Valves • Radio, TV and Telecommunications

23. There are capabilities strengths in technology and exploitation in all these sectors. The positioning in this table reflects where the core strength lies.

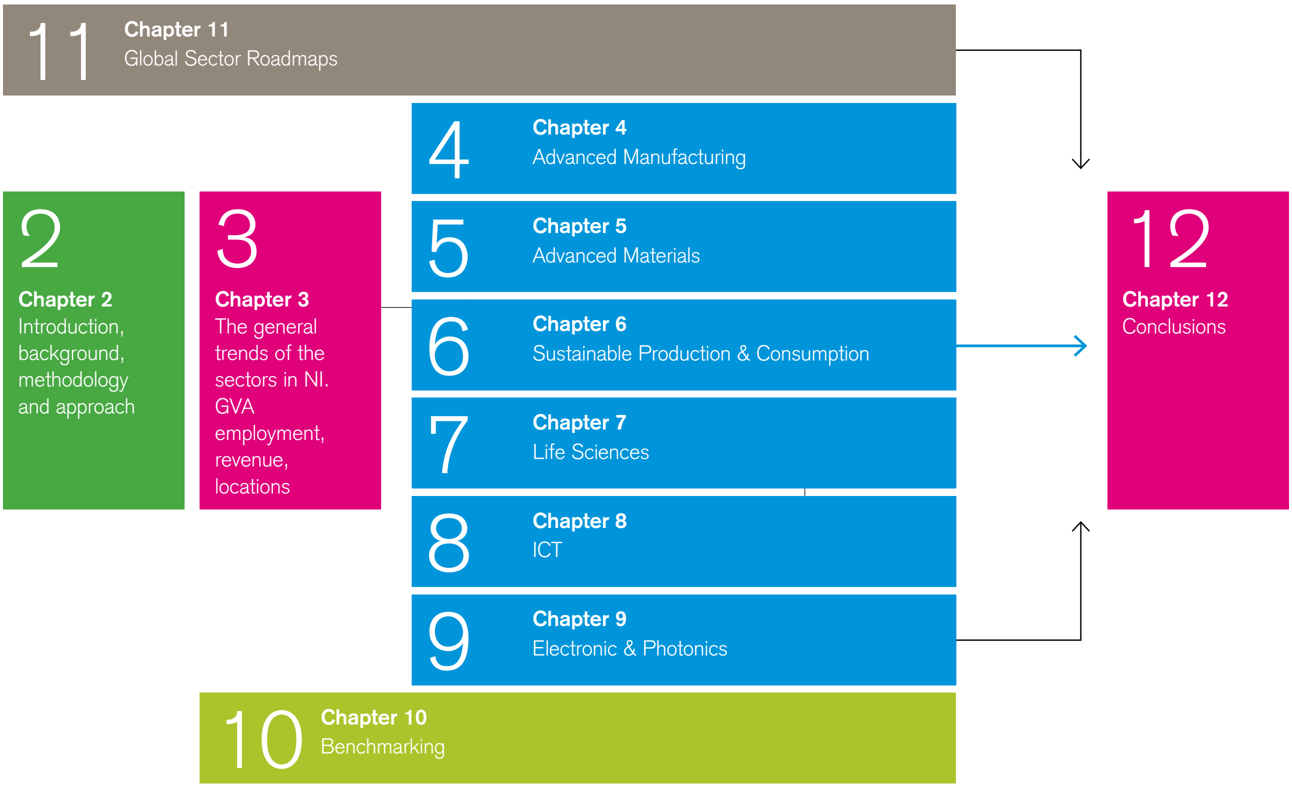
CONTENTS

REPORT NAVIGATION

THIS REPORT LOOKS AT SIX SECTORS IN NORTHERN IRELAND AS DEFINED BY THE UK TECHNOLOGY STRATEGY. ALL COMPANIES AND INSTITUTIONS IN NI ARE GROUPED INTO THESE SECTORS BASED ON DETI CODE DEFINITIONS. ALL THE DATA PERTAINING TO THESE COMPANIES AND INSTITUTIONS REFLECTS 2005 DATA AS THIS IS THE LATEST YEAR FOR WHICH COMPREHENSIVE COMPANY DATA IS AVAILABLE. THE UNIVERSITIES ARE LISTED AND REPORTED BASED ON RAE 2001 DATA.

1

FIGURE 1.1: CAPABILITY STUDY REPORT NAVIGATION



For the ease of reading, this report has the following navigation as presented in Figure 1.1

Chapter 1
It is recognised that this report is complex in terms of the data it represents and the background to that data. This chapter seeks to provide the reader with clear navigation and a connection between all the individual chapters.

Rationale: This report takes a top down approach. It defines the approach and methodology to the capability study. It then scopes each individual sector, describes the NI situation and then proceeds to develop an evaluation of that sector based on available information based lined in 2005. Once each sector is analysed, the benchmarking of NI is conducted and this is then further developed as the key roadmaps for each sector are outlined, in a global context.

Approach: This chapter describes each individual chapter in the report and relates them to each other.

Chapter 2: Introduction
This chapter provides a background to the Technology Capabilities Report and also explains the mechanisms of mapping the capabilities and the overall approach and methodology.

Rationale: The background to this report is important to be borne in mind. This work represents a first attempt to look at how existing capabilities exist within NI. These capabilities are defined in terms of exploitation pathways or scientific pathways and sometimes these items are not always linked together. For economic optimisation, all scientific capabilities should be linked to exploitation capabilities however this is not always achievable. The approach to the work is explained in detail including items such as benchmarking etc.

Approach: This chapter explains the three phases of the approach used to gather the data presented in this report. Ultimately, all data capture requires a degree of subjective judgement to determine if it is highly competitive, competitive or not. In this report, judgement is applied based on a rating of 1 - 5 for exploitation or scientific capability. This scoring mechanism is explained in full in this chapter.

Chapter 3: The general trends of the sectors in NI
In this chapter, the general trends of the sectors (as defined for this report) are outlined. These trends include GVA by sector, Employment, Revenue, Turnover and the relative concentration of locations.

Rationale: It is important to understand the significance of sectors (baselined to 2005) in this report. For example, this chapter explains that Sustainable Production and Consumption and Advanced Manufacturing are the most significant sectors, although these are underpinned by Advanced Materials, ICT and Electronics and Photonics capabilities.

Approach: All the sectors are compared to each other in terms of specific measurements, which are defined, explained and then analysed.

Each sector is then individually analysed in a specific chapter. This covers chapters 4 - 9 (inclusive) of this report.

Chapter 4: Advanced Manufacturing
In this chapter, Advanced Manufacturing is defined, described as a sector in NI, the key trends are identified and then the public, private and academic sectors (including HE/FE) are defined. This leads to a sector capability summary.

Rationale: Although all sectors are dependent on each other, they are defined and treated separately within this report. It is recognised that there are overlapping dependencies and these are referred to however, from a capability perspective, a company or institution, whilst having multiple capabilities is anchored in a specific sector.

Approach: The approach is to define the sector, describe it in the NI context, and then proceed to identify the key trends in the sector culminating in an evaluation of the private, public and academic capabilities in the sector. This is then pulled together into a series of conclusions.

Chapter 5: Advanced Materials
In this chapter, Advanced Materials is defined, described as a sector in NI, the key trends are identified and then the public, private and academic sectors (including HE/FE) are defined. This leads to a sector capability summary.

Rationale: Although all sectors are dependent on each other, they are defined and treated separately within this report. It is recognised that there are overlapping dependencies and these are referred to however, from a capability perspective, a company or institution, whilst having multiple capabilities is anchored in a specific sector.

Approach: The approach is to define the sector, describe it in the NI context, and then proceed to identify the key trends in the sector culminating in an evaluation of the private, public and academic capabilities in the sector. This is then pulled together into a series of conclusions.

Chapter 6: Sustainable Production & Consumption
In this chapter, Sustainable Production & Consumption is defined, described as a sector in NI, the key trends are identified and then the public, private and academic sectors (including HE/FE) are defined. This leads to a sector capability summary.

Rationale: Although all sectors are dependent on each other, they are defined and treated separately within this report. It is recognised that there are overlapping dependencies and these are referred to however, from a capability perspective, a company or institution, whilst having multiple capabilities is anchored in a specific sector.

Approach: The approach is to define the sector, describe it in the NI context, and then proceed to identify the key trends in the sector culminating in an evaluation of the private, public and academic capabilities in the sector. This is then pulled together into a series of conclusions.

Chapter 7: Life Sciences
In this chapter, Life Sciences is defined, described as a sector in NI, the key trends are identified and then the public, private and academic sectors (including HE/FE) are defined. This leads to a sector capability summary.

Rationale: Although all sectors are dependent on each other, they are defined and treated separately within this report. It is recognised that there are overlapping dependencies and these are referred to however, from a capability perspective, a company or institution, whilst having multiple capabilities is anchored in a specific sector.

Approach: The approach is to define the sector, describe it in the NI context, and then proceed to identify the key trends in the sector culminating in an evaluation of the private, public and academic capabilities in the sector. This is then pulled together into a series of conclusions.

Chapter 8: ICT
In this chapter, ICT is defined, described as a sector in NI, the key trends are identified and then the public, private and academic sectors (including HE/FE) are defined. This leads to a sector capability summary.

Rationale: Although all sectors are dependent on each other, they are defined and treated separately within this report. It is recognised that there are overlapping dependencies and these are referred to however, from a capability perspective, a company or institution, whilst having multiple capabilities is anchored in a specific sector.

Approach: The approach is to define the sector, describe it in the NI context, and then proceed to identify the key trends in the sector culminating in an evaluation of the private, public and academic capabilities in the sector. This is then pulled together into a series of conclusions.

Chapter 9: Electronics and Photonics
In this chapter, Electronics & Photonics is defined, described as a sector in NI, the key trends are identified and then the public, private and academic sectors (including HE/FE) are defined. This leads to a sector capability summary.

Rationale: Although all sectors are dependent on each other, they are defined and treated separately within this report. It is recognised that there are overlapping dependencies and these are referred to however, from a capability perspective, a company or institution, whilst having multiple capabilities is anchored in a specific sector.

Approach: The approach is to define the sector, describe it in the NI context, and then proceed to identify the key trends in the sector culminating in an evaluation of the private, public and academic capabilities in the sector. This is then pulled together into a series of conclusions.

Chapter 10: Regional Comparison/ Benchmarking
In this chapter, NI is compared as a region to other regions in the UK, and Europe and on a global level in general. The arguments supporting NI is that it gains at a global level from UK infrastructure but loses in terms of local connections of science and technology.

Rationale: There is a limited amount of quantitative data available at the regional level (which is what NI is considered as) and thus extrapolations of data are used given these constraints. Technology indicators measure capability at an aggregate level to allow tracking of changes over time, to inform policy making and also to ensure that these indicators actually drive economic development[24]. In the past 10 years, all developed economies have become interested in tracking their capability for technology and innovations. There is significant development in this area with the development of the European Innovation Scoreboard[25], the UNIDO (United Nations Industrial Development Scoreboard), OECD and UK regional comparators.

In comparing NI, this chapter looks at two input indicators for comparison and these are Regional Orientation and Technological Scoring.

Approach: The approach in this chapter is to develop comparisons with NI in the UK context, then a European context and ultimately in a global context. These results are then graphically demonstrated and then analysed and explained for the key messages.

Chapter 11: Global Sector Roadmaps
In this chapter, there is a presentation of the global roadmaps that are changing the sector that are discussed in chapters 3 - 9 above. This is because these sectors are developed in other countries and based on their current maturity a number of technology trends appear poised to have significant global effects in the next few decades. It is important to be aware that these sectors are not isolated and there is a significant amount of intersection and cross-fertilisation between each.

Rationale: This chapter presents roadmaps that all the identified sectors need to embrace in an NI context. These roadmaps do not determine the future of these sectors in NI but allow the Foresight groups develop an understanding of what would need to be considered for the future of the sectors in NI.

Approach: The approach is to describe each sector in global terms and the key technologies impacting these sectors.

Chapter 12: Conclusions
This chapter presents a model for understanding capability in the NI context. This model is based on understanding technology capability as it exists and how this capability is present in the NI environment. This model was evolved over the course of the study.

Rationale: There is a need to collate the results from all the previous chapters to produce a review of the NI Technology capabilities and how these impact critical items such as Technology Transfer, Technology Capability and the SME/FDI markets respectively.

Approach: The approach here has been to develop a model for how NI needs to consider the capability uncovered and how this relates to market exploitation channels which exist or need to be created in NI.

Chapter 13: Framework Conditions
This chapter presents an analysis of the Framework Conditions pertaining to the Technology Capabilities in Northern Ireland. Whilst the remainder of the report focuses on the Technology Capabilities work it has become important to recognise the framework conditions that characterise the NI economy. Framework conditions are the elements that make an environment conducive for the research, development and uptake of new technologies. They are not technology-based but refer to general issues such as incentives, funding, skills etc. Throughout all interviews

24. OCED 2000/2002
25. www.cordis.lu/itt

and workshops conducted a number of framework conditions were continuously raised. Rationale: There is a need to collate the results from all the meetings conducted in this study to present some critical elements that were raised across all companies. These include the Degree of Clustering, the SME Environment in NI, FDI in Northern Ireland, Education and Skills and Technology Transfer.

Approach: The content here reflects the common strands of thought developed in all the interviews and workshops that have been conducted to date. These issues are not technology-related but rather reflect the 'eco-system' in which the technology is operating.

INTRODUCTION

2

2.1 BACKGROUND

MATRIX, the NI Science Industry Panel, is an expert advisory panel reporting on matters pertinent to the exploitation and commercialisation of science, technology and R&D. Led by high-technology and R&D-intensive industry, it advises NI Government on the development of improved interfaces between NI business and the research, science and technology base. The aim is to ensure that the NI science and technology strengths are exploited for maximum economic and commercial advantage.

The Horizon Programme is the MATRIX Panel's strategic technology Foresight programme, seeking to identify key technologies that will be of specific commercial value to the NI economy over time-spans five, 10 and 15 years. It comprises of five technology Foresight panels which will seek to inform both NI Government policy and private sector business planning in a manner that best places the region for the exploitation of future commercial opportunities arising from its R&D and science and technology base.

As part of this programme MATRIX has commissioned this study and tasked it with identifying Northern Ireland's economic generating research and technology strengths. It is a complex and comprehensive study identifying six key technology areas:

- Advanced Manufacturing;
- Advanced Materials;
- Sustainable Production and Consumption (including Emerging Technologies);
- Life Sciences;
- Information and Communications Technology (ICT); and
- Electronics & Photonics.

These focus areas are based on the UK Technology Strategy launched by the Department of Trade and Industry (DTI) Technology Strategy Board in May 2006. Their medium-term strategies were developed in consultation with business and provided a technology focus, creating a dialogue for taking forward activity in areas where UK business can succeed. The strategies build on the Call to Action document published in November 2005.

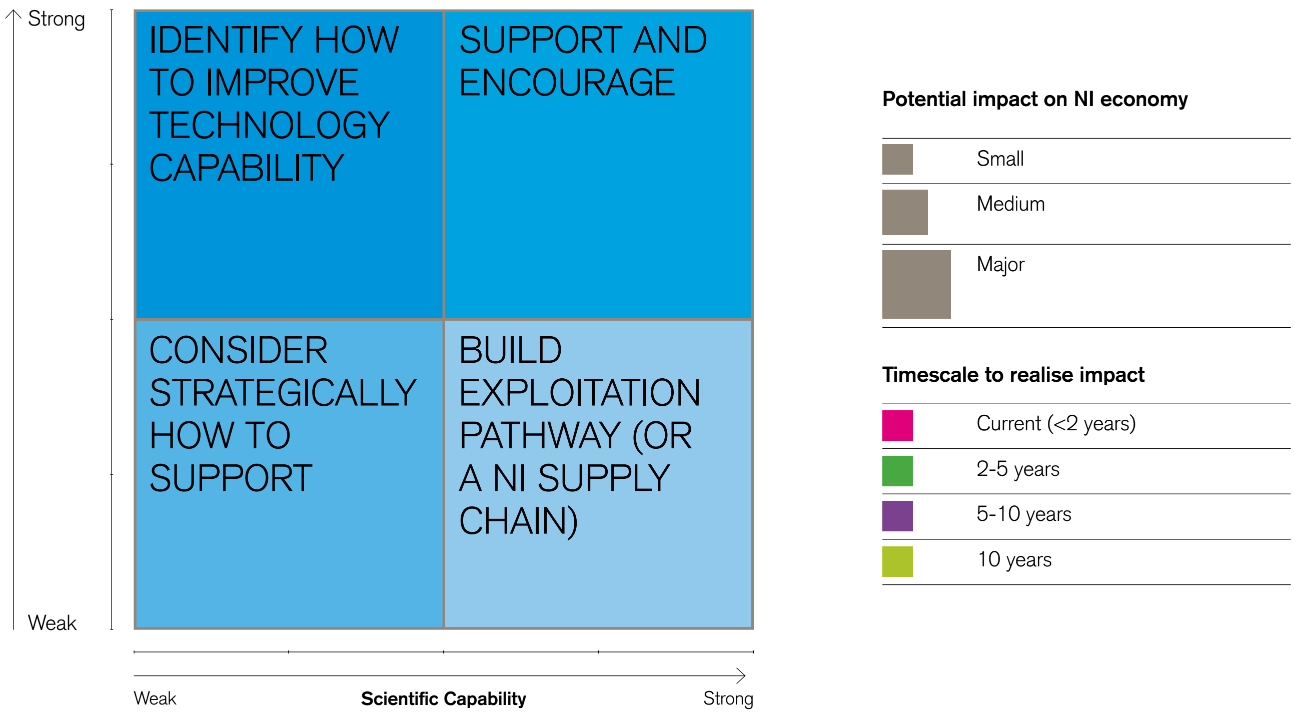
These technology strategies recognise the globalisation of the world economy, research and development and the fact that customers, competitors, suppliers and collaborators may be located in any country or region. They also recognise the requirement for companies to constantly strengthen their capabilities and find innovative ways to satisfy increasing customer demands.

2.2 INTRODUCTION TO TECHNOLOGY CAPABILITY

Technology Capability reports present a 'snap shot' of the existing presence of capability in a country or region. Capability itself is something that changes an on ongoing basis, and generally, the presentation of a complete picture is based on the development and trends in this capability over a period of time. This report presents the first 'snap shot' of capability in NI. In presenting this capability, efforts have been made to align the materials with that of specific sector reports conducted in recent years. These reports include:

SECTOR	REPORT	DATE
Life Sciences	NI Life and Health Technologies Sector	2007
ICT	OCO ICT Sector Review	2006
Manufacturing	Future role of manufacturing in Northern Ireland (PWC) and DETI Policy Response	2005/2006
General	The RTD centres of excellence	2006
General	Mapping Study of the RTD centres on the island of Ireland	2008
Various	Role of Nanotec in NI	2006
Energy	Energy Review/UK Energy Sector Review	2006

FIGURE 2.1: THE MATRIX OF CAPABILITY



In addition, a variety of smaller reports from DETI and other resources such as Lantra, AFBI, InterTradeIreland, and InvestNI have been used. A number of specific company reports have also been made available to us. However these remain confidential as per agreements with those companies.

Capability involves a degree of subjective judgement beyond the initial fact base of numbers. Some companies show intense degrees of research, development and innovation but do not classify it as such. Others group standard operations into such categories. However, capability is not about presenting a grading structure. It simply seeks to inform who, at any point in time, applies a variety of capabilities successfully to meet market needs.

It is also worth noting that the existence of capability itself is not sufficient for economic success[26]. There are other factors to be considered such as marketing, investment, scaling, and taxation.

These issues are not addressed within this report, but it is recognized that they exist alongside pure technology capability alone in determining market success.

For this report, existing capability is being measured according to two specific parameters:

- Scientific Capability; and
- Exploitation Capability.

All capability is mapped according to these categories and from there a matrix of capability is determined per category. This matrix is represented in Figure 2.1.

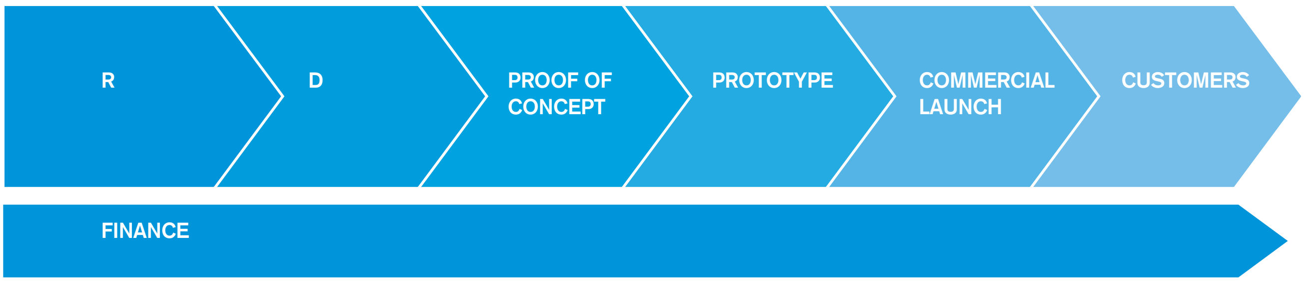
The capability scoring (discussed below) allows for the positioning of capability in one of the quadrants above. This informs of the strength of the scientific capability and as to whether it should be exploited further or needs to be strategically considered in terms

26. Prof. Rebecca Henderson/MIT Sloan School of Management/Developing and Managing a successful technology and product strategy

TABLE 2.1: HOW TO MEASURE SCIENTIFIC CAPABILITY

SCORE	CHARACTERISTICS
5	World Class Science - only one of 5 - 10 companies or institutions with this capability or equipment.
4	Amongst the best companies/institutions in Europe or the UK
3	One of a few companies/institutions in UK or Europe with this capability
2	One of several (20 plus) UK companies or institutions with this capability
1	No particular advanced capability

FIGURE 2.2: VALUE CHAIN OF EMBRYONIC OR EMERGING TECHNOLOGIES



of new support, supplementary support etc. The exploitation capability informs us of the strength of exploitation and whether this needs to be further supported by scientific support or considered strategically in terms of investment etc. Clearly, the ideal situation is for all capability to exist in the upper right hand quadrant and this is the case is developed economies where they are interesting synergies between the scientific capability being developed and the exploitation pathways. However, the reality in most economies is that there is a mixture of capabilities and all need to be constantly considered for investment, support or

Squares are used to position the specific capability identified and these tell another aspect based on their size. Their size relates to the economic impact of the capability (it could be possible to have deep scientific capability with high exploitation capability but with no real economic impact). Additionally, the colouring of the square informs of the timescale to realise the economic impact of that capability. For example, developing functional food capability has real economic impacts but only in a five-to-10-year horizon, whereas improvements in packaging or processing can be realised in two years.

How to measure scientific capability
Scientific capability is measured on a scale of 1-5 and this is outlined in Table 2.1.

Please note that we use the status of Highly Competitive, Competitive and Non-Competitive as these are parameters that are most easily understood. Scorings of 1or 2 place the capability in the lower part of the grid (Figure 2.1), whilst scores above that move into the higher parts of the grid.

For universities in NI, the RAE 2001 scoring is used to indicate capability.

FIGURE 2.3: ESTABLISHED TECHNOLOGIES SUPPLY CHAIN

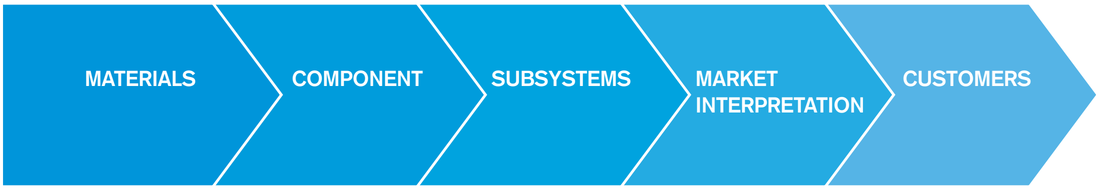


TABLE 2.2: MEASURING EXPLOITATION CAPABILITY

SCORE	ESTABLISHED TECHNOLOGY	EMBRYONIC TECHNOLOGY
5	World-Class company (competing in global markets with global competitors) and with elements of their supply chain in NI.	World Class company (competing in global markets with global competitors) pulling through the technology (funding or doing development) with complementary elements of the supply chain in NI.
4	Major company using the technology with elements of the supply chain in NI.	Major company pulling through the technology with elements of the supply chain embedded in NI or a history of start-ups in NI.
3	NI company using the technology with some aspect of the supply chain in the region.	NI company pulling through the technology with some aspects of the supply chain in the region.
2	NI company using the technology but with no supply chain in NI.	NI company pulling through the technology but no strong supply chain in NI.
1	No exploitation pathway.	No exploitation pathway.

Embryonic or emerging technologies
These are technologies with a very different value chain within Northern Ireland. Typically, they do not have a complete supply chain in NI or elsewhere. Typically, a degree of subjective judgement is applied to determine if the 'building blocks' of the supply chain actually exist and these would cover:

- Customer pull;
- Access to finance;
- Existing supply chains that can diversify into the proposed field.

For example, NI developing a riser technology for upstream oil and gas exploration might create some issues within a NI context as there is no supply chain readily available. Riser technology is only used in the US.

Established Technologies
Established technologies have a supply chain but not all of it is in NI and the Supply Chain strengths are based on the extent to which companies in NI secure in their position in terms of:

- Well-established relationships with customers;
- Well-positioned to resist restructuring of supply chain; and
- Value added of the entire value chain.

Measuring exploitation capability
Having recognised the variation of exploitation capability, the scoring mechanism as defined in Table 2.2 is used.

2.3 DEFINITIONS OF RESEARCH AND DEVELOPMENT

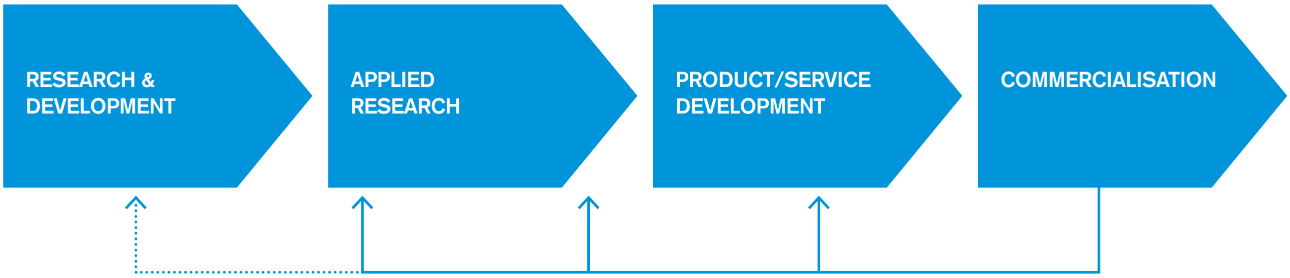
This report assumed an interactive model of innovation in terms of how R&D links to market commercialisation of products and services. The model selected is outlined below in Figure 2.4.

Whilst the historical model of innovation in economies suggests that the more R&D that is conducted the more innovation in products/services is occurring[27], this report assumes a higher degree of interactive innovation. This suggests that innovation is due to the outcomes of an interactive process in which many actors are working together and therefore does not happen from left to right in Figure 2.4 but happens outside of this cycle[28]. Hence, the starting point does not have to be academia but rather the impulses and ideas that tend to come from existing production or the specific markets[29] with no specific interaction amongst players and ideas being refined and generated at all stages of the overall process. This implies that basic research and development is not always the sole initiator. In fact, value is not maximised until the commercialisation stage. This report takes this view because, unlike academic reviews, it only considers the economic application of any ideas or investments which implies the implementation of changes in production or the introduction of new products/services to the market.

In this report, all definitions are seen from the interactive perspective and the key feature is not how individual actors perform but rather how these same actors interact with each other to create greater economic impact. The only aim therefore is to see all activities in the context of increasing competitiveness and rapid technological change that underpins such competitiveness.

A final note on this is to highlight that this report does accept the need to analyse key actors in terms of academic excellence, production excellence, marketing excellence etc and that this is accomplished through other means (RaE, IoM etc). However, in this report, the only perspective been taken is the ability of these actors to create economic impact in terms of employment, GVA and economic activity.

FIGURE 2.4: THE INTERACTIVE MODEL OF INNOVATION USED IN THIS REPORT



27. This is called a Linear Model of Innovation
28. Nelson and Winter 1992
29. Halvorsen and Lancave 1998

2.4
APPROACH AND METHODOLOGY

PA's approach was broken out into three phases, which will address all elements of our methodology, a summary of which is provided in Table 2.3.

TABLE 2.3: APPROACH SUMMARY

	PHASE 1	PHASE 2	PHASE 3
Objective	A baseline assessment of Northern Ireland's EXISTING capabilities in terms of the: (i) Industrial Sector (science and technology, facilities, skills and capacity). This sector will have to be sub-divided into Multi-national Corporations (MNC), Small and Medium Sized Enterprises (SME) and Start-Ups; (ii) Research Sector (science and technology, facilities, skills and capacity of academic institutions, public sector research establishments). Identify the key national and international technological, regulatory and investment trends impacting the identified sector.	Defining and agreeing the comparators for regional, nation and international benchmarking; Conducting the benchmarking exercise.	Analysis of conclusions from the capability mapping and the international benchmarking. Instructions on the re-use of the databases for updating capability and benchmarking details.
Approach	Identify current capabilities	Benchmark capabilities against other regional, UK National and International comparators.	Analyse
Output	Baseline report that: (a) Completes a baseline assessment of current capabilities (science and technology, facilities, skills and capacities) of the industrial, academic and public sector institutions. Academic institutions are listed and RAE 2001 scoring is indicated. (b) Identification of key national and international technological, regulatory and investment trends on the identified sectors and emerging areas. (c) Creation of a database that allows for the continual updating of these details over a period of time.	A benchmark report that: (a) Defines the measurements that are used for benchmarking purposes; (b) Benchmarks NI at a regional level against other UK regions, European regions and global regions. (c) Conclusions to be drawn from such benchmarking. (d) Creation of a database solution that would allow for the continual use of such benchmarking capability on an ongoing basis.	An analysis report that: (a) Identifies Northern Ireland's regional or global leadership opportunities in the selected sectors. (b) Identification of the conditions that will enable the achievement of this global leadership position.

THE GENERAL TRENDS OF THE SECTORS IN NORTHERN IRELAND

3

3.1 GENERAL TRENDS

In order to complete this assignment, a database of NI companies has been created. These companies have been sub-divided into their relevant categories and analysed in that respect. The analysis has been developed looking at company information, R&D information and other facts pertaining to those companies. These then have been validated using company interviews, and by discussion with various public sector bodies. In this chapter, we present an overview of the sectors collectively in terms of employment, growth, Gross Value Added and location. The data used for this trend analysis is from 2005 as this is the most recent year in which a consistent and comprehensive baseline can be established.

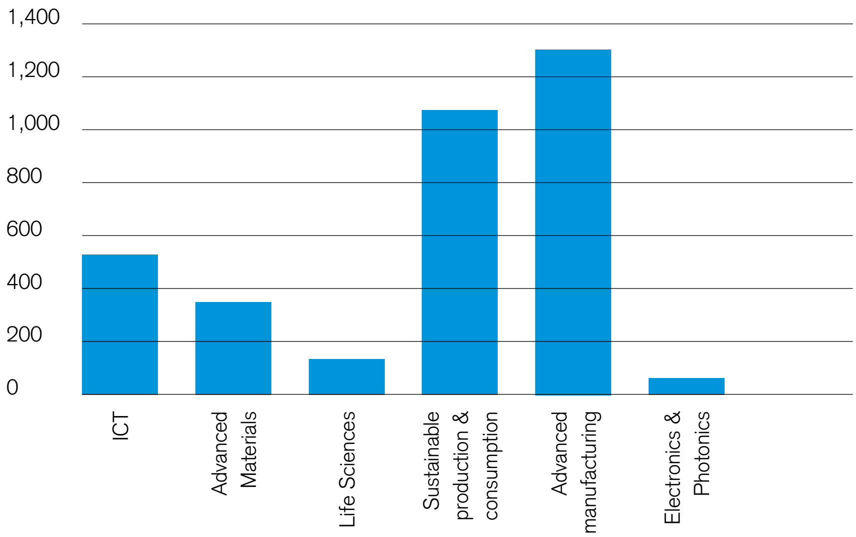
The general trends of NI can be viewed in the following perspectives:

3.2 GROSS VALUE ADDED BY SECTOR

Gross Value Added (GVA) at Basic Prices represents the income generated by businesses out of which wages and salaries, the cost of capital investment and financial charges are paid before arriving at a figure for profit. It includes taxes on production (e.g. business rates), net of subsidies and taxes on production (e.g. VAT and excise duty). All published GVA is given at what are termed basic prices. GVA therefore is used to evaluate the effectiveness of a sector in economic terms.

In essence, this chart highlights the varying degrees of impact that each sector is having on the Northern Irish economy. The advanced manufacturing sector is contributing nearly £1.3 billion to the economy. The electronics and photonics sector had a negative impact on the economy of -£90,975 or 3% of GVA as a result of the closure of one company (Nortel). When the negative effects of Nortel are excluded, a more accurate picture of Northern Ireland's economy is given and this is presented above. Although the main sectors remain unchanged, it does highlight that electronics and photonics are having a positive and growing impact on the economy. The sustainable production and consumption sector (which includes agriculture and food) and advanced manufacturing sectors are contributing almost £2.4 billion to the entire economy, thereby creating 71% of the economy. The ICT sector is growing quickly and produced over £500 million.

FIGURE 3.1: GVA BY SECTOR IN NI



3.3 EMPLOYMENT BY SECTOR

The trend of the NI economy being dominated by only two sectors continues in the field of employment with 63% of all employees involved in either advanced manufacturing or sustainable production and consumption. The remaining four sectors of the NI economy employ 37% of the workforce.

In general, all sectors have seen a gradual rise in the numbers of employees employed over the three-year period of 2003 - 2005. The electronics and photonics sector saw a slight drop in the numbers employed (due to the Nortel closure) but this then recovered again by 2005, reflecting a degree of resilience within the sector. The advanced manufacturing sector saw the highest rate of employment growth with an increase of 1,472 employees in this period.

FIGURE 3.3: EMPLOYMENT GROWTH BY SECTOR IN NI

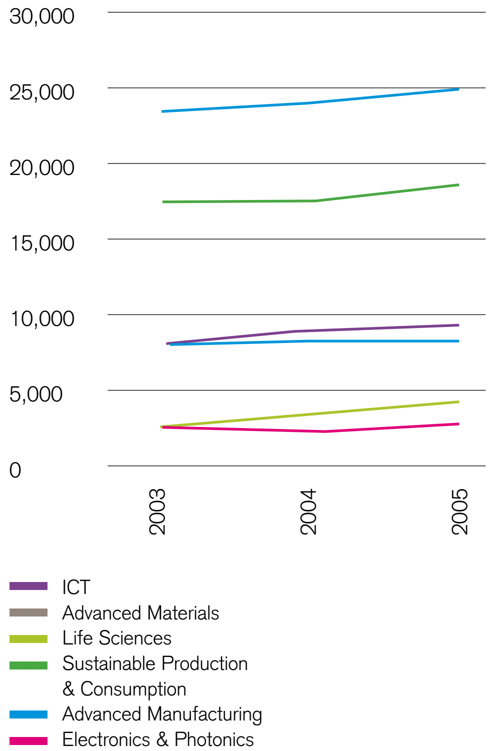


FIGURE 3.2: EMPLOYMENT BY SECTOR IN NI

	14% (9,132) ICT
	12% (8,129) Advanced Materials
	6% (3,920) Life Sciences
	27% (18,353) Sustainable Production & Consumption
	37% (24,859) Advanced Manufacturing
	7% (2,470) Electronics & Photonics

3.4
TURNOVER BY SECTOR

Turnover growth has been very steady over all sectors and in particular the advanced materials and sustainable production and consumption sectors which recorded strong rates of growth.

Around 75% of the turnover of the economy is relying on the same two sectors, which also show the greatest levels of growth in turnover. However, although sustainable production and consumption accounts for 32% of GVA, it accounts for 42% of turnover, highlighting the lower levels of value-added products in this sector. This is due to the nature of the structure of this sector and also the effectiveness of industry within the sector.

Figure 3.5 illustrates the sectors that are adding the greatest amount of value to their output. It illustrates for example that the sustainable production and consumption sector accounts for 42% of turnover, the turnover per employee is 30%, while the electronics and photonics sector has a turnover of just 5% but a turnover per employee of 20%. This highlights the higher value output of the electronics and photonics sector.

FIGURE 3.4: TURNOVER BY SECTOR 2003-2005 (£M)

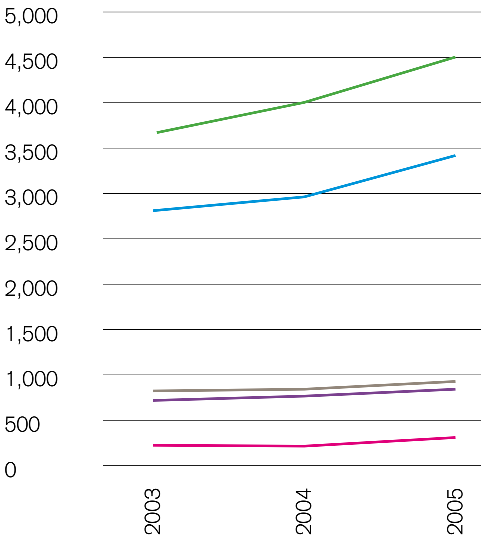


FIGURE 3.5: TURNOVER PER EMPLOYEE PER SECTOR 2005 (£M)

12% (£91,282)	ICT
14% (£109,894)	Advanced Materials
10% (£74,034)	Life Sciences
31% (£244,456)	Sustainable Production & Consumption
18% (£136,922)	Advanced Manufacturing
15% (£117,364)	Electronics & Photonics

3.5
LOCATIONS IN NI

GVA by Location 2005 (£M)
Figure 3.6 highlights the geographic location of the main economic areas in the NI economy. The Antrim and Belfast regions have by far the highest levels of economic activity, with 61% of the GVA originating in these regions. The 'other' region includes all companies where there was an inability to determine the exact location of or to determine the exact source of data from some companies.

Employment by Location 2005
The level of employment follows a similar pattern to the location of GVA. The Antrim and Belfast regions account for 51% of employment while Armagh also makes a large contribution at 16%.

FIGURE 3.6: GVA BY LOCATION 2005 (£M)

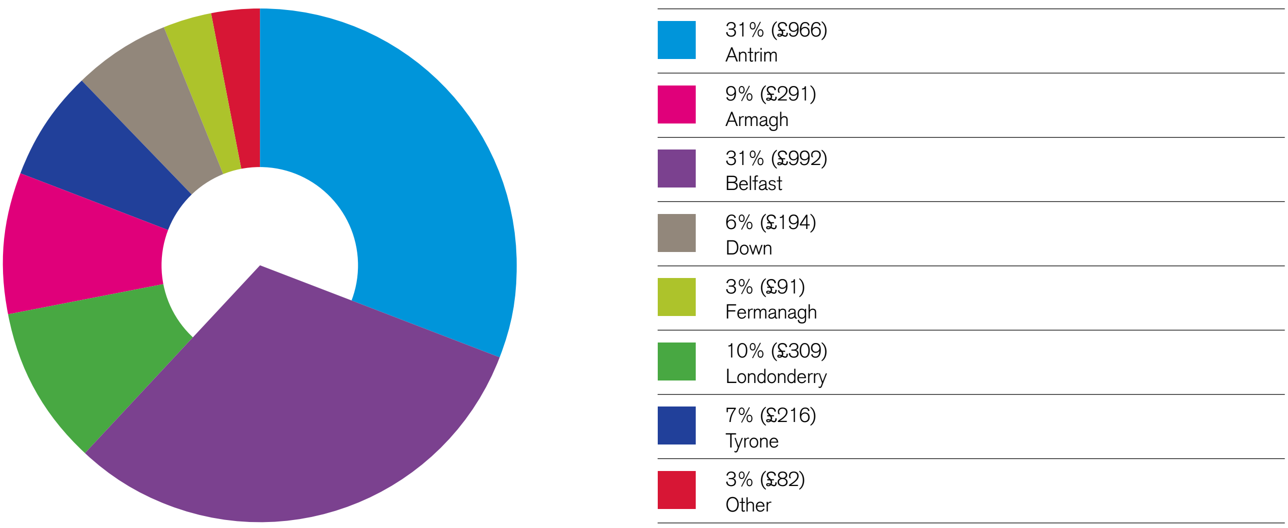
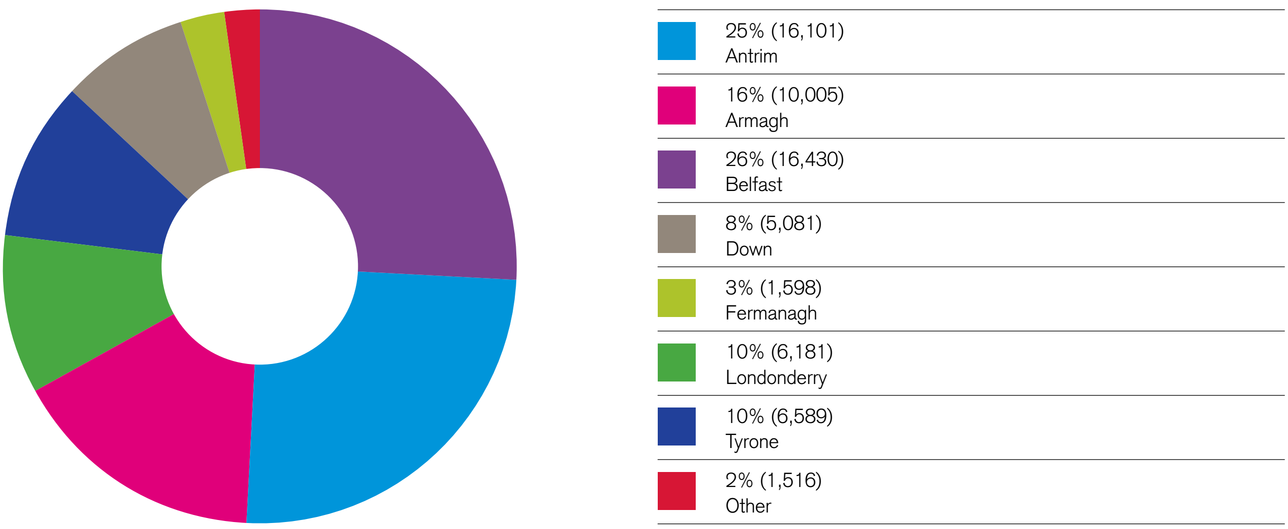


FIGURE 3.7: EMPLOYMENT BY LOCATION



3.6 HIGHER EDUCATION ENROLMENTS IN NORTHERN IRELAND

The ability to create a supply chain of Higher Education graduates for NI industry is a key theme in all the sectors reviews. In each sector, an analysis of the Further Education student numbers per sector is found. It is not as easy to develop such precision for the Higher Education sector as the cross-over of disciplines remains highly variable - hence Arts students enter the ICT sector and Medical students enter other sectors.

NI has a high standard of Higher Education as exemplified by the work of QUB and UU. However, the question remains as to the focus of the quantity of graduates. The most significant factor is the quantity (and quality) of graduates in specific areas of interest to all the sectors within Northern Ireland. A sample of data of the existing student population in NI was produced (courtesy of the Department of Employment and Learning) for the 2006/7 year. This data yields the following:

- There are some 47,865 students engaged in some form of Higher Education study within NI. These are primarily located in the universities of Queens and Ulster University.

These students are allocated across a number of specific programmes which are:

- Higher degrees through research programmes;
- Higher degrees through taught programmes;
- Other post-graduate courses (diplomas etc);
- Primary or first degree programmes;
- Other undergraduate education.

The categorisation of students in all programmes are:

- Medicine and Dentistry or subjects allied to these;
- Biological Sciences;
- Agriculture and Related subjects;
- Physical Sciences;
- Mathematical Sciences;
- Computer Sciences;
- Engineering and Technology;
- Architecture, Building and Planning;
- Social Studies;
- Law;
- Business and Administrative Studies;
- Communications and Documentation;
- Languages;
- Historical and Philosophical studies;
- Creative Arts; and
- Education

All of the categorisations above are required to build a strong economic base in NI. The emphasis of the categorisation however needs to be considered in the context of the overall focus areas for NI. The detailed analysis of enrolments in the categorisations of programme are presented in Figure 3.8.

The key findings from this analysis are:

- The largest categorisation of students are in Medicine, Dentistry and allied subjects to medicine. 21% of students are engaged in this categorisation. Across this base, the breakdown of higher degrees (60%) to primary (40%) indicates that there is an emerging well-educated base coming to the market;
- The second largest categorisation of students are in Business and Administrative studies, which accomodates 14% of the entire student population. Across this base, the breakdown of higher degrees (17%) to primary (83%) indicates the emergence of these degrees on the NI landscape;
- The remaining categorisation demonstrate some key points for the remainder of the student population.

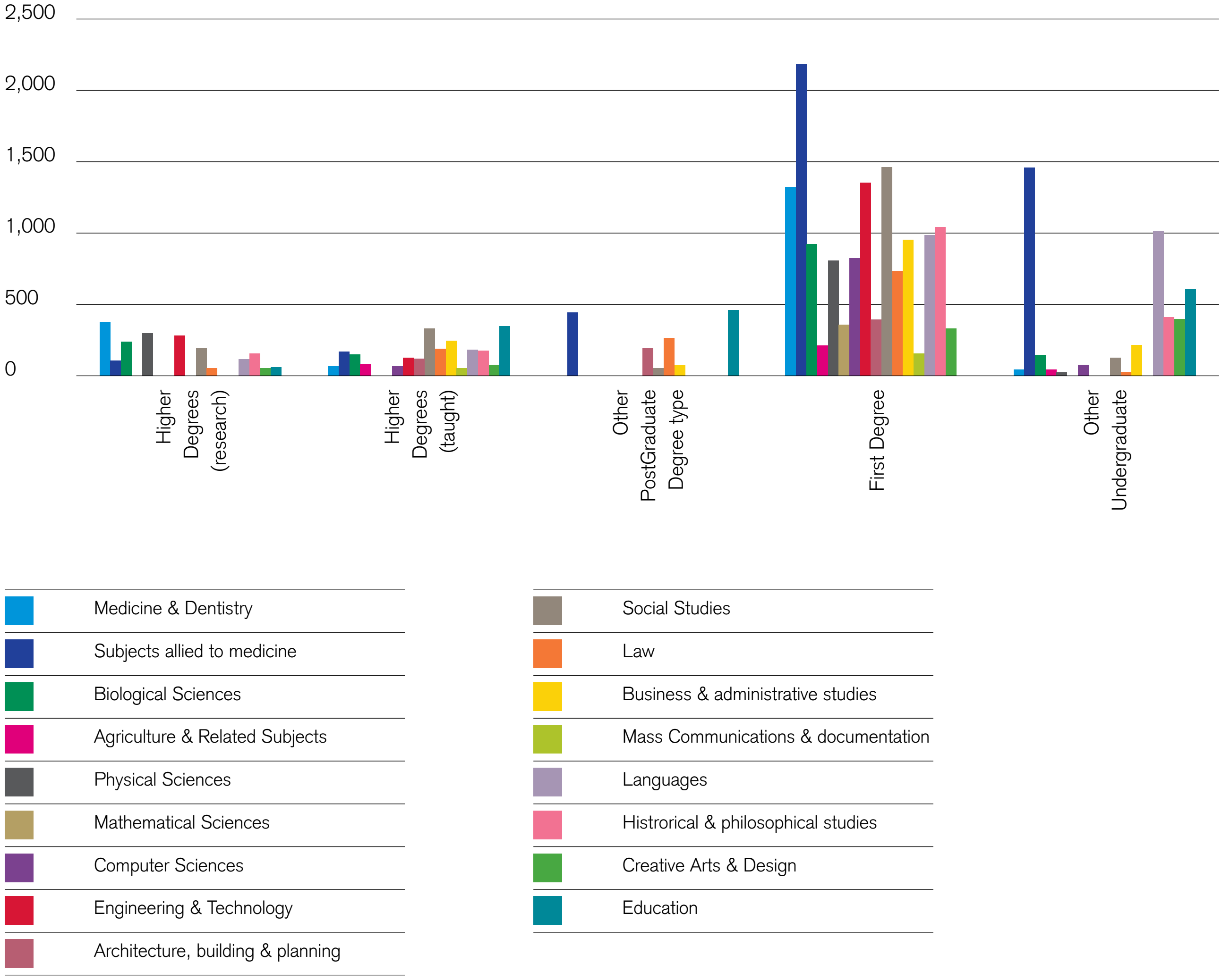
a) Agricultural Science and associated areas has 1% of the entire student enrolments with virtually no post-graduate enrolments;

b) Computer Science has 6% of the enrolments, with a split of 91% in primary degrees and 9% in undergraduate.

c) Engineering and Technology has 6% of the student population (an interesting benchmark would be social sciences on 8% and law on 4%, with creative arts on 5% and languages on 7%). Of that base, some 81% are primary degrees. The rest are in post graduate programmes;

NI needs the collective strengths of all enrolments bodies. The key question remains as to whether the emphasis within the enrolments is appropriate for the focus areas of the market. For example, the lack of numbers in Agriculture can serve to undermine the continuance of the food industry and equally the quantities in the sciences for industry needs to be fully considered. As outlined in all of the sectors in the subsequent chapters the demand for higher level students appears to be significant and the rebalancing of these numbers needs to be considered.

FIGURE 3.8: ENROLMENTS BY CATEGORY IN NI 2006/7[30]



30. Department of Employment and Learning 2008/Statistics Branch

FIGURE 3.9: TOTAL BREAKDOWN OF ENROLMENTS PER CATEGORY 2006/7

21%	Medicine & Dentistry
7%	Biological Sciences
1%	Agriculture & Related Subjects
4%	Physical Sciences
1%	Mathematical Sciences
6%	Computer Sciences
6%	Engineering & Technology
5%	Architecture, building & planning
8%	Social Studies
4%	Law
14%	Business & administrative studies
2%	Mass Communications & documentation
7%	Languages
4%	Histrorical & philosophical studies
5%	Creative Arts & Design
5%	Education

3.7 CONCLUSION

NI has the smallest economy of any of the twelve NUTS 1 regions of the United Kingdom, at €37.3 billion, or about two-thirds of the size of the next smallest, North East England. However, this is partly because NI has the smallest population. Currently, at £19,603, NI has a greater GDP per capita than both North East England and Wales[31].

Throughout the 1990s, the NI economy grew faster than the rest of the UK, due in part to the proximity of the economy of the Republic of Ireland (RoI). Growth slowed to the pace of the rest of the UK during the down-turn of the early years of the new millennium, but growth has since rebounded; in 2005, the NI economy is estimated to have grown by 3.2%, almost twice as fast as the UK as a whole, and future growth is expected to be stronger than that of the rest of the United Kingdom[32] , though lower than that of the RoI. The growth will be fuelled by the need to absorb additional capacity in the economy, the 'over heating' of the RoI economy in certain sectors and the ability to further link capability and exploitation channels within the economy.

At the end of 2005, there were 769,000 people in employment in Northern Ireland, the highest figure on record, and an increase of 3.3 per cent over the year. On the other side of the coin, the unemployment rate, at 4.2 per cent, was the second-lowest in the UK, with only the South West (3.5 per cent) performing better. It was a favourable performance compared with a EU25 rate of 8.2 per cent and a RoI rate of 4.3 per cent. Consumer spending fuelled by disposable income levels helped the service sector remain buoyant, with retailing, distribution and business and financial services all recording expanding levels of business, pushing output growth over the year to around 2.7 per cent.

Advanced Manufacturing is concentrated in and around Belfast, although other major towns and cities also have heavy manufacturing areas. Machinery and equipment manufacturing, food processing, and textile and electronics manufacturing are the leading industries. Although its share of economic output has declined, manufacturing output in NI has remained almost unchanged over the past five years after a period of steep manufacturing growth between 1998 and 2001.

As with all developed economies, services account for the majority of employment and output. Services account for almost 70% of economic output, and 78% of employees across all sectors. However, the public sector accounts for 63% of the economy of Northern Ireland, which is substantially higher than 43% of the United Kingdom as a whole. In total, the British government subvention totals £5 billion, or 20% of Northern Ireland's economic output. NI does offer lower wage levels - average weekly gross earnings of £320.50 compared with the UK average of £349.60 - and lower commercial property prices than the rest of the UK. But this has to be set against higher energy, insurance and transport costs.

31. Economic Performance Briefing/NI Office/1st Jan 2007
32. ibid

ADVANCED MANUFACTURING

4

4.1
ADVANCED MANUFACTURING

The Advanced Manufacturing sector in NI is perhaps the most disparate both in terms of size and speciality of all the sectors addressed in the frame of this capability study. It consists of some 139 companies that employ in the region of 25,000 staff and have a combined turnover of £3,404 million. There are 79 companies with an identifiable R&D programme and these companies have 808 staff engaged in these activities, which have a combined annual spend of £31 million.

4.1 SECTOR DESCRIPTION

Manufacturing is the transformation of raw materials into finished goods for sale, or intermediate processes involving the production or finishing of semi-manufactured items. Some industries, like semi-conductor and steel manufacturers use the term fabrication. Advanced Manufacturing is the making of a better product (in terms of function, sustainability, maintainability, lifecycle) suitable for more immediate use at a cheaper cost and involves the use of Advanced Engineering techniques such as Computer Aided Design, Process Control and Instrumentation[33] etc. It is a critical aspect of many industrial sectors. Generally, manufacturers must cope with rapid changes in markets—including workforce, process, and technology changes—while operating in a dynamic, competitive, and global environment. They deal with this environment by selectively focusing their resources and efforts to sustain competitive advantage. They pursue partnerships for research and development and for supply and production functions that they cannot efficiently accomplish themselves.

Manufacturing is, and will continue to be, of significance to Northern Ireland, despite recent public contributions that believe that manufacturing is not viable here.[34] It is important to remember that manufacturing effectively enables the services sector. Hence, while direct manufacturing employment is likely to continue to fall, the manufacturing economy in NI will have to change from one that competes on cost to one that has unique innovation and technological strengths in key technology areas embedded within its supply chain.[35]

Advanced Manufacturing in NI is highly variable and is considered to have a number of key strengths such as:

- Generally strong supply chain;
- Strong University links in certain specific cases;
- Strong UK Branding;
- High levels of responsiveness and flexibility;
- High levels of Foreign Direct Investment and ownership;
- Low employee turnover; and
- High levels of Government support.

There are also a number of concerns relating to the manufacturing industry in NI and these are:

- Productivity in manufacturing is among the lowest of any UK region. Latest figures show that NI has the lowest productivity in the UK;[13]
- Supply chain price sensitive;
- Eroding competitive position due to rising costs;
- Continuing need for increased productivity;
- Global competition;
- Availability of adequately trained workforce (in design and manufacturing); and
- The need to create a true competitive edge or defining capability which will differentiate NI from emerging countries.

On the skills side, it is recognised that there is a need for stronger linkages between the skills agenda and the innovation agendas. Skills availability and the perception of engineering and technology as a profession, together with graduate retention schemes and appropriate training offerings, are seen as key issues.

The Matrix panel decided to use the following sub-fields in order to understand the capability of the Advanced Manufacturing sector in NI and these sub-fields are presented in the following table:

33. The Employment and Training Administration in the USA (ETA) define Advanced Manufacturing as the accelerated use of high-tech processes in the manufacturing plant. This definition is not synonymous with 'high-tech manufacturing,' as the emphasis is on the high-tech processes used in production, rather than the output of high-tech products. The definition used here is derived from this.
34. The Future Role of Manufacturing in Northern Ireland/2005 noted that whilst employment numbers have fallen, the number of companies involved has grown with smaller companies operating in a more competitive environment.
35. Future of UK Manufacturing/DTI/2005

TABLE 4.1: THE SUB-FIELDS THAT ARE USED TO UNDERSTAND CAPABILITY WITHIN NI MANUFACTURING

ADVANCED MANUFACTURING SUB-FIELDS	DESCRIPTION
Traditional Manufacturing	This refers to a traditional manufacturing process and mechanisms whereby traditional products are made using well documented and existing technologies. There is relatively no degree of innovation or focus on improvement.
Lean and Sustainable Manufacturing Processes	This refers to 'lean manufacturing' techniques and processes which demonstrate resource efficient, low cost and sustainable manufacturing processes.
ICT	This refers to new business models introduced by the advent of ICTs and refers to new collaborative manufacturing environments, networked business processes (integrated supply chains) and services 'value added' support for products
Design, Simulation and Validation	This refers to new design techniques that are used for: • Resilience, reliability and maintainability; • Simulation and modelling of advanced structures and processes including micro and nano level type components; • Design for complete lifecycle including assembly, disassembly and recycling; • Large scale systems validation including testing, inspection, trend analysis etc.
Advanced Manufacturing Technologies and Processes	This refers to a number of recent developments in manufacturing which have advanced it into: • Rapid prototyping/flexible production; • Advanced forming and assembly tools and techniques; • New processes and processing technologies including self-assembly, bioprocesses etc; • New intelligent instrumentation and control techniques
Computational Science	Computational Science is an inter-disciplinary field which addresses problems using computational techniques. Computational science seeks to gain an understanding of science through the use of mathematical models on supercomputers. It has emerged as a powerful, indispensable tool for studying a variety of problems in scientific research, product and process development, and manufacturing. Several significant case studies demonstrate the use of Computational Science in Advanced Manufacturing. (www.boeing.com/commercial/777family/index.html). There are current examples within NI where computational science is used to gain competitive advantage.
Systems Engineering	Systems Engineering is defined as the ability to identify and manipulate the properties of a system as a whole, which in complex engineering projects may greatly differ from the sum of the parts' properties. The driver for SE is when it is no longer possible to rely on design evolution to improve upon a system, and the existing tools were not sufficient to meet growing demands, new methods began to be developed that addressed the complexity directly. The evolution of Systems Engineering as it continues to this day, comprises development and identification of new methods and modelling techniques: methods that can aid in better comprehension of engineering systems as they grow more complex.

The capabilities within companies in this area are analysed from this perspective.

4.3 KEY TRENDS IN ADVANCED MANUFACTURING

The future of the manufacturing sector in Europe has had much attention and NI is no exception. Major stories constantly focused on trade, European jobs and the perceived loss of the European manufacturing and industrial base due to offshoring, or outsourcing of white-collar, back-office, and technology jobs and the future role of manufacturing in the national economies of all European and the US.

However, an important perspective needs to be taken concerning manufacturing and technology. Since mass manufacturing began, many changes have been made in the way products are designed and manufactured. It has always been that a new technology offers both a remedy and a threat to manufacturing. In the future, a broader definition of the term ‘manufacturing’ will encompass an integrated system that includes the whole cycle of creation, production, distribution and end-of-life treatment of goods and product/services, realising a customer/user driven innovation system.

Additionally, the linkage between Advanced Materials and Advanced Manufacturing must be enhanced. Generally, Advanced Materials can significantly aid substantial improvements in productivity, quality and cost. However, it also challenges significantly the establishment concerned about impacts on the number, type, skill requirements and locations of manufacturing jobs. The timescale of product conception and development is shifting from the long to the shorter term - and ultimately to a near real-time response. The technologies that will have the biggest influence on manufacturing are based on molecular manufacturing which will use new biomaterials and bio-processing, microelectromechanical systems (MEMS), free-form fabrication and newer IT control technologies through improved computers. However, it will be essential to understand that no technology forecast works for manufacturing unless considered in the total picture of other influencing factors - skills, innovation, knowledge management, customer relationships and life-cycle waste reduction.

There are eight major trends within Advanced Manufacturing which NI must play to and these are:

1. Movement away from mass production to semi-customisation. For example, there will be specific treatments for specific diseases as opposed to broad spectrum treatments. This will lead to lower volume, higher margin products with specific lifecycles in R&D, prototyping, use of computational science (see below) and scale up.
2. Shift away from centralised production location to distributed production sites. This will be enabled by the ability to create Lab on a Chip (LOC) technological solutions and to move away from clean room environments to less costly bases of production.
3. Shift away from centralised business control of production towards collaboration between production.
4. Outsourcing will continue to grow, particularly in the medical device sector. In 2006 this stood at 6% compared to 90% in the electronics sector. It was confined to low margin products but China is manufacturing more complex products.
5. Advanced Manufacturing techniques (lifecycle analysis, green and lean culture).
6. Manufacturing sector will sub-divide into smaller, distributed specialised companies, which will plug into different networks in the global supply chain to find and use particular technologies; then disengage.
7. To be able to play in the new manufacturing supply chain, companies in high cost economies must be able to create and retain IP whilst manufacturing elsewhere. China will be the major mass manufacturer of mature technologies by 2020.
8. Extremely adaptive workforce, with fewer operatives and higher skills people who will be constantly learning through academic/industry switchovers.

These trends are enabled by the shift in manufacturing towards Advanced Materials and the leveraging of these new technology capabilities through intelligent and cheap ICT systems which manage supply chains effectively.

Advanced Materials trends and Computational Science

The trend in Advanced Manufacturing is driven by a concept called ‘minimal manufacturing’. This concept is the name applied to Advanced Materials, based systems that are capable of creating products with maximum functions from minimal resource inputs and with minimum end-of-life environment loads. These mechanisms will operate through the elimination of high cost capital items of manufacturing such as Clean Rooms, specific pressurised facilities. There will be entirely new technology introductions in 3-4 disruptive technologies and their associated applications will fundamentally change manufacturing.

The key enabler in this field is not Advanced Materials, but rather Computational Science. Computational Science becomes the simulations, statistical and testing of the essence of how Advanced Materials characteristics will behave in preparation, processing and manufacturing. Through associated theoretical prediction and optimisation, it should be possible to reduce prototyping stages in Product Develop and dramatically reduce lead-times in Product Development cycles thereby reducing costs. More significantly, these modelling tools should be capable of also ascertaining the lowest cost mechanism of development through theoretical prediction and optimisation. Through these mechanisms, manufacturing can reduce costs and contribute to a sustainable economy.

4.4
PRIVATE SECTOR CAPABILITY ANALYSIS

The following subfields of companies are examined in the context of the Advanced Manufacturing sector in Northern Ireland.

TABLE 4.2: ADVANCED MANUFACTURING COMPANIES IN NORTHERN IRELAND

ADVANCED MANUFACTURING SUB-FIELDS	MARKET SUBFIELD	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Traditional Manufacturing	Carpets/Rug Manufacture	A number of manufacturers using standard technologies and traditional skills to create products that are sold through a number of brands. The companies are constantly under price pressure as their products face threats from other geographies.	1	2	
	Inorganic Chemicals	A number of small suppliers of inorganic chemicals. No specific process/product is produced. Pressures remain on costs and the management of their own individual supply chain.	2	2	
	Plastics in primary form	There are a number of plastics companies in NI that manufacture for specific market segments. These use standard technologies and typically have a positioning in an established supply chain. Innovations are in the form of cost reduction and supply chain effectiveness.	2	3	
	Paints/Varnishes/ Coatings	Smaller companies that manufacture paints/coatings or printing surfaces. Technology remains standard and the pressure remains on cost reduction and supply chain effectiveness.	2	2	

ADVANCED MANUFACTURING SUB-FIELDS	MARKET SUBFIELD	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Traditional Manufacturing (continued)	Soaps/Detergents/ Clean/Polishing	Specialist market with specific chemical and non-biological cleaning agents being used. Companies are small and use products/technologies developed elsewhere. Innovation is focussed on cost reduction and supply chain effectiveness.	2	3	
	Perfumes and Toiletries	Specialist suppliers of products for the cosmetics industry. These tend to be localised and specialist competing with natural products from Body Shop etc. Pressure on price and brand in most cases.	1	2	
Lean and Sustainable Manufacturing	Man-made Fibres	Multi-national companies with operations within NI. Dupont and Invista Textiles being the predominant players. Employment levels relatively low and technology used remains as before. No demonstration of dramatic change within the sector in NI.	3	3	
Traditional Manufacturing	Rubber/Tyres	A mix of companies that provide basic levels of service to the rubber industry with a focus on tyres etc. Players tend to include Michelin and other smaller international companies.	2	3	
Lean and Sustainable Manufacturing	Construction Products	Dominated by one company, the Quinn group. Their manufacture of concrete products for construction possesses both scale and technology. High degrees of process innovation capability are embedded into the operation. This company is discussed in detail below.	3	4	

ADVANCED MANUFACTURING SUB-FIELDS	MARKET SUBFIELD	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Lean and Sustainable Manufacturing	Glass	As with construction products, this is also dominated by one company - Quinn Glass. The same model of high degrees of process innovation and scale are embedded within the operation.	3	4	
Traditional Manufacturing	Metallic Structures and Parts of Structure	A broad range of companies that manufacture metallic structures or components of these structures for a variety of sectors including shipping or speciality building. Technology used is not unique and the sub-field is very cost competitive.	2	2	
Advanced Manufacturing Technologies and ICT	General Mechanical Engineering	A mixed set of companies ranging from basic fabrication to advanced engineering solutions. Dominated by Schrader which is discussed in detail below.	4	4	
Traditional Manufacturing	Tools/Pumps/ Compressors/Lifting and Handling equipment	A large number of small companies engaged in a number of fabrication techniques including pumps, and materials handling. Specialist fabrication skills are required in a sector that is very price competitive but this sub-field manages this through the use of customised solutions as opposed to off-the-shelf options.	2	2	
	Agriculture/Forestry machinery	Companies that provide engineering solutions to the localised agricultural or forestry sectors. Customised solutions that are pertinent to NI are created although the skills are important.	2		

ADVANCED MANUFACTURING SUB-FIELDS	MARKET SUBFIELD	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Traditional Manufacturing	Mining, Quarrying, Construction	An extremely broad range of international and indigenous companies with a very specific focus in Northern Ireland. The brand names extend from Schlumberger to Powerscreen and Connect engineering. These companies have a high degree of speciality which is sometimes imported from elsewhere and applied to Northern Ireland. There is the emergence of a materials handling activity in mid-Ulster which reflects a growing engineering initiative which is achieving an economic model similar to that of Finland in terms of being a supplier of note of the global industry. This has developed a supply chain of support within mid-Ulster.	3	4	
Advanced Manufacturing	Weapons Systems	Dominated by one company, Thales, which is discussed below.	4		3
	Electric Domestic Appliances	Manufacturers of small white goods - toasters, heaters etc. No significant breakthrough technology although the marketing and scale of production is managed in a very innovative way. From a capability position, the strength is clearly in the supply chain management which is controlled from Northern Ireland.	3		3
Traditional Manufacturing/ Computational Science	Electric Motors, Generators, Transformers	A number of small and large manufacturers operate in this space although they are not linked together in a single supply chain. There is technology capability used in this sub-field, particularly by FG Wilson which is outlined in detail below.	2		2

ADVANCED MANUFACTURING SUB-FIELDS	MARKET SUBFIELD	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Lean and Sustainable Manufacturing	Motor Vehicles, Coach Bodies, Trailers	Number of specialist motor manufacturers - primarily based on Automotive bus (Wrightbus) and the resultant supply chain. This is a specialist customised sub-field within NI.	3	3	
	Automotive	Number of small NI companies that are focussed on the manufacture of parts and accessories or automotive industry. This includes engineering companies also. These are cost driven and have levels of innovation based on supply chain and product enhancements.	2		3
Traditional Manufacturing	Marine	Traditional sub-field in the building and repairing of ships. Once a predominant force however this is no longer a mainstay industry.	2		
Design, Simulation and Validation/ Advanced Manufacturing/ Computational Science	Aircraft	Bombardier and the traditional Short Brothers dominate this sector. These companies are outward-looking to a global market and are discussed in detail below. They keep abreast of developments in these fields and apply the established sciences from elsewhere.	4		3
Lean Manufacturing	Beverages	Range of companies from 'top end' to Coca-Cola. Traditional technology companies with a focus on brand, quality and cost.	3	3	

The majority of companies in the sector are classified by the utilisation of standard technologies and their input into a role in a specific supply chain. This implies that their emphasis tends to be on cost reduction, supply chain innovation and minor product innovations based on the inputs of that supply chain. This sector is still however the highest levels of GVA demonstrating the significance of manufacturing to any economy. There are however, a number of companies that demonstrate significant technology capability in the sector and these are selected for detailed discussions below.

SELECTED COMPANIES REVIEW

The majority of these companies are engaged in creating a specific aspect of manufacturing i.e. they either sub-contract or supply product to a specific market. From a capability perspective, their work is cost-sensitive and although technology is deployed it is less technology-focussed and more process-focussed. There are however seven significant companies in this sector in terms of a combination of R&D spend, turnover and number of employees. As can be seen from Table 3.2, these companies together account for some 40 % of turnover, 43% of employment and 80% of identifiable R&D spend in the sector.

Thales Air Defence Ltd
Thales Air Defence Ltd (formerly Shorts Missile Systems) develops and manufactures short-range air defence missiles such as VT1 and Starstreak. Such activities require real competencies in a number of fields related fields such as mechanical, aeronautical and electronic engineering, optics, ballistics, propulsion and safety engineering. Thales also has a significant capability in advanced system engineering, platform integration, armaments integration, product design, and process and supply chain management. They also have physical assets such laser laboratories, precision machining and assembly and advanced test facilities at their disposal.

FG Wilson
FG Wilson manufacture a variety of generators sets and are the largest such manufacturer in Europe and the third largest in the world. They have a strong competency in the application of Lean, SAP and 6-sigma to their manufacturing process and have research capability with regards to noise reduction, electronic control for engine management and to a lesser extent the application of composite materials in the manufacture of generators. Their Larne facility also houses one of the largest anechoic chambers in Europe.

Schrader Electronics
Schrader make tyre pressure monitors. They have core competencies in design, electronics, RF interfaces and the application of innovative ways to power their sensors (kinetic motion). Schrader also have good competencies in the field of process engineering and improvement (application of Lean) as the nature of their market is high volume/low cost.

Quinn Manufacturing Ltd
Quinn Manufacturing covers a variety of sectors, including the manufacture of plastics and glass. Quinn's core capabilities are with regards to process innovation as their business model is based around the procurement of existing large scale organisations using the latest technologies, and to make them more profitable by improving their internal processes.

Bombardier Aerospace
Bombardier make aircraft components. Their core competencies are in the application of advanced composite materials to their manufacturing process, and their product design and development capabilities. They also make extensive use of Lean and 6-Sigma in their manufacturing process. Bombardier has close links with the education sector in NI both at the HE (Aero and Manufacturing courses at QUB) and FE levels (Aero Structures at BIFE). Despite or perhaps because of their size (with the exception of FG Wilson they are much larger than all other manufacturers), they have very little cooperation with other smaller indigenous companies.

Wrightbus
Wrightbus manufactures public transport vehicles - principally buses and trams. The have core competencies with regards to mechanical and electrical engineering, the application of plastics and composites to bus manufacturing and understanding the costs and issues associated with vehicle ownership and running costs. All of these in turn contribute to their product design capabilities. Wrightbus are also currently undertaking some early stage research into the design, development and manufacture of hybrid electric propulsion systems. Wrightbus also demonstrate key capabilities in process/performance improvement, end-to-end manufacturing, the application

TABLE 4.3: ADVANCED MANUFACTURING COMPANIES IN NORTHERN IRELAND[36]

COMPANY NAME	TURNOVER (£000)	TOTAL TURNOVER AS % OF SECTOR TURNOVER	R&D SPEND (£000)	TOTAL R&D SPEND AS % OF SECTOR R&D SPEND	NO. OF EMPLOYEES	NO. OF EMPLOYEES AS % OF SECTOR EMPLOYMENT	R&D STAFF	FULL-TIME R&D STAFF AS % OF SECTOR TOTAL
Thales Air Defence	78,002	2.3%	10,004	32.6%	542	2.2%	89	11.0%
F G Wilson (Engineering)	553,127	16.3%	4,777	15.6%	2,384	9.5%	144	17.8%
Schrader Electronics	44,659	1.3%	3,534	11.5%	416	1.7%	71	8.8%
Quinn Manufacturing	70,036	2.1%	n/a	n/a	507	2.0%	n/a	n/a
Bombardier	440,590	13.0%	4,365	14.2%	5,354	21.5%	25	3.1%
Wrightbus	101,234	3.0%	995	3.3%	943	3.4%	18	2.2%
Ulster Carpet Mills (Holdings)	36,280	1.1%	574	1.9%	412	1.7%	11	1.4%
Totals	**1,323,928**	**38.9%**	**26,749**	**78.9%**	**10,558**	**42.5%**	**358**	**44.3%**

of Advanced Technology and Materials, Vehicle systems integration and industrial design including automotive styling.

Ulster Carpet Mills (Holdings) Ltd.
Ulster Carpet Mills manufacture very high quality carpets. Their core strengths can be summarised as lying within processing technologies. Specifically they have a highly advanced and innovative process control mechanism that uses RFID technology and they also developed the control software around this.

36. DETI Statistics 2005

SUMMARY OF PRIVATE SECTOR CAPABILITY

Most of the advanced manufacturing sector in NI remains in a situation where scale and technology threaten the viability of the sector. The sub-fields remain traditional and innovations tend to be short term initiatives to reduce costs, and enhance the supply chain. The focus on these prevents a structured approach to new product development, or even significant product regeneration.

An analysis of the leading capability companies in NI shows that there are demonstrable strengths in a number of distinct areas and these are:

1. Fundamental Advanced Materials knowledge and the incorporation of these materials into the product supply chain at relatively low costs. The key areas of strengths are composites, alloys, plastics and optical materials;
2. Fundamental advanced product design and a 'systems' approach to engineering which builds the design concept into the overall entire supply chain (raw materials, production through to shipment);
3. Advanced process control and management in the manufacturing process remains a key strength of all the highly competitive companies in Northern Ireland;
4. The ability to rapidly and cost effectively apply new innovations and technologies to scale. For example, there are companies demonstrating capabilities with fuel cells and hybrid technologies. Additionally, some companies are successful through the acquisition of new technology (at a global level) and applying this technology at scale to their own operations;
5. The leading companies tend to work in multi-disciplinary teams which recognise a distinct functional competence but also see the need to create new approaches to existing problems.[37]

How are the significant changes in Supply Chain and Product Design being driven

There is a key shift inherent in the culture of the leading manufacturing companies in Northern Ireland.

Traditionally, the approach to the Value Chain was expressed in a simplified version as demonstrated in Figure 4.1 below. The idea was that Customer Service succeeded Sales and Marketing as the primary contact point with the customer/sector and that Production/Logistics and R&D followed on from the input provided by Sales and Marketing. This encouraged companies to search the world looking for cost effective operations that existed within relevant markets that could provide these functions within a defined corporate strategy.

We see in the key companies in NI that the opinion on this has changed. This was primarily driven by two factors:

1. The need to continually cut costs and provide additional value to customers created an issue that this chain could not address;
2. The filtering effect of each aspect of the chain on each other, created an aberration in how demand was seen and deemed to be met. This created inventories that were produced as a result of mislead market analysis.

The Value Chain of these companies has started to change to embrace a very different structure, which should be constantly capable of reducing costs and providing value added through the elimination of waste and constant innovation cycles within the organisation. This is represented in Figure 4.2 below:

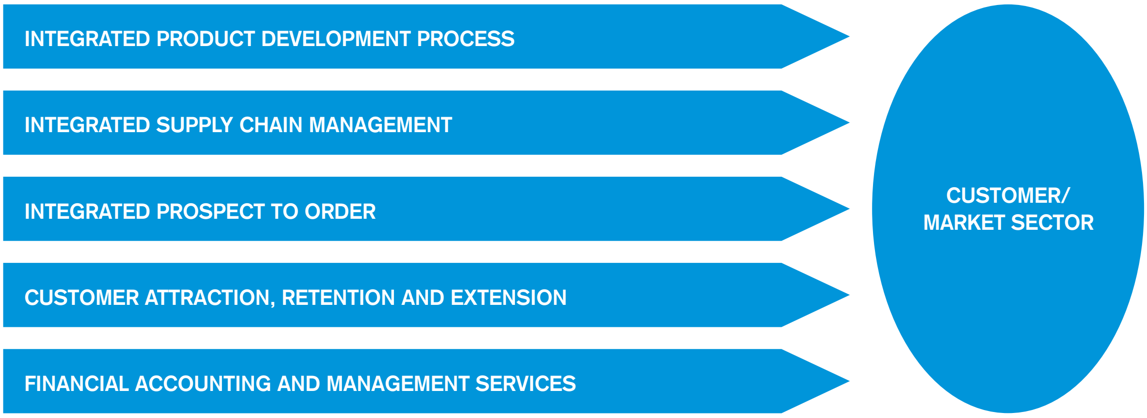
The key difference here is the focus and integration of all activities on the market sector or the customer thereby always creating value and driving an innovation cycle that supports and challenges the need for profit and customer focus within the organisation.

The conclusion is that the Integrated Product Development Process is an R&D cycle that works at primary research, applied research and development whilst all the time focusing on customer needs and integrating its designs and concepts with production/logistics requirements, customer support requirements and standard financial requirements.

37. This reports acknowledges that the culture and environment in companies in never perfect, however these are the key driving issues.

FIGURE 4.1: EXISTING VALUE CHAIN IN MNCS

FIGURE 4.2: THE DEVELOPING VALUE CHAIN OF SUCCESSFULLY COMPETITIVE COMPANIES



Additionally, Supply Chain Management works to produce, distribute and deliver results to the customer, in a manner that they require.

The Customer Care process becomes as focussed on customer retention and the sell on of new services as it might in simply supporting the sales process. Within this context of organisational focus, the overarching emphasis on every function is to get closer to the market and the customer and to share data that enables that closeness. Sales and Marketing becomes a vital link in ensuring and facilitating all functions to achieve that closeness. It is evident that the companies that have a customer interface as opposed to performing ‘black box’ cost operations have greater capability in all facets of their operations.

Within this environment the emphasis shifts from being cost driven to being value added and driven by market insight. Business units are more profitable and successful and the value to the overall organisation is increased. In essence, the mandate moves from cost centre to profit centre, using customer contacts (through multiple channels) and a movement to manage the entire customer life cycle.

4.5 PUBLIC SECTOR ANALYSIS

Although no longer in operation (operations ceased in 2006 in NI[38]), the DTI Manufacturing Advisory Service and the Manufacturing Technology Partnership did provide services to improve competitiveness by increasing innovation and the profitable use of technology in industry. The MTP brought together small manufacturing companies, academics and technology experts; and in doing so, enabled Northern Ireland's small companies to develop affordable and appropriate technical solutions.

The MTP attempted to provide low-cost, hands-on help to improve profitability and business performance throughout the value chain of a company - ranging from operations to customer service. The services were provided through QUB, UU, the North West Institute, Belfast Institute, ANIC and the Loughrey Campus of CAFRE. Clearly, the choice of service provider was dependent on the location and need of the company. However, the focus of the services were on Lean Manufacturing (reducing costs and defects), Health and Safety, Basic Web Design, Serviced Offices, Knowledge Transfer Programme (similar to the UK model), an incubator programme (labelled SEBI) and an EU funded training and mentoring programme (SMILE).

The programme offered the services to all the sectors that are engaged in Manufacturing and this reflects a broad range of companies - Agrifood to wireless detection units. Most of the companies serviced are small in size and revenue and the focus has been on relatively localised markets.

This service is highlighted here for illustration purposes only. The services addressed some degree of technology transfer to the SME community and this element remains an important facet of the technology landscape, irrespective of how it is addressed.

This programme has been replaced by a programme in InvestNI through the Innovation and Capability Division. This initiative has seen an increase in collaborative research being conducted at a European level amongst companies sharing common themes and goals. It has also seen the integration of the NI Aerospace supply chain into the overall UK National Aerospace Technology Strategy. The work of this function is developing capability through research of various types enables the strengthening of the existing supply chains within NI.

38. The MAS continues to operate in the rest of UK. Operations in NI ceased in 2006.

4.6 ACADEMIC SECTOR ANALYSIS

Within the academic sector there is also well developed and diverse set of capabilities with regards to Advanced Manufacturing in both universities, and this is summarised in the following table. It should be noted that the numeric references in this table refer to the unique numeric reference given to the research institute/group in Appendix B of this report, where a more comprehensive description of each can be found.

There are capabilities within the NI HE sector, which with the equipment to support them, creates a very strong capability in Aerospace, Nanotechnology, Build Environment, Electrical and Electronic manufacturing, Design and Manufacturing and Computational Science. It is also apparent that there are emerging strengths in Energy and Sensors. It is noticeable that the range of skills and capabilities is greater than those utilised in the current sector itself implying that there is some misalignment between them.

With regards to FE, the following table lists the FE courses, the number of students enrolled in them and their locations that are of relevance to the Advanced Manufacturing sector. It shows that there is quite a level of diversity in both the types of courses available, and their locations, which is important as FE students are much less mobile than HE students. It also shows that the total number of students in FE at this time undertaking manufacturing related courses exceeds 5,500.

TABLE 4.5: ADVANCED MANUFACTURING CAPABILITY IN THE HE SECTOR[39]

NO	INSTITUTION/GROUP	LOCATION
1	NI Technology Centre	QUB
2	Polymer Processing Research Centre	QUB
6	The Institute of Electronics, Communications and Information Technology (ECIT)	QUB
17	Electrical Power and Energy Systems	QUB
19	Intelligent Systems and Control	QUB
20	Knowledge and Data Engineering	QUB
23	Atomistic Simulation	QUB
29	Design and Manufacturing	QUB
30	Centre of Excellence for Integrated Aircraft Technologies (CEIAT)	QUB
31	Internal Combustion Engines and Gas Turbines (ICERG)	QUB
41	Built Environment	QUB
56	Information Engineering Research Group	UU
58	Intelligent Systems Engineering Laboratory	UU
64	Centre for Sustainable Technologies	UU
65	NI Centre for Energy Research and Technology	UU
68	Electrodes and Sensors Group	UU
71	Engineering Composites Research Centre (ECRC)	UU
72	Advanced Metal Forming Research Group	UU

39. The breakdown of HE Enrolments in NI is presented in Chapter 3, section 6.

TABLE 4.6: ADVANCED MANUFACTURING CAPABILITY IN THE FE SECTOR

SUBJECT CODE OF COURSE	TOTAL	LOCATION
General Engineering	654	Armagh, Castlereagh, Causeway, East Antrim, East Tyrone, Limavady, Lisburn, Newry & Kilkeel, North East, North West, Omagh, Upper Bann
Integrated Engineering	621	BIFHE, Castlereagh, Causeway, East Tyrone, Fermanagh, Newry & Kilkeel, North East, North West, Upper Bann
Refrigeration	128	Castlereagh, East Antrim, Fermanagh, Limavady, Lisburn
Computer Aided Engineering	122	Fermanagh, North East, North West
Others in General Engineering	54	East Antrim, North West
Civil Engineering	223	BIFHE, North West, Omagh, Upper Bann
Mechanical Engineering	545	Armagh, BIFHE, Causeway, East Antrim, East Down, Fermanagh, Limavady, Lisburn, North East, North West, Omagh, Upper Bann
Mechanisms & Machines	8	Upper Bann
Agricultural Mechanics	83	Omagh, Upper Bann
Engineering: Automobile/Motor Vehicle	1,306	Armagh, BIFHE, Causeway, East Antrim, East Down, Fermanagh, Limavady, Lisburn, Newry & Kilkeel, North Down & Ards, North East, North West, Omagh, Upper Bann
Automobile Assessment	8	BIFHE
Motor Cycle Engineering	20	Castlereagh
Vehicle Bodywork	122	Fermanagh, North East, North West
Road Transport Engineering	54	East Antrim, North West
Motor Vehicle Electronics	50	BIFHE, East Antrim, Fermanagh, North East, North West
Mechanical/Electromechanical Engineering	128	Castlereagh, East Antrim, Fermanagh, Limavady, Lisburn
Mechanical/Production Engineering	21	East Antrim
Others in Mechanical Engineering	108	Castlereagh, North West, Omagh
Aeronautical Engineering	58	BIFHE
Aerospace Studies	52	BIFHE
Engineering Design & Manufacture	300	BIFHE, North Down & Ards, North West
Manufacturing Engineering	215	BIFHE, Lisburn
Fabrication Engineering Craft Practice	115	BIFHE, East Antrim, North West,Upper Bann
Mechanical Engineering & Maintenance	183	BIFHE, Lisburn
Sheet Metal Work	9	Upper Bann
Welding	198	BIFHE, East Antrim, East Tyrone, Limavady, Omagh, Upper Bann
Others in Production Engineering	21	BIFHE, Newry & Kilkeel
Plant/Process Engineering	10	BIFHE
Other Engineering	197	BIFHE, Castelreagh, Causeway, East Tyrone, Limavady, Lisburn, North East, North West, Omagh, Upper Bann
Sum	**5,613**	

4.7 OVERALL SECTOR CAPABILITY MAPPING & CONCLUSIONS

Introduction
The overall capability in NI Advanced Manufacturing capability outlined above is summarised in Figure 4.3. For the sake of clarity, it is worth pointing out that this analysis does not reference the scale of capability but rather if the capability exists or not.

This capability demonstrates that traditional Manufacturing within NI is fading as new forms of Advanced Manufacturing capability is being developed from within industries such as Aviation, Lean and Sustainable Manufacturing in Construction, Beverages etc and the newer capabilities of Design, Simulation and Validation alongside advanced manufacturing techniques are showing the highest degree of potential within Northern Ireland. There is a clear indication however that the full strengths of the Academic Sector are not being exploited in full and the gap between the traditional manufacturing companies and others appears to be growing all the time. The future of Advanced Manufacturing in NI as outlined in section 4.3 above will depend on the ability to further leverage the capabilities in the top quadrant.

The same analysis can be applied to the sectors identified within Advanced Manufacturing. This is represented in Figure 4.4.

This analysis also presents the same picture by sub-sector. Traditional industries are under some degree of difficulty in terms of cost and logistics and the scientific application remains relatively weak - although the scientific base in NI is strong. The key industries are Aerospace, Automotive, Construction Products and Glass and even domestic appliances where some significant scientific capability is rapidly aligned with exploitation pathways to market. These same pathways could also be used by other sector (including the traditional industries) but there is a disconnection within the sector which prevents this from happening.

FIGURE 4.3: NI ADVANCED MANUFACTURING CAPABILITY

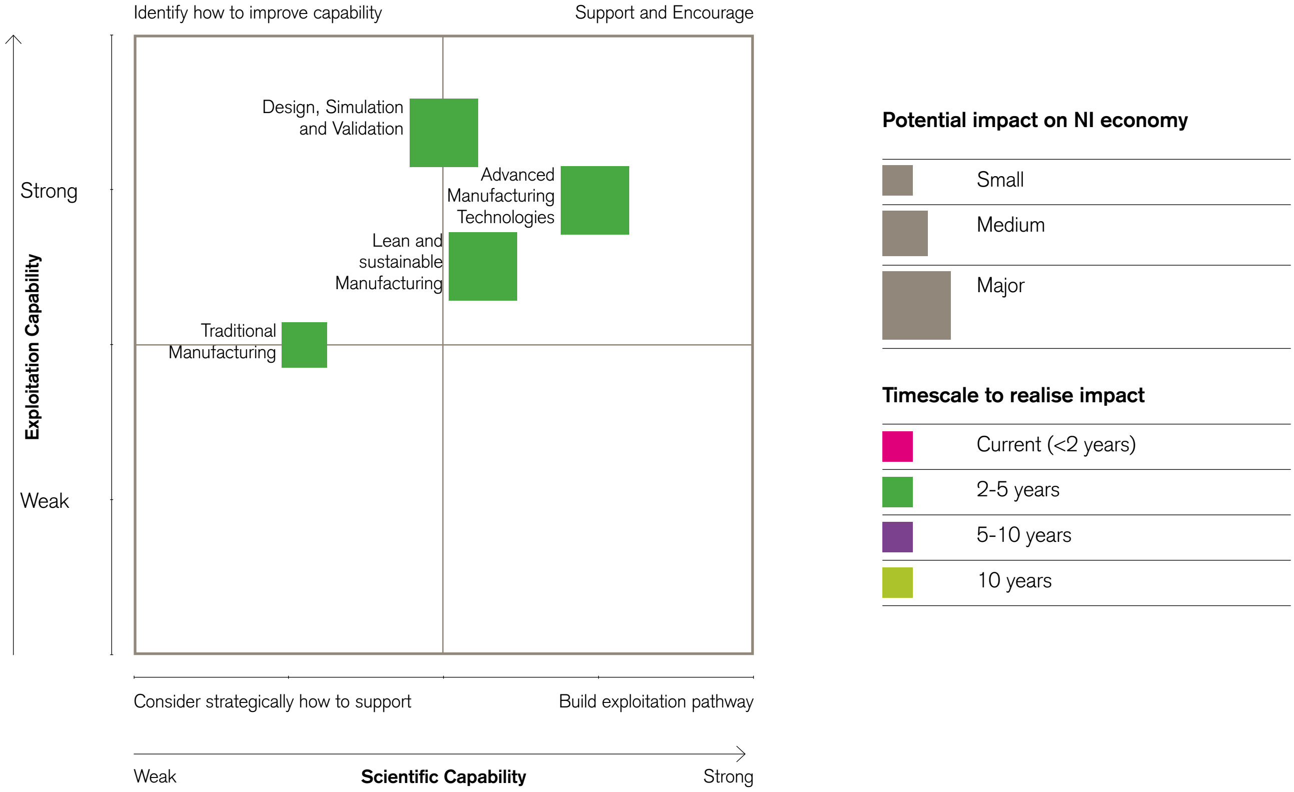
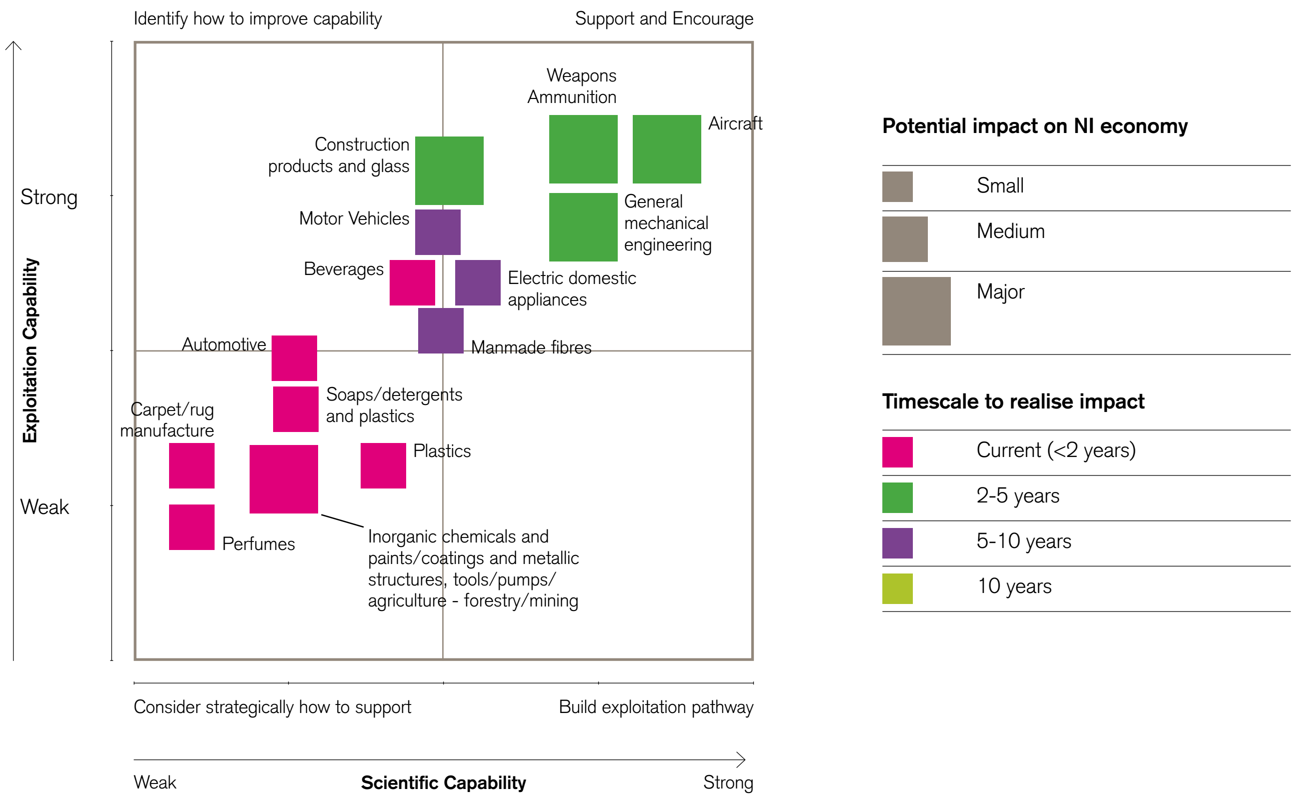


FIGURE 4.4: NI ADVANCED MANUFACTURING BY SUB-SECTOR



4.8 OVERALL SUMMARY

The key summary from the analysis of Advanced Manufacturing is as follows:

1. Traditional manufacturing has declined in NI as it has declined throughout the UK however; the proportion of decline is less than the UK. The demise of the traditional fields of manufacturing - textiles, shipbuilding etc create an overall negative viewpoint however outside of those sub-fields, there is growing strength in the sector in NI. This is reflected in the growth of GVA even when headcount reductions are taken into consideration;
2. The profile of manufacturing needs to change in NI. The majority of companies in the sector are dealing with cost related items which makes them vulnerable. There are fewer larger companies in the sector, but those that do exist have developed highly competitive capabilities in Lean manufacturing, Design, Advanced Materials (Metals, Composites, and Catalysis) and associated Manufacturing techniques and an ability to use the university structure in the region. It is also worth noting that these companies have strong interdisciplinary approaches to finding solutions and all of them have some degree of customer interaction;
3. The development of the matrix above indicates that any future growth in this sector in NI must come in the higher skilled production processes. These can happen in niches such as Transport; Engineering (Glass, Construction); ICT and Bioscience;
4. There are scientific capabilities in NI that are not being exploited locally from a manufacturing perspective and these relate to Construction, Packaging, Advanced Materials and a fuller use of Computational Science to deliver competitive advantage;
5. As NI will continue to increase its spending in R&D it must recognise that this spending is only part of the journey into a knowledge economy. Successful innovation is as much about execution as it is inspiration to get a new product to market. This is something that, irrespective of technology, the highly competitive companies in NI understand. There is a real need to take a transformational approach to niche manufacturing that are needed to make NI a 'true' innovation centre creating new solutions to traditional problems.

For NI manufacturing, it will be important to take a balanced approach with some surer, near term innovations which result in line extensions and new platforms as well as some breakout innovation. The way to attract the big branded corporates (who tend to control the routes to market for new products) is to create local entrepreneurial eco-system/clusters which will include angel investors and VC and PE funds around research and educational centres of excellence which NI already has. Ultimately concepts need to be modelled and tested, detail designed, rapid prototyped, toleranced, patented, documented within approved quality systems, pass through regulatory processes, designed for manufacture, reliability and cost competitiveness, optimum commercialisation strategies and business models identified, scaled -up, tech transferred to manufacturing partners, etc. This is the new world of manufacturing which NI can continue to play in if the full extent of existing capabilities is leveraged.

ADVANCED MATERIALS

5

5.1 ADVANCED MATERIALS

Advanced Materials is a strength sector in Northern Ireland. It consists of almost 55 companies with a collective turnover of £867 million, employment of 7,081 which has been growing year-on-year. Most significantly, this sector shows the highest number of total companies engaged in some R&D capability (33) and has a total spend of £4.2 million per annum, with almost 1% of employed staff engaged in R&D. This sector also demonstrates the closest affiliations with the university and research organisations.

5.2 SECTOR DESCRIPTION

Advanced Materials is the generation and application of knowledge relating to the composition, structure and properties of materials and their use in specific applications. Broadly speaking, Materials Science focuses on understanding the relationship between the composition and structure of existing and new materials. Materials Technology focuses on exploiting the opportunities of existing and new materials in applications. Advances in materials science and technology are viewed as a key enabler for product development and innovation in most sectors. This area of research and development has become multi-disciplinary and now spans most scientific and engineering disciplines.

In this report, Advanced Materials is defined as the collective term for a set of techniques and processes aimed at the measurement and manipulation of matter with the aim of an improved understanding of all materials, and the use of this understanding to design and prepare new materials with exactly the desired structural and functional properties. By this definition, Advanced Materials, which includes the emerging nanotechnologies, allows the composition and structure of materials to be controlled and characterised on the atomic and molecular scales. Advanced Materials also includes computational technologies,[40] which underpin the key abilities to design and simulate the properties and performance of materials.

NI does possess capability in Advanced Materials ranging from Nanotechnology which is used for fabrication and energy to some aspects of nanoclays used in polymers and ceramics. Given the multidisciplinary nature of Advanced Materials and their impact on most other sectors, it is important to recognise that whilst this capability is leveraged in specific companies in Northern Ireland, it is equally possible to demonstrate that this capability could be used in Agri-food, Transport, Life Sciences, ICT and other sectors to create new possibilities. Most importantly, from an Advanced Manufacturing perspective, the advent of Advanced Materials is fundamentally changing the structure and nature of manufacturing and this is something that NI can further exploit.

40. All recent reports on Advanced Materials refer explicitly to Computational Science being an integral aspect of Advanced Materials.

5.3 KEY TRENDS IN ADVANCED MATERIALS

The use of advanced materials both directly and as applied within manufacturing across the different sectors is growing continually on a global basis. The advances in areas such as communications and healthcare create specific needs for advanced materials and ensure continued growth in that need for the foreseeable future. There is continued pressure for this growth against a background of continued focus on sustainability, issues such as global warming and respect for the environment. While there are pressures on the continued availability of different materials given they are a finite resource, materials themselves will also play a key part in new technologies aimed at improved sustainability in areas such as alternative energy production (e.g. fuel cells).

Applications of Advanced Materials can be found in all sectors and can be sub-divided into two principal types, based on possible impact. These are presented in Figure 5.1.

This diagram (Figure 5.1) demonstrates the impact of Advanced Materials on the sectors (Low to High). It also shows the market impact of products within those sectors in terms of Value Added.[41] For example, Medical Technologies are significantly influenced by Advanced Materials and the resultant products have high market prices and profitability. The industries in the above diagram are divided into two main categories. These are:

High Impact: The 'inventive' type
This refers to a small but growing number of 'disruptive' products or processes made possible only by Advanced Materials. These new products and processes extend current capabilities as a result of invention. Such products may already exist in concept or in the laboratory, but the means to realise them are only now being developed. The products within this category are:

- Considered to be 'disruptive' from a market perspective, in that they would offer new properties or characteristics to those offered before;
- Offer the potential of different lead-times including processing time, reduced time to market; and
- Dependent on new manufacturing processes.

Examples of this category are the next generation of semi-conductors, active medical devices and intelligent drug delivery platforms or alternative energy sources such as fuel cells.

Medium/Low Impact: The 'innovation' type
This refers to a wide range of existing products and processes into which Advanced Materials have been incorporated. These products can be characterised as having 'Advanced Materials Inside' i.e. the product is largely the same as before but it has evolved to having more properties (in terms of increased functionality or reduced cost of manufacturing). The products within this category are:

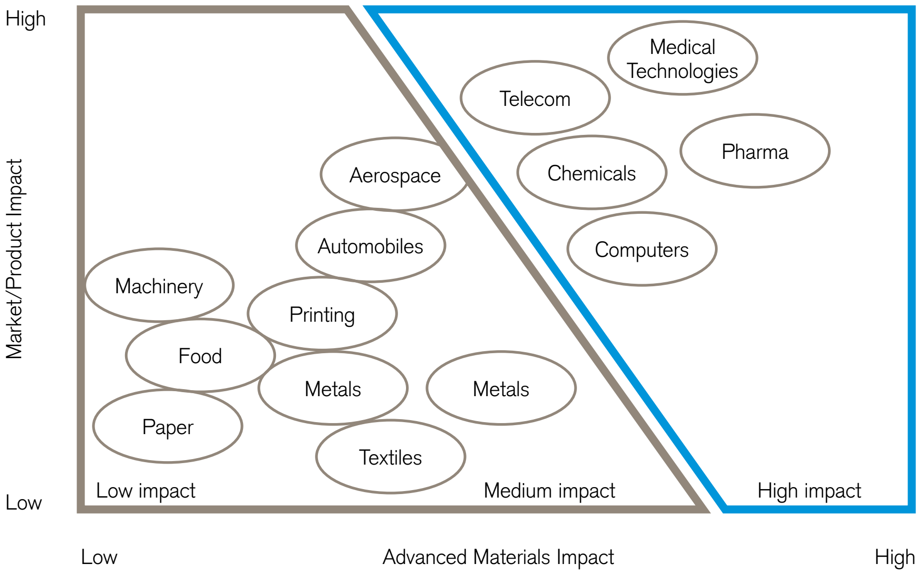
- At a relatively advanced stage of their development in terms of market availability and manufacturing capability (in most cases they use existing or modified manufacturing processes and require some regulatory approval before being used);
- Capable of a return on investment within the next 2-3 years as the materials currently exist and require application to existing products and/or expanded markets;
- Capable of adoption for capital-intensive corporations but are also applicable to some SMEs and can have an impact on such SMEs in terms of product positioning, competitiveness or new markets; and
- Adaptable to existing manufacturing processes.

Examples of this category are Aerospace/ Automotive products.

Investment in materials - from research through to development and innovation - will lead to new wealth creation, supporting existing high-tech industries and creating new spin-offs. This area represents continued and growing opportunities for Northern Ireland.
The table below (Table 5.1) indicates that the traditional fields of Advanced Materials and developments within those fields have already clear leadership in a Global context (US) and a European context.

41. This implies additional price point or a bundling with service that provides higher degrees of value added.

FIGURE 5.1: THE IMPACT OF ADVANCED MATERIALS ON SECTORS



Source: PA Consulting - Sectoral Impact of Advanced Materials

TABLE 5.1: ADVANCED MATERIALS SUB-FIELDS - LEADERSHIP ACTIVITY IN VOLUME OF PUBLICATIONS, PATENTS AND COMPANY START-UPS[42]

SUB-FIELD	DESCRIPTION
Metals	Dominated by the US, Japan, UK (static) with two non-traditional countries emerging - China and Korea. UK remains static and appears to be losing ground.
Catalysts	Dominated by the US. However strong growth emerging from Italy, Holland, Germany and France. Emerging centres in China, India and Korea.
Ceramics	Dominated by the US and Japan with Germany being the only European country with significant activity.
Magnetics	Dominated by the US and Japan. UK share is decreasing whilst Holland and Germany are showing leadership positions.
Composites	Global surge in activity with equal shares between US, Japan and Europe. Within Europe, UK has the lead followed by Germany and France. Europe could now move to the front line of composites manufacturing and modelling.
Optical Photonic	US has the lead with Italy showing the latest surge in Europe whilst the UK, Germany remain static but remain dominant in Europe. Japan remains static and there are emerging nations with China and Korea showing activity.
Superconducting	US has the lead with significant challenge from Japan. There is some activity in Europe but the UK is not to the forefront of this.
Polymers	US has the lead globally and is driven forward by the chemical industry there.
Nanostructured Materials	Slight lead from USA, driven by venture capitalist funds. However UK showing significant strength in Europe with high growth.
Multifunctional Materials	Data Not available
Computational Science	USA has the lead globally however strong emerging contenders in Japan and the UK in Europe.

42. Materials R&D/National Research Council/USA.

5.4
PRIVATE SECTOR CAPABILITY ANALYSIS

Given the broad applicability of advanced materials there are a large number of companies in NI that use advanced materials within their manufacture/ production processes. Using the sub-fields defined in Table 5.1 above, the allocation of companies to sub-fields demonstrated in Table 5.2 below.

TABLE 5.2: ADVANCED MATERIAL COMPANIES IN NORTHERN IRELAND[43]

ADVANCED MANUFACTURING SUB-FIELDS	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Biomaterials	Biomaterials are materials (synthetic and natural; solid and sometimes liquid) that are used in contact with biological systems. Although biomaterials are primarily used for medical applications, they are also used to grow cells in culture, to assay for blood proteins in the clinical laboratory, in processing biomolecules in biotechnology, for fertility regulation implants in cattle, in diagnostic gene arrays, in the aquaculture of oysters and for investigational cell-silicon 'biochips'. The commonality of these applications is the interaction between biological systems and synthetic or modified natural materials. Biomaterials are rarely used on their own but are more commonly integrated into devices or implants. Thus, the subject cannot be explored without also considering biomedical devices and the biological response to them. Biomaterials can be metals, ceramics, polymers, glasses, carbons, and composite materials. Such materials are used as moulded or machined parts, coatings, fibres, films, foams and fabrics	Biomaterials companies are found primarily in the diagnostics space with Biosyn, Diagnostics, and Fortress Diagnostics. Other companies such as Gendel and Sensor Technology Devices also use this capability. Finally, interesting developments are occurring with Biomaterials in Xenosense and Xiomateria.	4		3

43. DETI Database 2005

ADVANCED MANUFACTURING SUB-FIELDS	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Ceramics	Materials that remain critical components of many larger materials systems and commercial products. The field of ceramics has continued to expand. For example, work on ceramic materials for electronic devices has significantly expanded into both thin films and nanostructured materials. The need for higher performance wireless systems has pushed the ceramics field to develop new microwave materials. Similarly, there is a new focus on active optics, such as optical amplifiers, and efforts in bioceramics and in ceramics for power sources, sensors, filters etc.	Ceramic strength is not evident in NI except through the presence of AVX-Kyocera who use Ceramic components.	3		3
Coating	The development and production of novel coatings and surfaces. Applications are found in all technologies from microelectronics and optics to medical devices and sensor technologies. Coatings are used for scratch resistance properties, making surfaces water or dirt repellant, improvement in antireflection properties, photoactive coatings and the development of non-abrasive and non-reactive coatings.	Not a key strength in NI although the technology is used in a number of companies including DuPont, Kent Plastics, Perfecseal, Seagate and Sensor Technology and Devices. Most of the applications are used in conjunction with other materials for packaging or magnetic purposes	3	4	

ADVANCED MANUFACTURING SUB-FIELDS	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Composites	Materials with exceptional strength and stiffness-to-density ratio alongside other physical properties. They can be formed into more complex shapes than pure metallic components. The combination of materials with complementary properties makes it possible to derive a composite material with most or all of the benefits of both materials and few of the weaknesses of the individual component materials.	There are a number of clear cut composite companies in NI (BE Aerospace, Creative Composites, Macrete, aspects of the Quinn Group). Composites also form an integral aspect of work in Bombardier.	4	4	
Multi-functional Materials	Materials that integrate multiple properties, some of which are structural and others, which are functional (i.e. optical, thermal etc). The end systems include aspects of smart materials and biologically inspired materials involving all the main materials types such as polymers, ceramics, metals etc.	Multi-functional materials are used predominantly across the medical technology companies (Amtec, Meridian Medical Technologies, Micro-flextronics, Montupet and Schrader. Some textile manufacturers such as William Clark and Sons and TSM have started to use these materials for new products. Thermomax for example are showing significant leadership using Multi-functional materials with Coatings.	3	4	

ADVANCED MANUFACTURING SUB-FIELDS	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Electronic Materials	Materials primarily for semi-conductor devices such as strained silicon technology or displays, optical memories, storage technologies etc. Primarily, electronic materials are been driven by the consolidated industry roadmaps from the International Technology Roadmap for Semi-conductors (ITRS). Another area of increased interest in the electronic materials is sensors of all types: mechanical, fluidic, biological, chemical, radio frequency, and optical.	Electronics materials are used in a select number of companies ranging from Gazer Technologies, Heartsine, Icemos (a featured company), and Seagate. With the exception of Icemos, the capability is generally used in multiple applications.	3		4
Magnetic Materials	Materials that are used for more efficient, smaller, and lighter electric generators and motors; research on 'soft' ferromagnets to decrease coercivities and for use in more efficient transformers that consume less energy; research on ferrites for improved high-frequency operation (especially for radar); and research on magnetetic tropec materials for information storage. Biomagnetism includes targeted drug delivery; detection and separation of antigens; magnetically improved magnetic resonance imaging (MRI) resolution in localized areas; localized control of biological or cellular activity; and magneticheating probes for local thermal treatment.	Magnetic Materials are used in few companies with FG Wilson Engineering, Randox Laboratories and Seagate being the only examples of scale use of these materials.	3	4	

ADVANCED MANUFACTURING SUB-FIELDS	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Metals	Traditional materials that have changed significantly in the past 20 years.	There are few applications of Metals in NI outside of FG Wilson, Monupet.	3	3	
Polymers	Materials that are critical to the chemical industry. In recent years, these have been overtaken by environmental and life cycle concerns. These trends are offset by research growth in the polymer user industries such as computation, communications and medical technologies.	Polymers are used throughout the sector in NI. Examples are BCO technologies, Boxmore plastics, Brett Martin, Clarehill plastics, Colorite, Denroy, DuPont, Perfecseal, Huhtamaki,	3	3	
Superconducting Materials	Materials that are centred on the mechanism for superconductivity in high-temperatures. The scientific challenge is to discover room-temperature superconductors.	N/A			
Catalysts	Materials from chemistry and biology that ensure that reactions are set in motion and accelerated with less energy. They are therefore central to process optimisation. The foremost topics in catalysis continue to be environmental catalysis, fuel processing, selective oxidation, acid-base catalysis, biocatalysts, gas-to-liquids, production of hydrogen, asymmetric catalysis, photo catalysis, and chemical processing.	Catalysis capability is well established in NI primarily in academia through the work in QUB and work in UU. The awareness of catalysis in industry was reduced however 'newer' more recent advanced materials companies were aware of the capabilities. The growing importance of catalysis was recognized by newer industries across a variety of sectors.	4	3	

ADVANCED MANUFACTURING SUB-FIELDS	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Nanostructured Materials	Materials that have led to new findings in materials in the past number of years. The inter-disciplinary cooperation between physics, chemistry, biology and engineering is a pre-requisite to this sub-field. On this basis, these materials increasingly occupy technology fields and markets of existing microtechnology as, in addition to providing further miniaturisation, they allow for the exploitation of new phenomena, which occur at nanometer scale only. The current focus is on nanostructure materials, chemical nanoanalysis and ultrathin functional layers.	These are the most widespread materials used within the sector in NI. Companies ranging from Almax, Andor, AVX, Biosyn, Bombardier, Delta Packaging, Fusion Antibodies, Icemos, Seagate Technology, Thermomax are all using Nanostructured materials	4	4	
Computation Science	The ability to predict behaviour in materials and simulate outcomes	Bombardier, Randox etc.	4	3	

The companies and their key sectors are presented in Appendix C. It is apparent that the NI shows stronger positioning in the newer disciplines where there is a convergence of the traditional sub-fields (composites, multi-functional materials and nanostructured materials) and a reliance on multi-disciplinary skills aided by Computational Science capability.

SELECTED COMPANIES

Within the broad spectrum of companies that use advanced materials we focus here on subset of those companies where advanced materials forms a key part of their overall business model and with active R&D focused in this area. These companies account for 84% of the Research and Development spend within the Advanced Materials sector and their activities are summarised here.

Brett Martin
Brett Martin produces roofing and rainwater products for the construction industry through extrusion and injection moulding. The company is not highly active in product R&D but has made continued improvements across production processes with a high degree of innovation apparent in achieving improved efficiencies and productivity. The company has introduced complex auto assembly capability along with using Six Sigma and Lean approaches.

Colorite Europe
Colorite Europe Ltd is a small company with about 35 employees highly active in Research and Development of new plastic (PVC) compounds for the production of medical/healthcare equipment. The company is part of a larger US group (Tekni-Plex, Inc.), acting as a group R&D centre for plastic compounds, and has its main markets in South East Asia. Colorite is currently engaged in a significant Start programme and has carried out a number of projects funded through Compete. The company have significant in house capability through the calibre of staff they attract and supplement this with links to the MPRI and PPRC at Queens. They also use a non-production line for prototyping some of their new developments.

Icemos Technology
Icemos was founded in 2004 from a company background that originally existed as BCO Technologies before being taken over by Analog Devices in 2000. The company is focused on development of Advanced MEMS using Silicon on Insulator (SOI) as the basis for manufacture and leading Trench Edge techniques to achieve unique product characteristics. Icemos have three core capabilities:

- Grinding and polishing of wafers
- Bonding of wafers
- Trench Edging to refill wafers

which they focus on the ‘customisation of engineering substrates’ for a range of customers. The company exports 100% of their products and a significant level of activity involves working with customers on products that are not yet in full production. They have developed strong relationships with customers in key sectors such as life sciences/healthcare. Icemos has developed new approaches to manufacture of Photo Diode arrays, supported by a Compete grant.

Radius Plastics
Radius Plastics is part of the Uponor Group focusing on extruded products and is considered to be a development ‘hub’ for the group. The company has moved from a traditional focus on the telecoms industry to address other sectors such as petrochemicals, and construction. Radius has a highly active product development function where they develop 70 to 80 products per year based on very short cycle times for development. Many of these products are variants but in some cases they have successfully developed new products for new sectors as part of their overall diversification strategy. The company relies mainly on their in house expertise with limited interaction with the Universities.

Titan Environmental
Titan Environmental is a division of International Kingspan Group and manufactures storage containers primarily aimed at the construction and civil engineering industry. It is part of the largest rotational moulder in Europe with seven manufacturing sites across Europe. The focus of R&D is on development work aimed largely on improving existing product ranges, with limited diversification at the Banbridge plant to date.

Wilsanco Plastics
Wilsanco Plastics manufactures packaging for the dairy industry, predominantly plastic pots for dairy products such as yoghurts and creams. The primary focus of their R&D staff

TABLE 5.3: ADVANCED MATERIALS COMPANIES IN NORTHERN IRELAND[44]

COMPANY NAME	TURNOVER (£000)	TOTAL TURNOVER AS % OF SECTOR TURNOVER	R&D SPEND (£000)	TOTAL R&D SPEND AS % OF SECTOR R&D SPEND	NO. OF EMPLOYEES	NO. OF EMPLOYEES AS % OF SECTOR EMPLOYMENT	R&D STAFF	FULL-TIME R&D STAFF AS % OF SECTOR TOTAL
Brett Martin	66,855	7.50%	86	1.00%	359	4.40%	1	0.60%
Colorite Europe	7,0	0.80%	265	3.10%	25	0.30%	2	1.30%
Icemos Technology	496	0.10%	1,727	20.10%	12	0.15%	25	16.10%
Radius Plastics	13,069	1.50%	206	2.40%	73	0.90%	4	2.60%
Titan environmental	23,675	2.70%	240	2.80%	238	2.90%	6	3.90%
Wilsanco Plastics	11,466	1.30%	211	2.50%	201	2.50%	1	0.60%
Seagate Technology[45]	151,777	17.00%	4,424	51.50%	1,921	23.60%	77	49.70%
Totals	**274,484**	**30.90%**	**7,159**	**83.40%**	**2,829**	**34.75%**	**116**	**74.80%**

is on product development (variants of the current product range). The majority of product development is customer led and funded although Wilsanco also carry out speculative product development in some cases. The capability is strong around testing and analysis of polymers and there is ongoing research collaboration with Queen's University Belfast and some activity beginning with University of Ulster. The patents that exist for Wilsanco products and processes are inherited from their Swiss parent company.

Seagate Technology
Seagate Technology was founded in 1979 and has been established in NI as Seagate Technology (Ireland) since 1993. It is the global driver of innovative solutions for the storage industry. The breath of solutions offered by Seagate is not matched by any other hard drive manufacturer with a market offering of over 40 products ranging from home computing to enterprise data centres. Seagate delivers advanced solutions for every industry that requires digital storage. The company leads the industry in research and development, with a focus on bringing to market new technologies that will meet the needs of future generations. Since its inception, Seagate has consistently delivered breakthrough innovations and raised the bar for digital storage solutions. The company has been first to market with technologies that power your digital life, from the home to the hand to the car and the office, such as perpendicular recording, hardware-enabled full disk encryption and hybrid drives, and continues to invest in the development of new technologies to increase performance, speed and areal density (the ability to store more data in less space). The statistics of the Seagate operation demonstrate the significance of their operation to NI;

- 35% of the global market
- 2 sites in NI - one makes disc substrates and one makes heads
- Advanced clean room facilities
- R&D expenditure £4,497,000
- Employees 2,244
- R&D staff 80

44. DETI Statistics 2005.
45. Seagate Technology figures are updated in the profile described above.

SUMMARY OF PRIVATE SECTOR CAPABILITY

They hold world class technological capability in a number of fields including thin film deposition, lithography, surface engineering and metrology and operate clean room facilities up to class 100. They are also expert in the application of 6-sigma, lean and theory of constraints to both production and design and the NI plants hold the core IP on thin film sensor manufacture. They have links with the Physics and Electronics departments at QUB and Nanotechnology at UU through KTP's and support to taught courses.

In Springtown, Seagate has over 1,300 employees with 50 in R&D positions. The annual salary bill exceeds £25 million with other expenditures exceeding £3 million. There is an external local sub-contractor network of significant value also. Through the Northern Ireland Consortium for Advanced Materials and the Seagate Plan, the company supports a wide range of university research in NI, UK and Europe to total of £100,000 per year.

The company also sponsors community and educational activities such as the annual Young Innovators competition.

There are 55 companies involved in this sector in NI. These companies vary dramatically in size from SMEs to large scale entities (such as Seagate). They all have a commonality in terms of the Advanced Materials sub-fields that are used and most of the effective companies in this sector are already working actively with the universities in either applied or fundamental research.

The sector in NI shows an emphasis on Nanostructured Materials, Biomaterials, Multi-functional Materials and Polymers. More significantly in the fundamental aspect of work on Nanostructured, Multi-functional and Biomaterials work which demonstrates highly competitive capability. The private sector in this regard is closely aligned with the work of the universities which is also very significant.

5.5 ACADEMIC SECTOR

The Advanced Materials area is well represented across research centres focused on areas such as materials use in nanotechnology, polymers in medical devices, structural and sustainable materials. The range of activity reflects the broad applicability of advanced materials as the underpinning foundation for the development of products across many sectors.

There are particular strengths in Nanotechnology, with over 150 researchers active in this field and links with key companies across Northern Ireland. A summary of research centres in NI is provided in the Table below:[46]

TABLE 5.4: SUMMARY OF CAPABILITY IN THE HE SECTOR IN THE DOMAIN OF ADVANCED MATERIALS[47]

NO	INSTITUTION/GROUP	LOCATION
23	Atomistic Simulation[48]	QUB
67	NIBEC	UU
76	Bioimaging Research Group	UU
71	Engineering Composites Research Centre	UU
72	Advanced Metal Forming Research Group	UU
63	FireSERT	UU
64	Centre for Sustainable Technologies	UU
24	Centre for Nanostructured Media	QUB
15	Innovative Molecular Group (Biomaterials)	QUB
21	NI Semiconductor Research Centre (NISRC)	QUB
30	Centre of Excellence for Integrated Aircraft Technology	QUB
28	Polymer Processing Research Centre	QUB
32	Medical Polymer Research Institute	QUB
41	Centre for the Built Environment	QUB
67	RTD Centre Nanotec NI	QUB/UU
75	AFBI (BioMaterials)	DARD
104	CentaCat	QUB

46. Ref – report from Invest NI on centres of excellence and others from Nanotec NI.
47. The breakdown of HE Enrolments in NI is presented in Chapter 3, section 6.
48. Originally, this centre was included in Advanced Manufacturing however, it has now been moved to Advanced Materials.

With regards to FE, the following table lists the FE courses, the number of students enrolled in them and their locations that are of relevance to the Advanced Materials sector. It includes all Chemistry, Physics and Mathematics courses and shows that in total some 4,800 students are enrolled on these courses at this time.

TABLE 5.5: SUMMARY OF CAPABILITY IN THE FE SECTOR IN THE DOMAIN OF ADVANCED MATERIALS[49]

SUBJECT CODE OF COURSE	TOTAL	LOCATION
Chemistry	396	BIFHE, Castlereagh, East Antrim, East Down, North Down & Ards, North West
Others in Chemistry	394	BIFHE, North East
Physics	208	BIFHE, East Antrim, East Down, North Down & Ards, North West
Others in Physics	2	BIFHE
Physical Sciences	18	East Antrim
Applied Science	113	BIFHE, Castlereagh, Lisburn,North West
Others in Other Physical Sciences	64	BIFHE, East Down
Mathematics	3,555	Armagh, BIFHE, Castlereagh, Causeway, East Antrim, East Down, Fermanagh, Lisburn, North Down & Ards, North East, North West, Omagh, Upper Bann
Numerical Methods/Analysis	23	Upper Bann
Others in Mathematics	28	BIFHE
Sum	**4,801**	

49. All NI FE colleges have been reorganised in 2007 into six regional colleges. This has not been considered in this analysis other than to note that it has occurred. Please see Appendix D for further reference.

5.6 OVERALL SECTOR CAPABILITY MAPPING & CONCLUSIONS

Advanced Materials is an enabling layer of most of the sectors that currently exist and will potentially continue to develop within Northern Ireland. The relationships between Advanced Materials and the sectors in demonstrated in Figure 5.2.

This figure shows the impact of the Advanced Materials sub-fields defined in Section 5.1 above on the focus and support sectors identified by Matrix. The scoring in this figure is derived from reviews of the sectors within the region supported by sector workshops and individual company interviews. Figure 5.2 must be interpreted from the perspective of the individuals sectors, as they currently exist in Northern Ireland.

It is apparent from this analysis that developments in all Advanced Materials sub-fields are of varying importance to each sector in NI. Falling behind in Advanced Materials capability has significant impacts in terms of competitiveness for all sectors. Recent studies from the US ('Materials R&D, Time for a National Strategy - National Research Council of the National Academies USA'), the UK ('Enabling the Future - A Perspective on UK Materials Research') and Germany ('Materials Innovations for Industry and Society - Federal Ministry for Education and Research') reinforce this position. Without new materials and the understanding of these materials and their processing, it will become increasingly difficult to sustain the development of sectors in NI.

Computational Science is an integral aspect of all Advanced Materials. Through the use of simulation and modelling techniques, it is possible to understand and predict how materials will behave in specific applications and this reduces cost, lead-time and enhances product performance.

FIGURE 5.2: RELATIONSHIP BETWEEN ADVANCED MATERIALS AND THE NI SECTORS

ADVANCED MATERIALS SUB-FIELD	BIOMATERIALS	CERAMICS	COMPOSITES	M-F MATERIALS	ELECTRONIC MATERIALS	MAGNETIC MATERIALS	METALS	OPTICAL MATERIALS	PLOYMERS	SUPER CONDUCTING	CATALYSTS	NANOSTRUCTURED MATERIALS	COATING	COMPUTATIONAL SCIENCE
Identified Sectors														
Transport (Aero/Auto)	2	2	1	1	2	2	1	2	1	2	2	1	1	1
Life Sciences	1	1	2	2	2	2	3	2	1	3	3	1	1	2
Advanced Manufacturing	3	2	1	1	1	1	3	3	1	3	2	2	2	1
Agrifood	1	2	2	2	3	3	3	3	3	2	2	2	1	2
ICT	3	3	3	3	3	3	2	1	1	2	3	2	2	2
Construction	3	2	3	3	3	2	1	3	2	3	3	3	2	2

1. Very high to high   2. High to medium   3. Medium to low

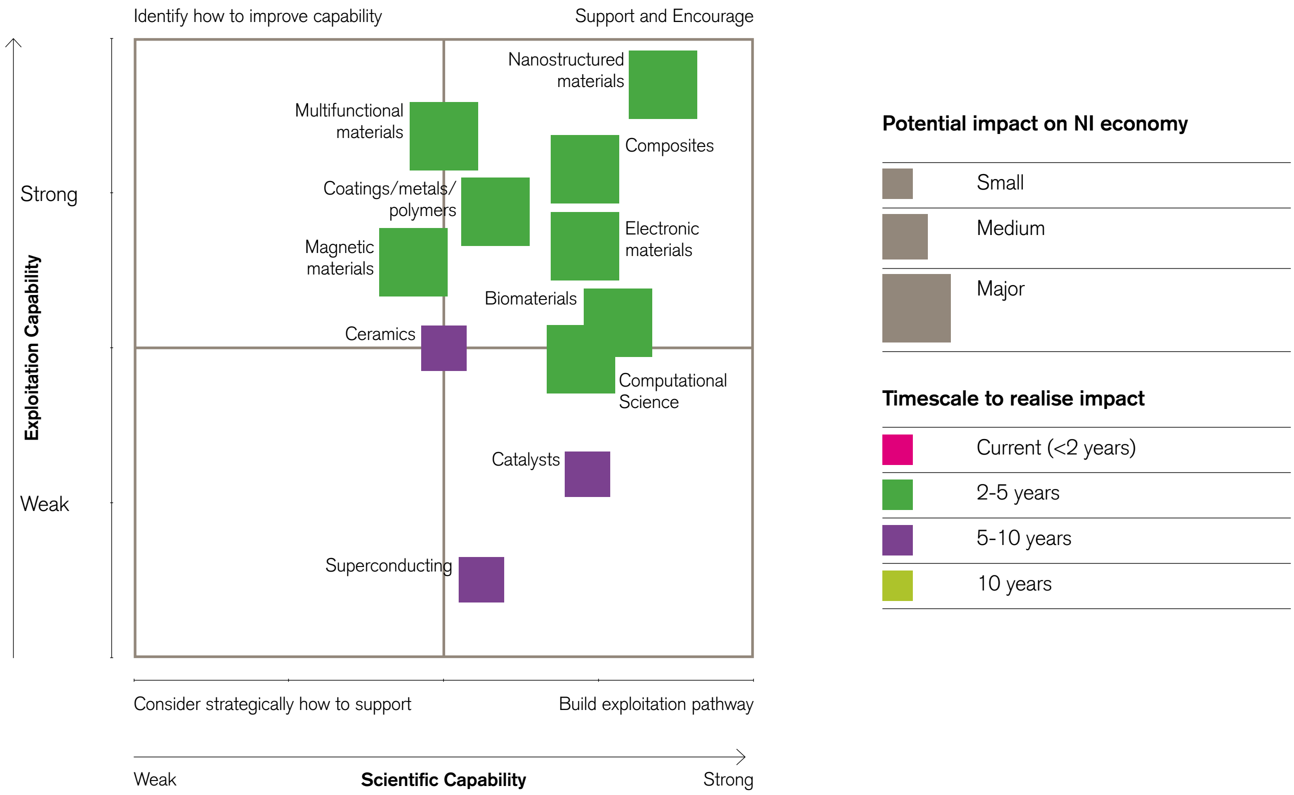
The key capabilities of NI in Advanced Materials therefore are represented in Figure 5.3 below. For completeness, it is important to recognize that this represents capability only and makes no reference to scale.

The significance of this analysis concludes that NI has significant Advanced Materials capability which is seen to underpin all sectors in NI ranging from Agri-food to Textiles to Aerospace. This coverage of spectrum recognizes the important global analysis from section 4.3 above namely that Advanced Materials underpins all sectors and the capability of materials, whilst once distinct to individual sectors, is transferred to all sectors.

Figure 5.3 demonstrates that NI has international standard capability in most of the sub-fields of Advanced Materials. However, the same analysis indicates that the quantity of this R&D is not sufficient for the range and size of sectors within the region. Unlike most other sectors however, there appears to be instances of tight connections between academia and industry in this sector.

The analysis of the industrial and academic strengths shows that a rich focus area for NI is the convergence area between traditional material sectors and a focus on the inter-disciplinary and multi-discipline areas of advanced materials (specifically Biomaterials, Nanostructured Materials, Multifunctional Materials and Composites) where, aided by computational science, NI is demonstrating some key capability on a scale that makes it viable for future company growth. It would be possible for the region to create a niche leadership focus within the UK.

FIGURE 5.3: ADVANCED MATERIALS CAPABILITY IN NI



5.7 SUMMARY OF ADVANCED MATERIALS

The key summary from the analysis of Advanced Materials is as follows:

- Advanced Materials capability underpins the key industries and sectors that currently exist within NI. This capability is seen by industry as a critical defining factor;
- NI is 'punching above its weight' in Advanced Materials as there are many interesting alignments of industry and academia;
- It would appear that a common additional positive in this sector is the multi-disciplinary nature of the teams used and their focus on industry problems whilst dealing with deep science based issues;
- The customer focus nature of some of the work in academia has been well noted and this appears to raise the question of how such collaborations can be further scaled and exploited;
- In some sectors, there are scientific capabilities that are not fully exploited - the emphasis on the Build Environment for example, the use of Biomaterials and the development of computational science as a key component of Advanced Materials are the primary examples.

SUSTAINABLE PRODUCTION AND CONSUMPTION (SP&C)

6

6.1 SECTOR DESCRIPTION

The Sustainable Production and Consumption (SP&C) sector is the generic expression that is used to cover the industry sectors of Energy, Construction, Agriculture and Food. However, in the context of this capability review and in alignment with the definition of the area adopted by the MATRIX Panel, environmental technologies and energy are also included within the definition. It must be noted however that the report addresses Energy and the Environment in the following respects only:

1. The impact of Energy (Cost, Scarcity etc) and Environment (Climate Change, Regulation etc) on the sector;
2. The impact of the sector on Energy (Biofuel etc) and the Environment (Climate Engineering, Alternative Uses of Products etc)

In this context, it is reasonable to support a proposal for MATRIX to consider establishing separate Energy and Environment issues. For the purposes of this report therefore, the scope of is deemed to cover the following scope.

This sector is the second largest employer as indicated in chapter 2 however it is one that experiences change and difficulty. As with similar sectors in other geographies, there are predominantly two types - those that supply the local market with services (bakeries, smaller food companies) and those that are focused on the export related markets. The smaller companies, focused on a local market, do have opportunities to grow but clearly that is related to service capability as much as product capability.

TABLE 6.1: THE SCOPE OF THE SP&C SECTOR IN THIS REPORT

SUB-FIELD	DESCRIPTION
Plant breeding and biotechnology	Plant breeding is the purposeful manipulation of plant species in order to create desired genotypes and phenotypes for specific purposes. This manipulation involves either controlled pollination, genetic engineering, or both, followed by artificial selection of progeny. Plant breeding often, but not always, leads to plant domestication. Plant breeding has been practiced for thousands of years, since near the beginning of human civilisation. It is now practiced worldwide by government institutions and commercial enterprises. International development agencies believe that breeding new crops is important for ensuring food security and developing practices through the development of crops suitable for their environment. The advent of Biotechnology in Plant Breeding has enabled faster levels of development.
Plant production and protection	Plant production is the systematic movement from breeding to full scale production in specific environments. Plant protection supports this movement by ensuring the integrity of the pollination and genetics of the plant.
Animal production and husbandry	Animal production and husbandry, also called animal science, stockbreeding or simple husbandry, is the agricultural practice of breeding and raising livestock. The area covers disciplines such as nutrition, genetics and breeding, or reproductive physiology. Graduates of these programs may be found working in the veterinary and human pharmaceutical industries, the livestock and pet supply and feed industries, or in academia.
Animal breeding and biotechnology	Animal breeding is the purposeful manipulation of animal species in order to create desired genotypes and phenotypes for specific purposes.
Animal health and welfare	Animal health and welfare is capability that seeks to prevent animals from contracting disease or illness.

SUB-FIELD	DESCRIPTION
Aquaculture and fisheries	Aquaculture is the cultivation of aquatic organisms. Unlike fishing, aquaculture, also known as aquafarming, implies the cultivation of aquatic populations under controlled conditions. Mariculture refers to aquaculture practiced in marine environments. Particular kinds of aquaculture include algaculture (the production of Kelp/seaweed and other algae); fish farming; shrimp farming, shellfish farming, and the growing of cultured pearls.
Forestry and landscape	Forestry is the art, science, and practice of studying and managing forests and plantations, and related natural resources. Silviculture, a related science, involves the growing and tending of trees and forests. Modern forestry generally concerns itself with: assisting forests to provide timber as raw material for wood products; wildlife habitat; natural water quality regulation; recreation; landscape and community protection; employment; aesthetically appealing landscapes; biodiversity management; watershed management; and a 'sink' for atmospheric carbon dioxide. Forest ecosystems have come to be seen as one of the most important components of the biosphere, and forestry has emerged as a vital field of science, applied art, and technology.
Management of natural and biological resources	The planning, organising and control of natural and biological resources for specific purposes - commercial, social etc.
Engineering, mechanisation, ICT	The use of mechanism and engineering principles to enhance productivity and effectiveness. The use of low cost ICT solutions to further enhance the capability of the sector through enhanced efficiency.
Food technology, human nutrition and consumer concerns	Food technology, or Food tech for short, is the application of food science to the selection, preservation, processing, packaging, distribution, and use of safe, nutritious and wholesome food. Food scientists and food technologists study the physical, microbiological, and chemical makeup of food. Depending on their area of specialisation, food scientists may develop ways to process, preserve, package, or store food, according to industry and government specifications and regulations. Consumers seldom think of the vast array of foods and the research and development that has resulted in the means to deliver tasty, nutritious, safe, and convenient foods.
Environmental Technologies (expanded definition to NI only)	Environmental technology or 'green technology' is the application of the environmental sciences to conserve the natural environment and resources, and by curbing the negative impacts of human involvement. Sustainable development is the core of environmental technologies. When applying sustainable development as a solution for environmental issues, the solutions need to be socially equitable, economically viable, and environmentally sound. Some environmental technologies that retain sustainable development are; recycling, water purification, sewage treatment, remediation, flue gas treatment, solid waste management, renewable energy, and others.
Energy generation and distribution (expanded definition to NI only)	Energy is the scalar physical quantity that is a property of objects and systems of objects which is conserved by nature. In Sustainable Production and Consumption, this covers several different forms, such as kinetic, thermal, electromagnetic, chemical, etc . As energy may be transformed from one form to another, it is never created or destroyed. Although the total energy of a system does not change with time, its value may depend on the frame of reference. In SP&C there are opportunities to develop further the release of embedded energy.

6.2 KEY TRENDS

SP&C is an important sector in the NI economy. It is currently the second largest employer but remains a sector that is experiencing deep changes worldwide. Whatever is to happen, the sector cannot remain as it has in the past because of:

- Energy as a key differentiator in company and country competitiveness;
- Fundamental shifts in energy understanding, consumption and security[50];
- Fundamental shifts in understanding CO2 emissions and global warming;
- Construction industry changes been brought about by standards, legislation and increased competition;
- Newer technologies being applied to construction are fundamentally changing the shape of the industry;
- Changes in the construction industry brought about by materials, new regulations and emerging affordable housing concepts;
- Critical global events (World Trade Organisation (WTO) is aspiring to remove all agriculture exports subsidies by 2013);
- CAP reform which will have major implications for the size and structure of the sector and the rural environment;
- Critical sector events (food prices are changing, customer viewpoints on nutrition and cheaper imports from third world countries);
- Fundamental shifts in global patterns - availability of land for farming, water scarcity, water purity, urbanisation and migration;
- Land usage including soil erosion, land degradation and competition of natural resources between energy and food;
- Shifts in dietary patterns of entire populations from grain-based diets to meat and dairy products;
- Emerging pressure on the sector concerning Carbon Footprints (from the Retail Side), new directives (Water Frameworks, Nitrates), Energy Costs and emerging constraints on items such as Phosphates. These are sure to increase the cost base within the sector. Whilst this will impact agriculture and food first, it will also impact energy and construction.

50. The European Union has agreed a commitment to use biofuel in 10% of road transport fuels by 2020. The European Commission is also pursuing a target of 20% of renewables in overall consumption by 2020.

6.3
THE ENERGY SECTOR

As with most countries, NI (as part of the UK) has seen significant changes in the energy sector in the past ten years. The Energy White paper of 2003[51] consolidated changes with the reduction in CO2 emissions by 60% (2050), the reliability of energy supplies, the sustaining of industrial and business competitiveness and the assurance of affordable home heating.

Greenhouse gas and CO2 emissions
Although net emissions in the UK fell between 1990 and 2005, this trend was reversed in 2005 and NI (as a growing economy) contributed to this increase. Although there have been reductions in greenhouse gases, the NI contribution to these remains relatively static.

Reliability
It is important, for economic security, that the market provides sufficient capacity to meet maximum gas and electricity demand. As electricity prices have increased, NI opened a new facility in winter 2005/2006 (CoolKeragh), the Moyle Interconnector[52] has been completed and the Scotland - NI has pipeline is underway. The NI - Republic of Ireland interconnector and cross-border gas pipeline complete NI connectivity in terms of power.

Competitiveness
Competitiveness in NI has moved forward somewhat. Historically, prices in NI were higher than UK average and there was no gas network in NI. This has changed. Prices are now on a par with the UK and over 100,000 natural gas customers exist in Belfast[53].

NI Energy Strategy
The NI Energy Strategy, from June 2004, outlined specific targets for the sector in NI and these included:

- 1% electricity savings per annum from 2007 - 2012
- Target of renewable energy generation of 12% of electricity consumed by 2012;
- Support mechanisms been developed to encourage renewable energy, CHP and new energy efficiency programmes.

These initiatives have seen significant changes in Wind Energy for rural business (typically grant aided), Clever homes pilots, new home energy initiatives and public awareness campaigns. The last years have also seen the introduction of competition in the electricity and gas markets with the completion of the all-island power generation market in Nov 2007.

Alternative energy in NI
The alternatives market in NI has started although this has not been on a large scale. The opening of the market and the creation of new inter-connectors have allowed for the entry of new players into the NI market, although there remain challenges in ensuring universal competition in the market. In the course of this study alone, several large players outlined initiatives to tackle the NI energy market. The issue of carbon footprint however is going to start to impact generation by 2010 and NI has been relatively immune to this process to date (although the Scandinavians and others have been experiencing this for some time). The concern of price rises etc; will imply that the pressure on alternatives will increase.
The renewables initiative in NI will need to gather some momentum however beyond the current status. Interesting pilots using land, wind, sea etc; are already underway however, the mass required for these pilots to make material impact appears to be someway off. There could appear to be a lack of clarity on the market in NI, in terms of what alternatives can deliver, however it would appear that the emergence of new carbon tariffs will change this.

The drivers of NI emissions can be categorised as those belonging to a growing economy. The trends since 1998 see increases in energy usage in Transport and Business usage whilst reductions occur in agriculture and energy production itself. The drivers of such change are clearly population growth, economic growth, energy, agriculture and waste itself. However, it would appear that Green House Gas emissions have stabilised in the years of 1990 to 2004[54]. Comparisons with Denmark, Scotland and the Republic of Ireland also demonstrate that NI is seeing increases on a smaller scale than others across transport, residential and agriculture.

For NI, the key challenge is to deal with the widespread difficulty of reducing emissions with the growing economy and a rising population. However, there are clear NI opportunities from existing trends and pilots in terms of gas, energy markets, agriculture etc.

There is a need for change as 2010 approaches and this will probably imply a step change for NI in terms of energy generation and consumption. The ultimate will be how consumer behaviour, transport strategies, residential.

51. Our Energy Future - Creating a low carbon economy
52. This has been facilitated by the creation of the Northern Ireland Energy Holdings (mutualised company) which owns and operates some of the transmission network and this includes this interconnector and the Scottish NI Pipeline.
53. Phoenix Natural Gas which is now owned by Terra Firma
54. E3 International Pty

6.4 CONSTRUCTION SECTOR

Introduction

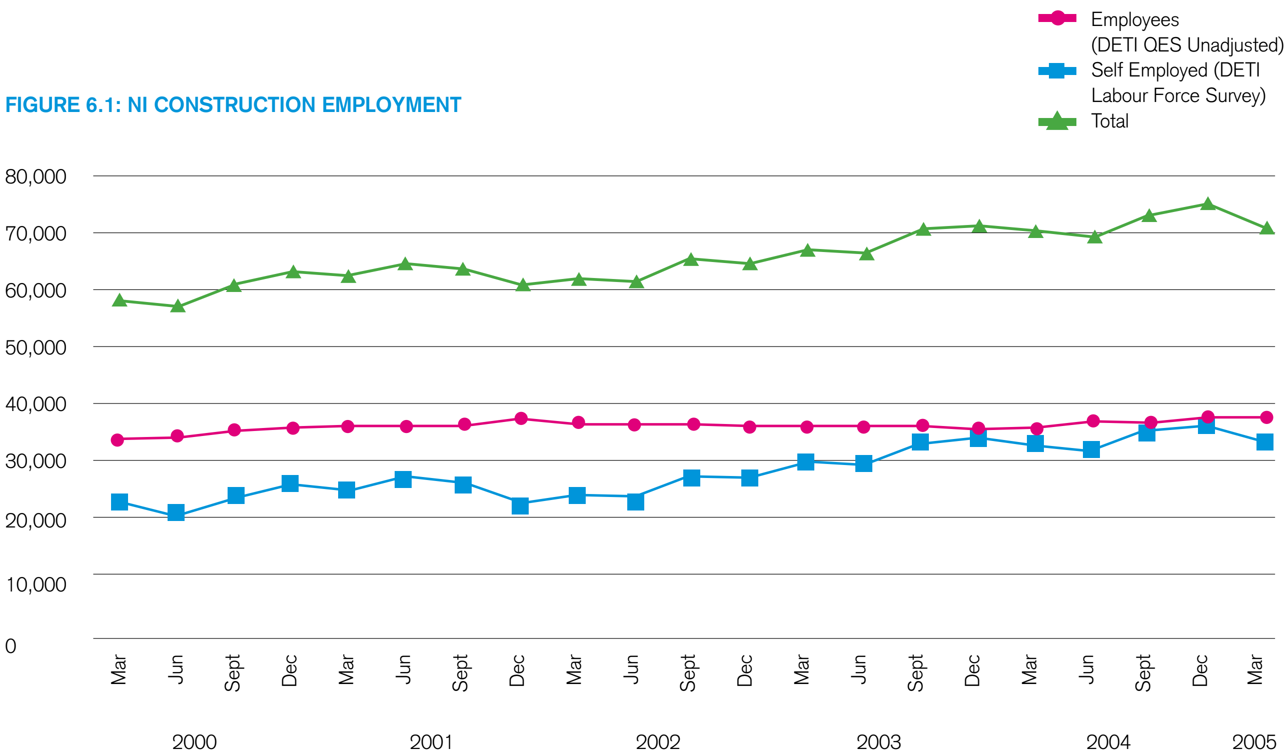
As with all growing economies, the construction industry plays a major role in leading the development of infrastructure in terms of construction. The scale of projects has also increased significantly alongside the volume of projects in the past five years. In NI the Government sector in currently 35% of the entire construction spend. This has also grown from a base of £676 million in 03/04 to a current £1,232 million in 07/08. The key areas of spend are in Water Service, Health Estates, Roads, NIHE and CPD. The next ten years of investment by the Government will reach £16 million[55].

Construction is currently employing almost 65,000 people in NI which is 8% of the total workforce. The total output of the business is £2.6 million per annum, including the public sector. It is worth noting that between 1996/2005[56], this number increased by 23,000 alone, which indicates a growth rate of over 2,000 per annum. This growth is forecasted to 85,000 people indicating strong growth continuing, however this would be subjected to demand continuing despite turmoil in the financial markets.

The sector is characterised by smaller companies, despite the larger companies that do exist and will be presented below. There are an identified 4,000 companies in the sector and most of these (65%) are companies of less than 5 people, which only nine companies have a turnover of £50 million or more.

The growth in the sector in NI has been significant however, challenges remain for the sector to develop sustainability and ultimately an export driven business. Naturally, most of the focus is on the existing infrastructure deficit in NI however, the question remains if new developments in materials and methods can ultimately be exported to the UK, Republic of Ireland and other European markets. Some key local companies (Mivan, Lagan Group, Pressfold, MJM Marine and McMullen Architectural Systems) which already play on a European/global stage. However, there is a broad range of supply companies within the sector ranging from concrete products, specialist joinery, shopfitting, window units, sawmilling and timber and some steel companies that build structures to the local market only and this needs to be addressed.

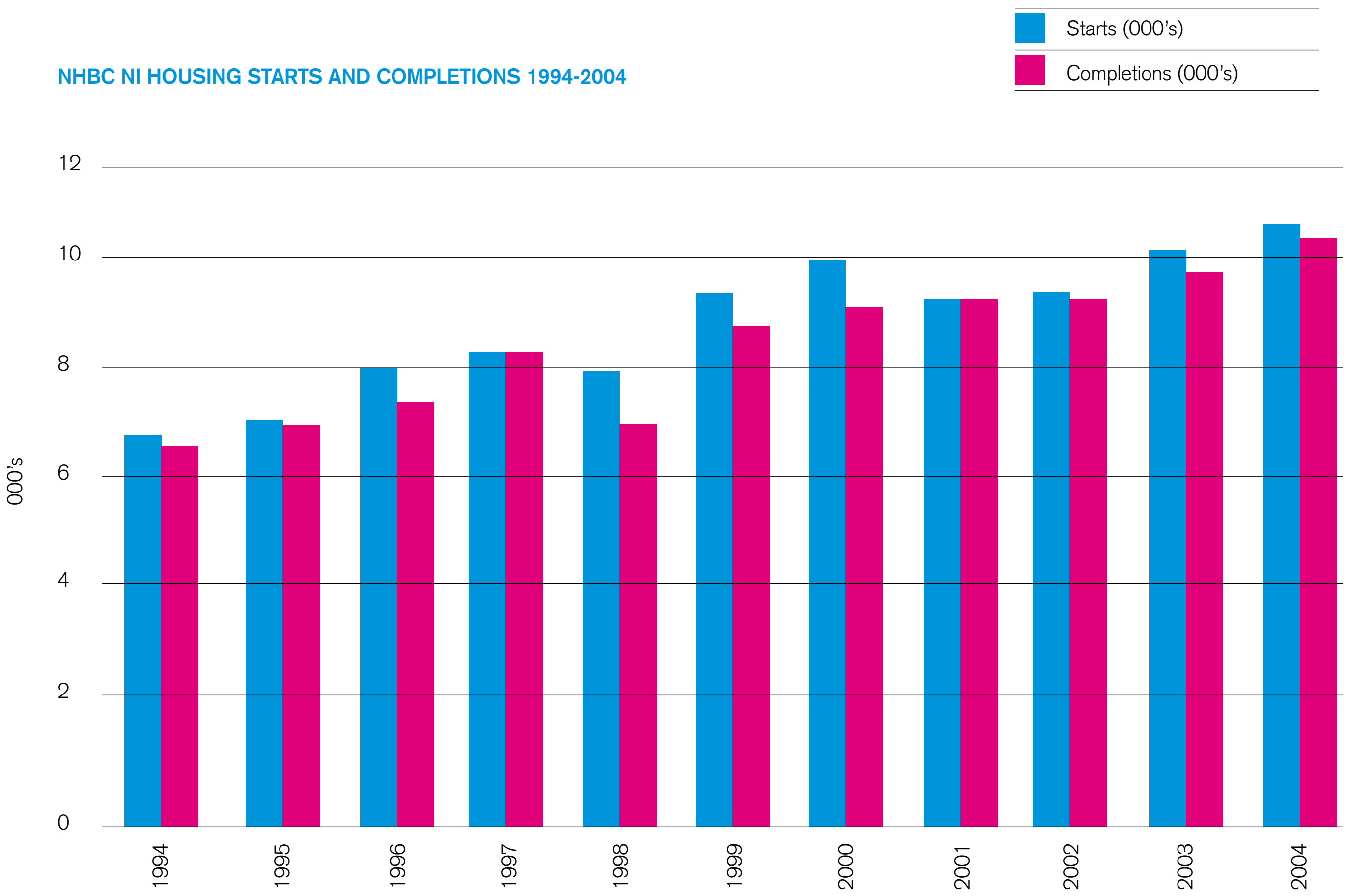
FIGURE 6.1: NI CONSTRUCTION EMPLOYMENT



55. Investment Strategy for Northern Ireland - Strategic Investment Board 2006
56. All numbers in this report use 2005 as a baseline

FIGURE 6.2: NI HOUSING STARTS AND COMPLETIONS

NHBC NI HOUSING STARTS AND COMPLETIONS 1994-2004



KEY CHALLENGES TO THE CONSTRUCTION INDUSTRY

The major challenges to the NI Construction industry the future can be defined as:

- **Changes in building philosophy - more than just a place to live/work/play**
  Building ownership is accumulated wealth and a major portion of individual equity. Therefore personalisation and customisation is a requirement. This is the opposite to industrialisation and productivity improvement which the industry needs. The focus on volume at the moment in NI would indicate that there is a need to think more strategically about buildings in general.

- **Buildings are becoming less affordable**
  Buildings are becoming less affordable to people. As the cost of houses/offices increases so does the debate on the durability of houses. The challenge of building affordable, durable homes becomes more challenging as costs of materials and labour increases.

- **Fragmented building industry**
  As a business, the building industry is fragmented and is typified by small builders with many trade contractors. This 'outsourcing' approach to building implies significant management challenges to builders coordinating key activities and developments.

- **Whole building, systems thinking is emerging**
  The needs and opportunities for whole building approaches to buildings are now being recognised by individuals, companies and associations within the industry. The concept of 'system thinking' is being reflected in some key providers however environmental/energy/ ustainability is accelerating this thinking.

- **Labour**
  Labour remains a critical factor in the industry from a cost and quality perspective. The labour question can be sub-divided into a question of skills[57] and the ability of the existing workforce to change to rapid developments in the industry which implies constant re-skilling and upgrading of skills. The broad range of skills required for the professionalisation of the industry in terms of business development, management of customer relationships etc are increasing as customers seek improved reliability and more highly skilled staff for their investments.

- **Process and Tools for productivity**
  The concept of process and tools to enhance productivity is an exception rather than the rule. Except for volume producers the application of JIT/TQM and Lean to materials needs to be addressed.

  Additionally, new trends such as PPP, integrated project teams, integrated information systems, the adoption of best practice and off-site fabrication require new toolsets.

- **Regulatory Process**
  The regulatory process with regard to construction standards has been changed in recent years. Application of new technologies is often delayed as approval of new products and materials is slow to happen.

57. A study of the NI Labour Market for Construction Skills - ERINI

KEY DEVELOPMENT AREAS FOR THE FUTURE

The sector will continue to grow as government spending on infrastructure will continue, however there are a number of elements that need to be addressed by the industry principally:

1. Improved business planning and the development of a broader range of skills;
2. Improved business efficiencies such as project management, supply chain management, supplier management and information technology;
3. Development of formalised qualifications and continuous training schemes to upskill and enhance internal capabilities;
4. Development of broader systems approach to construction including sustainability, energy, disposal and the use of innovative materials to enable these fields;
5. The need to address the skills agenda for construction as identified in the relevant skills task force reports including the Construction Skills Business Plan for Northern Ireland 2007 - 2011.

6.5
THE AGRICULTURE AND FOOD SECTORS

In the FSIP a number of megatrends are clearly defined as drivers for the food industry. These trends have altered somewhat in the past 18 months in a manner that is being indicated in the Figure 6.3.

The importance of the food megatrends continues to attract significant attention from the food industry[58] and remain a strong focus for New Product Developments and marketing to 2013. However, as consumers become more sophisticated in their understanding of the food industry's advertising and marketing techniques, and more aware of their personal health, the food industry needs to focus more specifically on specific sub-trends such as sustainability, functional foods (products with added health benefits), convenience, natural products, Halal foods (to target the huge, fast-growing Islamic market), and 'posh nosh' (to target time-poor, cash-rich consumer groups).

The eight trends in Figure 6.3 below are interlinked with one or more of the three megatrends, as can be defined as seen in Figure 6.4. Functional foods, for example, may be primarily viewed as 'healthy', but they are also hugely convenient for people who choose to consume foods that they regularly purchase, such as bread with added omega-3, to optimise their health. Functional foods can also be indulgent such as confectionery products or desserts that are fortified with nutrients such as minerals or essential fatty acids.

FIGURE 6.3: HOW FOOD IS RAPIDLY CHANGING - 2005 TO 2007

20|20 Megatrends	MATRIX Megatrends
Health	Beyond health (functional)
Convenience	'Extreme' convenience
Ethnic Influences	Ethnic influences and fusion flavours
Free From' foods	'Naturally good for you'
Good versus Bad fats	Posh nosh - premiumisation
Premium and indulgence	Sustainability
Bespoke foods	Halal

FIGURE 6.4: THE THREE MEGATRENDS OF FOOD - 2007 TO 2011

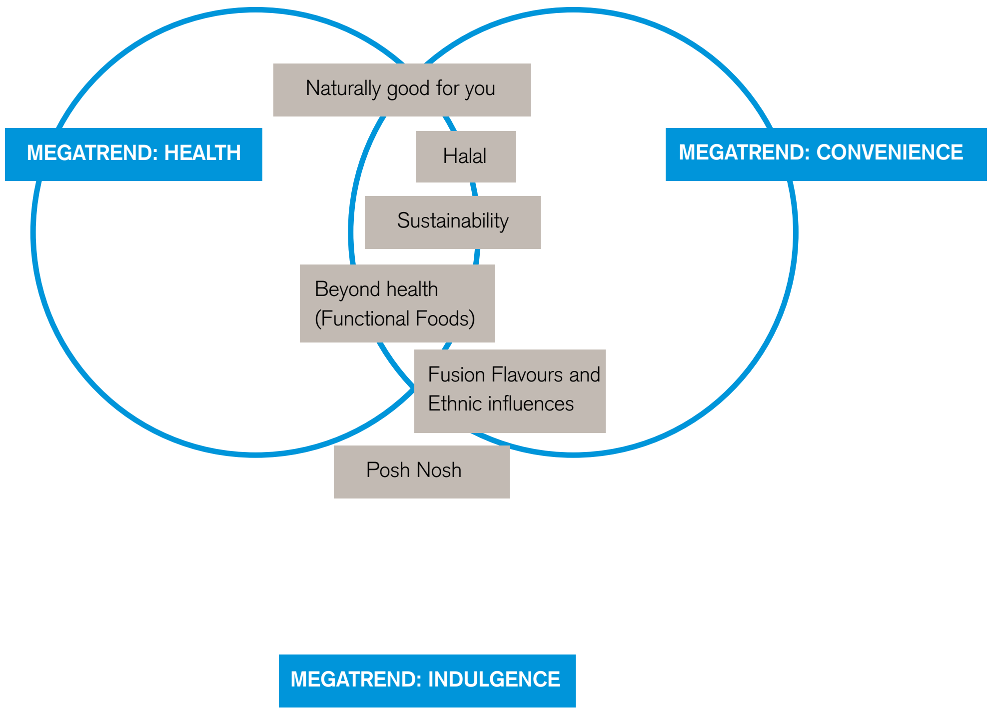


TABLE 6.2: TRENDS AND DRIVERS INFLUENCING THE GROWTH OF FUNCTIONAL FOODS

TRENDS	MAIN DRIVERS
Protection of child health	The incidences of blood pressure, cholesterol and diabetes affecting children (0-18 years) are on the rise. Therefore, consumers are increasingly turning towards functional foods in view of their health benefits in order to counter the rise of such diseases in children.
Focus on weight-loss	Consumers are increasingly gravitating towards reduced-portion-size and lower-calorie products, in order to resist the growing epidemic of obesity. According to estimates, nearly 50% of adults worldwide are conscious of their food intake.
The growing role of phytochemicals	Phytochemicals are increasingly moving into the mainstream backed by the growing interest in antioxidants. Phytochemicals are garnering attention due to their role in reducing the risk of cancer and in modualting metabolism in humans. Thus consumption of fruits and vegetables that contain phytochemicals is expected to grow strongly in the future.
Consumer urge to derive multi-benefits through grocery purchases	Grocery purchases are now largely affected by consumer urge to minimise the isk of future health afflictions. Consumers are increasingly attempting to balance their purchase portfolio with food items that can reduce obesity, heart diseases, high blood pressure, cholestrol and cancer. The implication for food companies is that they have to balance their portfolio of offerings in order to meet consumer needs.
Attraction towards health fats	Consumers have become highly discriminative in terms of opting for oils that are healthier, in order to avoid certain unhealthy fats. Consumers are gravitating towards products that are low in saturated fat. Oils such as olive oil are increasingly being consumed as they offer healthy fat.
Ageing population	Research indicates that people above the age of 50 are likely to report physical ailments such as oesteoporsis, joint pain/arthritis, eye problems, heart ailments and acid reflux/digestive problems. Therefore, such people are likely to be attracted towards products that have proven health benefits, thus necessitating a new approach of marketing such products to this growing demographic category.

6.6 SP&C PRIVATE SECTOR CAPABILITY

The private sector in NI is dominated by large scale food production with approximately 83 companies accounting for £4.5 billion in turnover[59]. As with all food sectors, there are two predominant company types - those that supply the local market with services (bakeries, smaller food companies) and those are that focussed on the export related markets. The smaller companies, focussed on a local market, do have opportunities to grow but clearly that is related to service capability as much as product capability.

The large producers, with an export market, focus on processing and are under continued pressure on margins and their focus remains on reducing cost and improving efficiencies across their operations. They compete on a global market that is subject to radical shifts based on issues beyond the control of NI based companies, e.g. climate conditions in Australia leading to two years of drought, or political decisions in the US to use increased quantities of grain for alternative fuels.

The total sector R&D investment is approximately £6.6 million with approximately 153 staff directly engaged in R&D. This is small relative to the turnover but is not surprising given the nature of the companies involved and their priorities.

TABLE 6.3: SP&C CAPABILITY IN NORTHERN IRELAND

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Plant breeding and biotechnology	Legacy strength in NI plant breeding has traditionally existed although it is predominated managed by state funding, through AFBI. There remains a passion within the structures in NI for plant breeding and this uses biotechnology capability for more effective results.	Potato Partners NI (in conjunction with AFBI) are renowned in this space and well considered (see detailed description below).	3	3	
Plant production and protection	As with Plant Breeding, the production and support infrastructure remains relatively small. Traditionally, the scientific capability is driven by AFBI.	There are a number of smaller companies in this space who deal with a local market, managing the supply chain with relatively small degrees of innovation. John McArdle, Joseph and Andrew Thompson, Kemira Growhow, Reen Compost, Westland Horticulture	2	3	

59. In June 2006 there were 26,700 farms alone. The direct involvement/investment of the agriculture industry in R&D has historically been extremely low and there are natural barriers to involvement such as the fragmented structure of the industry the average size of enterprise on the producer side, existing costs and the lack of time and skills. Whilst there are exceptions to the norm, this Capabiluty Report focussed on the food and feed industries whilst recognising the significance of the producer community.

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Animal production and husbandry	Animal production is practises through the herd mechanism in all producers. New breeds are introduced in a structured manner (see summer milk project).	Generally all producers are involved in this phase of activity and the technology aspects are developed on the state side by DARD/AFBI.	3	2	
Animal breeding and biotechnology	There remains a passion for Animal Breeding within NI and the use.	Relatively small number of companies with some interesting technologies being deployed. This sub-field when coupled with Animal Health and Welfare shops some real strength. Companies include ABNA Limited, John Mackle, John Thompson, United Feeds.	3	3	
Animal health and welfare	Animal health and welfare is a traditional strength in NI where, it could be argued it once lead the way in Europe as co-operation between state (DARD - APHIS) and producers was significant. Some ground has been lost and APHIS needs a refresh with a new model of operation.	Some interesting companies in this space that develop new products and capabilities that a re immediately supplied to market. Questions remain as to the level of innovation. Companies include Devenish Nutrition, G E MCLaron and Sons Ltd. Devenish which is discussed in detail below drives this sub-field.	4	4	
Forestry and landscape	State run forestry is the normal operation in NI. The exploitation of these forests is relatively small scale and recreational only.	Mourne Compost	1	1	
Management of natural and biological resources	State run management of natural resources again with limited private investment. Recreational exploitation only.	Forker Garden Products	1	1	

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Aquaculture and fisheries	Historically small sub-field in NI - 34 companies of full time and part time staff that turnover £75 million which tend to go to markets such as GB (50%), Germany (White Fish) but no real inroads into the US, Asia markets or the French/Spanish markets. Tend to sub-divided further into groups such as Pelagic Group, Whitefish Group, Processed Shellfish Group, Live Shellfish Group and a Trout and Salmon Group. However the key trends in this sub-field - sustainability (including ethics), Traceability, Health and the fundamental Consumer Trends are not being heavily investigated or predicted. This is a follower sub-field that watches the developments of Scotland or the RoI.	Typically small companies with limited capability other than the core product and deploying following technology. We have noted the commencement of independent microbiological testing, new quality programmes etc but these tend to be embroyonic. Companies in this space include, Ballyduff Seafoods, C & N Chambers, C & O Milligan, Cuan Sea Fisheries, Denholm Fishselling, Donegal Prime Fish, Dundrum Bay Oyster Fishery, East Coast Seafoods, Elmore Fish, Ewing's Seafoods, George Cully and Son, George Milligan and Sons, Glen Oak Fisheries, Henning Brothers Fishing Company, Keenan Seafood, Kilhorne Bay Seafoods, Kilkeel Kippering Company, Middleton Seafoods, Mourne Shellfish, Navital (UK), Northern Salmon Company, Parkgate Fish/Euro Shell Fish, Rockall Seafoods, Rooney Fish, Silverfin Fish Merchants, S & P Milligan, Sperrin Mountain Spring Trout Hatchery ,T. H. Nicholson, T. S. Foods.	1	2	

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Engineering, mechanisation, ICT	Significant investment ground performing a wide range of capital projects ranging from small to medium and large. Tends to use following technologies although there are some examples of newer ICT and building technologies being introduced particularly in relation to sustainability and reduced costs. Lack of connectivity to excellent materials research in this field in noted.	BSG Civil Engineering, David Patton & Sons, Felix O'Hare and Co, Fraser Homes, Gilbert Nash Limited, Graham Martin, H&J Martin, Henry Brothers, Heron Bros, Howden Power, John Graham , MacAleer and Rushe, McLaughlin and Harvey, Mcnicholas Construction, Mivan Group, Northstone NI, Taggart Homes, TAL, Whitemountain	2	3	
Food technology, human nutrition and consumer concerns	This is the predominant sub-field in this sector. The key characteristics are fragmented between large companies in food processing which have high employment, high turnover, good supply chains but are struggling to make margins in an increasingly competitive but also radicially changing world. New scientific capability in packaging, processing and products is rarely exploited due to time and cost pressures and yet the global markets for these products indicate that such a change is necessary.	This sub-field consists of bakeries, food processors, diary co-ops and niche food companies. There are significant players (discussed below) and relatively small players. Innovation in product, packaging etc remains an issue within this sector and there is little connectivity between the Life Science capability and the food capability in NI although this convergence is clearly happening. Allied Bakeries, Anglo Beef Processors, Armaghdown Creameries, Associated Processors, Avondale Foods, Ballyrashane Co-Op, Bite Snacks, British Bakeries, Crossgar Poultry, Dale Farm, Davison Quality Foods, Eurostock Foods, Evron Foods, Foyle Meats, Glanbia Cheese, Grampian Country, Huburt Brown Kerr, James Finlay, Kerry Foods, Lindon Foods, MacNeice Foods, McColgan Brothers, McErlains Bakery, Mourne Country Meats, Moy Park, O'Kane, Omagh Meats, Strathroy Dairy, Pritchitt Foods, Pritchitts, Tayto, TMC Dairies, United Dairy Farmers, W D Irwin, W D Meats.	3	4	

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Environmental Technologies (expanded definition to NI only)	A relatively undeveloped sub-field in NI that uses existing technologies imported from elsewhere. There are some clear examples of leadership - PRS Environmental have a bio-refinery and Randox have a water quality monitoring field test. Additionally, the work being completed in projects such as Brooke Hall and Just Farm Energy demonstrates technology that can be further exploited within NI.	Most companies are supplying standard services or consultancy to support local enterprise or facilities. Interestingly some new developments arise in this respect in the Agricultural community (Brooke Hall Estate, Farm Energy) where interesting environmental projects are underway. Additionally, there are new biorefineries such as PRS Environmental which reflect the exploitation of latest technology. The more traditional companies would be Clearway Disposals, Cleanaway Disposals, Greenway (Ireland), Acer Environmental, Alpha Environmental, Aspinwall and Company, Hays Chemical Distribution, Hydrogeological and Environmental Services, KMM MarEnCo, Plastics Fabrications and Environmental Technology, Randox Labatories, Unitherm Products	4	3	
Energy generation and distribution (expanded definition to NI only)	Energy sector tends to consist of traditional energy suppliers with traditional networks. The trend of moving to smaller local distributed networks has not taken place as yet.	AES (NI), Airtricity Energy Supply, NIE PowerTeam, Phoenix Gas, Premier Power	3	4	

SELECTED COMPANIES

The key companies in this sector in NI are presented in Table 6.3.

United Dairy Farmers Group/Dale Farm
Dale Farm is part of United Dairy Farmers Group, the UK dairy farmers cooperative of 2,500 dairy farmers. Dale Farm processes more than 40% of the total milk pool and have strong relationships with the supermarket multiples as part of their key customer group. The company also supply large quantities of milk powder to the Middle East and Africa. The Group Technical Centre is based at Ballymena where there is continued investment in product and process development with over 60 product development projects running at any one time and 10 process and packaging change initiatives. Much of the focus is on variant product development and on improving processes to gain increased efficiency and productivity. There is ongoing collaboration with QUB and with the NI Centre for Food and Health (NICHE) at UU where the expertise and instrumentation of academic research environments compliments the in-house skills of Dale Farm.

Moy Park Limited
Moy Park is Northern Ireland's largest food processing company and one of Europe's leading poultry companies, employing over 7,000, and supplying Ireland, UK and European markets primarily with chicken products. The company has a strong focus on the strength and efficiency of its supply chain and has taken steps to vertically integrate much of the business from hatching chickens to different stages of processing. It is often placed in the position of having to fulfill a large order within a 24 to 48 period and therefore must have agility within its processing capability to deal with this.

There is significant investment in product development aiming to continually extend the range of products, mainly chicken based, and some effort to improve process efficiency. Moy Park is a key partner in Trace Assured, a partnership with other food producers aimed at providing a traceability services to food producers within NI and capitalising on the low disease status of NI.

John Thompson And Sons
John Thompsons & Sons have over 100 years experience in the manufacture of high quality animal feeds. The company collaborated with AFBI in a project aimed at improving the rearing of heifers and ultimate profitability in dairying. Eight dairy farmers, from across NI, are involved in the project. These farmers are adopting a 'blueprint' approach to their heifer rearing to ensure that they can calve good quality heifers at 24 months of age. The 'blueprint' is based on the latest research information and uses a simple approach to measuring the size of a few heifers in each age group on the farm at chosen intervals.

O'Kane Poultry
O'Kane Poultry has been working with major food groups for over 30 years, and have also new but well-established relations with other well-known supermarket chains, which they supply on a UK and Ireland wide basis.

O'Kane Poultry employ a team of Product Development Technologists to cover new product development for the company. Development areas include turkey products, value-added chicken products, cooked chicken products, and breaded/coated chicken and turkey products. The team develop new products using test kitchen facilities onsite and have use of specialist equipment to ascertain optimum cooking instructions. New products also undergo rigorous shelf life and organoleptic trials prior to launch. New and innovative packaging formats are continuously under investigation in our endeavour to give the most desirable outcome to our customers.

Devenish Nutrition
Devenish Nutrition supply both technical advice/guidance and products to those involved in pig, poultry, cattle and horse rearing. They have a significant focus on research, aiming to improve the nutritional qualities and impact on food, and collaborate with Universities both in NI and Republic of Ireland on research projects. Most of these projects are part of long term research partnerships, which Devenish Nutrition has developed

TABLE 6.4: THE KEY COMPANIES IN SP&C IN NORTHERN IRELAND[60]

COMPANY NAME	TURNOVER (£000)	TOTAL TURNOVER AS % OF SECTOR TURNOVER	R&D SPEND (£000)	TOTAL R&D SPEND AS % OF SECTOR R&D SPEND	NO. OF EMPLOYEES	NO. OF EMPLOYEES AS % OF SECTOR EMPLOYMENT	R&D STAFF	FULL-TIME R&D STAFF AS % OF SECTOR TOTAL
United Diary Farmers	205,012	4.6%	1,894	28.5%	249	1.4%	7	4.6%
Moy Park	290,958	6.5%	1,878	28.3%	3,047	16.6%	63	41.2%
John Thompson and Sons	90868	2.0%	634	9.6%	141	0.8%	17	11.1%
O'Kane Poultry	54946	1.2%	438	6.6%	978	5.3%	18	11.8%
Devenish Nutrition	25551	0.6%	274	4.1%	81	0.4%	1	0.7%
Pritchitts	41853	0.9%	258	3.9%	171	0.9%	4	2.6%
Avondale Foods (Craigavon)	26,984	0.6%	195	2.9%	368	2.0%	11	7.2%
Northstone NI	132,978	3.0%	n/a	n/a	314	1.7%	n/a	n/a
Kerry Foods	146,024	3.3%	n/a	n/a	932	5.1%	n/a	n/a
McLaughlin & Harvey	152,563	3.4%	n/a	n/a	321	1.7%	n/a	n/a
Total	**1,167,737**	**26.0%**	**5,571**	**84.0%**	**6,602**	**36.0%**	**121**	**79.1%**

with academic and research institutions in collaboration with industry partners.

Pritchitts
Pritchitts specialise in supplying dairy-based food products. Pritchitts now supply customers in over 60 countries across the globe. Pritchitts have an innovative project range with many specialised products and recently won an award for product innovation with Millac Cappuccino Milk.

Avondale Foods (Craigavon)
Established as a vegetable grower and packer but has used innovative product formats to branch out into other markets; soups, sandwich fillings, sauces, dressed salads, bakery, ready prepared vegetables and salads. Avondale supply their own 'Country Kitchen' brand and also customer own-brands throughout Ireland and the UK.

Avondale Foods employ a new revolutionary cooking method, which prevents the loss of vital nutrients and a new on-site baking facility has allowed for new product ranges i.e. Pizzas, which will allow for further exploration of new markets.

A number of NI companies were not in the 2005 database however their activities have been noted in this sector. These companies include:

Dunbia
Dunbia (Dungannon Meats until 2006) is an NI-based food company, with four sites located throughout NI, two in Ireland, two

60. DETI 2005

in UK. They are headquartered at Granville near Dungannon. They possess a large and impressive customer portfolio, including many of the leading supermarket chains in the UK and Ireland, along with customers in the wholesale and further processing sectors. They source the majority of beef, lamb and pork raw materials from top quality (certified) producers in Northern Ireland, Wales (Sheep), RoI (Cattle). The company's facilities in Dungannon consist of an abattoir, a retail packing plant and a hide and offal processing plant. The abattoir has the capacity to process 1500 cattle, 3000 sheep per week and bone 1200 quarters daily. The packing facility has a weekly capacity of 800 tonnes of finished goods encompassing fresh beef, lamb and pork as well as some value-added products. It employs almost 2,000 people of which 800 (almost) are in NI. We have no figures for Turnover (not quoted) or Profit (not quoted) or R&D (not quoted). When asked, we were also declined. We know they do some work on R&D, but cannot quantify what exactly. Predominantly it works to help with packaging we believe.

Foyle Food Group

The Foyle Food Group was established just over thirty years ago and is a producer of high quality beef and lamb primals. The group employs approximately 750 employees across five sites that are located in Foyle Meats, Omagh Meats, Donegal Meat Processors, Foyle Proteins and Hilton Meats Cookstown. The volume of processing extends to 180,000 cattle and 450,000 lamb per year. All of the group facilities are EC approved and benefits from continuous investment in state of the art machinery and equipment. The focus of the group is on beef and lamb products that are well branded and exported internationally. Historically, the group has focused on high quality output and sought relative technologies that supported that quality. In recent years, they have developed an environmental programme with KPIs for each site to monitor energy and identify improvements in terms of energy consumptions, various types of waste and recycling. This work is being completed with the partnerships with Sustainable Energy Ireland, the Carbon Trust and Invest NI.

6.7 PUBLIC SECTOR

Originally part of the Department of Agriculture and Rural Development, the Agri-food and Biosciences Institute (AfBI) is the largest science and technology organisation in NI with around 800 people. They were formed as an NDPB in 2006 with an approximate annual budget of £40M and the organisation is focused on four areas of work:

- Diagnostics & Analytical;
- Research & Development;
- Training and education (this is a reducing area);
- Specialist Advice.

The Department (DARD) retains the strategic direction role of the sector within NI and AfBI exist to operationalise part of that direction. The organisation has specialists in Plant Science, Veterinary Science, Agriculture, Food and Environmental Science, and Economics. The primary role relates to the strategy and activity of DARD although they have received additional funding from sources such as:

- Food Standards Agency;
- DCAL;
- DoE;
- Home Office;
- European Commission;
- Research Councils.

AfBI have a responsibility to provide an emergency response capability to DARD and other government departments in the event of national emergencies (e.g. situations such as Foot & Mouth).

A key strength of AfBI is in the multidisciplinary skills (veterinary science, plant science, agriculture food and environmental science, and economics) available across the Institute and the ability to bring these skills to bear on real problems.

The organisation has a diverse range of resources such as its extensive library, a seagoing vessel for analysis of maritime environments and reference laboratories for a range of areas such as milk testing. It has an internationally recognised Biomaterials Research Group (through its research into Flax fibre) and recently its Veterinary Science Division came top of a world survey of the impact of publications on veterinary science with four of its researchers considered to be in world top 20.

AfBI are currently developing their research strategy and future plans and are still going through a significant change since being established in 2006. The organisation will work much more closely with RoI and have ability to access RoI science funding through partnerships. AfBI are also recruiting a Commercial Director to develop business beyond the core role of support for DARD and are seeking to agree on the principle of three way collaboration with the NI universities. AfBI is located at Newforge Lane and Stoney Road but it does have Memoranda of Understanding with both UU and QUB that allow researchers to collaborate with each university.

6.8 CAFRE

The College of Food, Agriculture and Rural Enterprise (CAFRE) is an integral part of the NI Department of Agriculture and Rural Developments Service Delivery Group. The College supports technology transfer and innovation. CAFRE also provides a range of training programmes aimed at farmers, farm family members and those who work in the land-based industries. These training opportunities allow participants to learn and develop new technical and practical skills. CAFRE offers Industry Training in areas such as Environmental Conservation, Agriculture, Information Technology, Food, Business Management and Health and Safety. There are three college locations in CAFRE and these are:

- Enniskillen Campus - Agricultural College - Enniskillen Campus has a reputation for turning out highly motivated and professionally trained men and women destined for successful careers in industries associated with the land. The Campus uses comprehensive up-to-date teaching and learning facilities.
- Greenmount Campus - Agricultural and Horticultural College - Greenmount offers a range of full time, part time and short courses to people entering and those already working in the NI Agrifood industry.
- Loughry Campus - Food Science College - The Loughry campus is centrally located in the heart of Northern Ireland, between Cookstown and Dungannon.

CAFRE can be seen as a Further Education college but it is separated here because of the uniqueness of its proposition to the Agriculture and Food sector in NI.

6.9 ACADEMIC SECTOR[61]

TABLE 6.5: SUMMARY OF CAPABILITY IN THE HE SECTOR IN THE SUSTAINABLE PRODUCTION AND CONSUMPTION SECTOR

NO.	INSTITUTION/GROUP	LOCATION
43	Institute of Agrifood and Land Use	QUB
56	NI Centre for Food and Health (NICHE)	UU
75	Agrifood and Biosciences Institute (AFBI)[62]	
1	NI Technology Centre[63]	QUB

With regards to the FE sector (CAFRE has been separated out as indicated above), the following table summarises the courses that are related to sustainable production and consumption, and numbers of students currently enrolled. It shows that in total there are some 3,700 FE students, although almost 75% of these study food hygiene and in their cases it is likely that most will be employed in the catering/service industry.

61. The breakdown of HE Enrolments in NI is presented in Chapter 3, section 6
62. AfBI HQ is at Newforge Lane, Belfast and it no longer has a major role in the delivery of HE, albeit it provides supervision for a number of PhD students hence the inclusion in this table.
63. It is recognised that the NITC has a technology transfer role and as such is not a research institution. However, the role played in the overall NI landscape is significant and it has been requested that this be acknowledged. Hence the inclusion in the table.

TABLE 6.6: SUMMARY OF CAPABILITY IN THE FE SECTOR IN THE DOMAIN OF SUSTAINABLE PRODUCTION AND CONSUMPTION

SUBJECT CODE OF COURSE	TOTAL	LOCATION
Animal Related Studies	95	BIFHE, East Antrim, Fermanagh, North Down & Ards
Animal Management	100	BIFHE, Fermanagh, North East
Agriculture/Horticulture	11	Castlereagh
Horses on Farms & Estates	50	North Down & Ards
Horticulture	375	Castlereagh, East Down, Newry & Kilkeel, North Down & Ards
Farm Business Administration & Management	100	Newry & Kilkeel
Food Hygiene	2,750	BIFHE, Castlereagh, Causeway, East Antrim, East Down, East Tyrone, Fermanagh, Lisburn, Newry & Kilkeel, North Down & Ards, North East, North West, Omagh, Upper Bann
Meat Inspection	7	Upper Bann
Meat Technology	18	Upper Bann
Food & Drink Processing	1	North West
Others in Food Science	18	Limavady
Environmental Science	37	North West
Environmental Studies	61	East Antrim, Fermanagh, North West
Others in Environmental Science	27	BIFHE
Quarrying	83	Omagh
Energy Studies	29	Lisburn
Sum	**3,762**	

6.10 OVERALL SECTOR CAPABILITY MAPPING & CONCLUSIONS

The sector in NI is currently comprised of large volume producers focused on retaining markets and margins, and under increasing pressure to do so. The focus in the industry is very much on the immediate needs and innovations to meet those needs (hence the ‘D’ in ‘R&D’).

The research organisations in the Agri-food sector in Northern Ireland

The main research links are to QUB, NICHE, CAFRE and AfBI and expertise and equipment which these possess. The development of functional foods and new nutritional products are seen as a key area of focus however the critical issue is around challenge of the immediate needs of the industry being met by longer term research agendas. This leads to a ‘pace’ being different between industry and research and this ‘gap’ shows a mismatch between scientific capability and exploitation capability. The review demonstrates that there is highly competitive capability in Plant and Animal Breeding, there is also competitive capability in Animal Health and Welfare although this is perceived to have been stronger in the past, it remains a key asset of the sector and whilst no longer differentiating itself remains competitive. The impact of NICHE on the food aspect of the sector is noted in UU as is the work being completed in Genomics in QUB. The CAFRE input tends to be limited to applications of competitive intelligence to develop capability for the sector although the work related to Food Technology development and Packaging that is carried out there is important to the sector. It is perhaps worth noting that there are significant gaps in this profile. These gaps are filled by the capabilities that exist within other sectors but are not applied to Agri-food in Northern Ireland. This is to become a significant theme throughout this analysis.

The industrial enterprises in Agri-food in Northern Ireland

The industrial enterprises selected to determine the capability outcome represent 85% of the R&D spend within the sector. The emerging picture from this analysis demonstrates that the emphasis is clustered around Animal Production and Feed Production or Animal Rearing. The findings are that some of this research is fundamental and highly competitive however, the majority of company spend occurs at the processing side around developments in packaging, supply chain and processing. There are some examples of fundamental research looking into new food products however the emphasis remains on addressing short term issues that constantly impact margin and profitability[64].

64. The Moy Park development on Traceability is noteworthy. This is a fundamental development that adds significant value to the development of the sector in Northern Ireland.

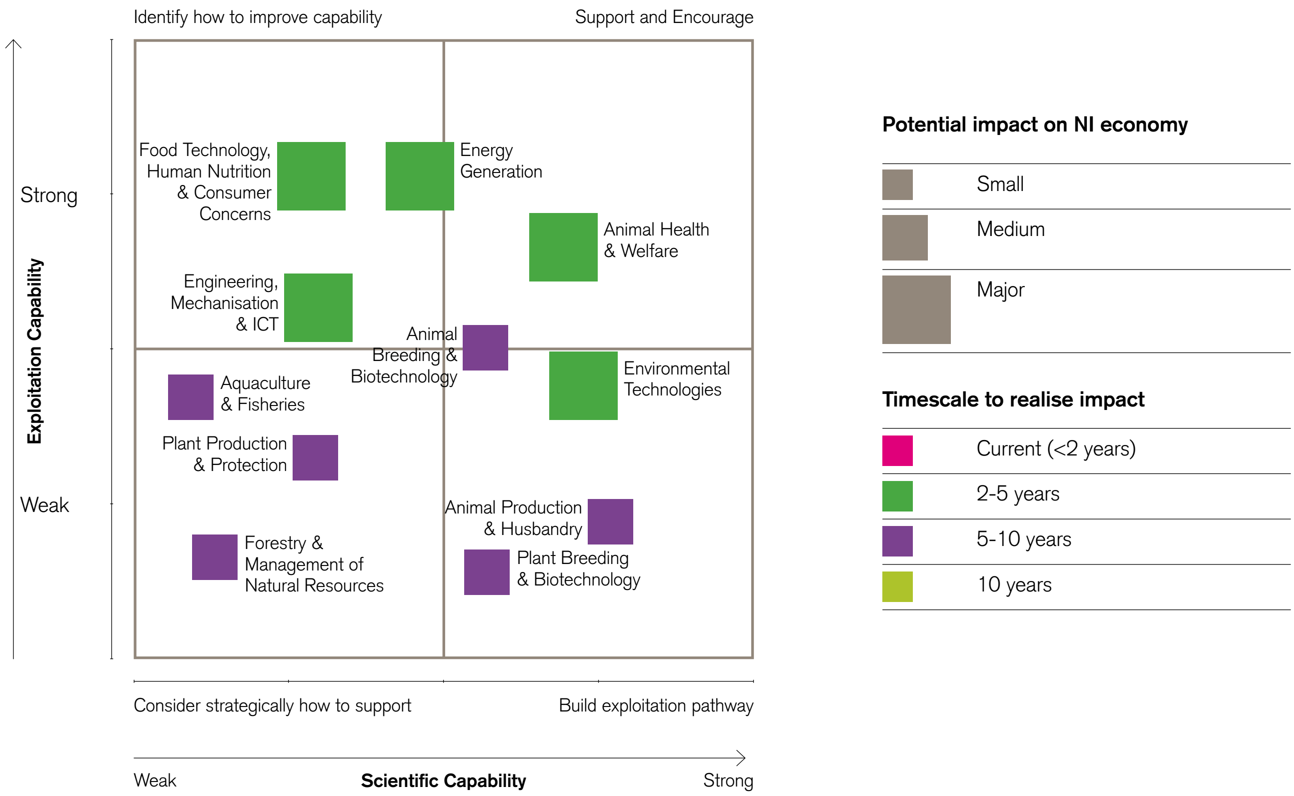
6.11
A SUMMARY OF AGRI-FOOD IN NORTHERN IRELAND

The existing NI Agri-food sector has two distinct aspects to it. The first aspect looks to a competitive capability to exploit technology in the Poultry and Dairy processing sectors in particular. These exploitations have immediate short term economic impacts in terms of employment and revenue and they tend to be focused on keeping companies viable in an extremely competitive environment. The burden of emerging legislation and food safety issues may threaten this approach however these are the areas with key short term economic impacts.

There is however competitive scientific capability in Veterinary Science, Animal Health, Plant Science, Food Safety and Food Nutrition. However, beyond that, packaging and processing appears to have mostly development activity (we note the development on Traceability) with relatively small increments of improvement.

It should however also be noted that capabilities from other sectors (advanced materials etc) are not being exploited within Agri-food even though the future of the sector will appear to depend on those capabilities.

FIGURE 6.5: SUSTAINABLE PRODUCTION & CONSUMPTION CAPABILITY IN NI



6.12 CONCLUSIONS

The Agri-food sector in NI contains a wide range of capabilities which have allowed it to evolve over the past thirty years. This evolution has taken place in the context of multiple innovations in product and packaging which are being brought quickly to the market and R&D excellence in centres such as NICHE, AfBI, QUB etc where highly competitive capability does exist.

However, in order to move forward radically within the sector the following conclusions can be drawn:

- The Agri-food sector in NI is a net importer of capability from around the world. There is a need for a mechanism to gather intelligence and bring it to the sector. In order to accomplish this, NI Agri-food companies and research units are going to need to collaborate with the broader UK, the Republic of Ireland and countries such as Switzerland, Sweden, New Zealand, Holland, Japan and Australia.
- There are competitive scientific capabilities in Animal and Plant genetics and breeding and energy capability. There are competitive exploitation capabilities in Processing, Packaging and Supply Chain (although this is developing) and embryonic capability in food tracking;
- The entire sector remains relatively fragmented and this implies that capabilities are not being fully exploited. This can be related to a lack of multidisciplinary thinking within the sector. For example, the interaction with Life Sciences needs to be augmented as does the interaction with other industries to create disruptive solutions in packaging, processing and the broader use of ICT;
- The pace of development needs to be considered as this mismatch creates some challenge within the sector. The broader fields of fundamental research are perceived to conflict with the industry needs when a new model of operation can improve collaboration and operation. The Department (DARD) has the strategic role in determining the research projects relevant to the sector in NI;
- The strengths of AfBI, QUB and UU need to be harnessed in a multidisciplinary manner to augment capability in the sector. In particular, the role of AfBi needs to be refocused;
- There are capabilities outside of the sector directly such as Advanced Materials (BioMaterials and Nanotechnology), Computational Science (BioInformatics), Life Sciences (Human Genomics, Study of Diet and Humans, Nutrigenomics), and Proteins (Dairy, Beef etc) which can be used to significantly advance the Agri-food sector.

LIFE SCIENCES

7

7.1 SECTOR DESCRIPTION

Life Sciences is the general term used to encompass the fields of biotechnology, pharmaceuticals, biomedical technologies, life application technologies, nutriceuticals and biomedical devices. In essence it combines all elements of biology, chemistry and technology that contribute to the discovery and development of products for the healthcare and wellbeing of humans and animals. The Life Sciences sector in NI consists of approximately 60 companies that had, in 2005, a combined turnover of some £290m, and employ in the order of 4000 staff. Twenty-eight of these companies have an identifiable R&D capability, and spent in 2005 some £33m and directly employed some 600 staff in R&D.

For the purposes of this report, the scope of Life Sciences is deemed to cover the following:

TABLE 7.1: THE SCOPE OF THE LIFE SCIENCES SECTOR IN THIS REPORT.

SUB-FIELD	DESCRIPTION
Medical Devices	The creation, design or manufacture of an instrument, apparatus, implement, machine, implant, invitro reagent or other items that is: recognised in national formulary; or supplemental to them and intended for use in the diagnosis of disease or other conditions and in the cure, mitigation, treatment or prevention of disease in man or animals; or intended to affect the structure or any function of the body of man or other animals, and which does not achieve any of its primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolised for the achievement of any of its primary intended purposes; or diagnostic equipment includes medical imaging machines are used to aid diagnosis. These include ultrasound, MRI, CAT-scans, PET, and x-ray machines.
Pharmaceuticals	The creation, manufacture and distribution of substances with solid, living and non-living organisms that produce a change in function with medicinal properties. This encompasses drug composition and properties, interactions, toxicology, therapy and medical applications.
AgriBiology	The various chemical products used in agriculture. In most cases, agrichemical refers to the broad range of insecticides, herbicides, and fungicides, but it may also include synthetic fertilisers, hormones and other chemical growth agents, and concentrated stores of raw animal manure. Most agrichemicals are toxic, and all agrichemicals in bulk storage pose significant environmental and/or health risks, particularly in the event of accidental spills. In many countries, access to and use of agrichemicals is highly regulated. Government-issued permits for purchase and use of approved agrichemicals may be required, and significant penalties can result from misuse, including improper storage resulting in spillage. On farms, proper storage facilities and labelling, emergency clean-up equipment and procedures, and safety equipment and procedures for handling, application and disposal are specific areas of concern, often subject to mandatory standards and regulations.

SUB-FIELD	DESCRIPTION
Medical Disposals	Disposable instruments, devices and materials that are used within medical and surgical procedures.
BioTechnology	Refers to recombinant DNA based and/or tissue culture based processes. Hence, modifying plants or animals by breeding, which has been practiced for thousands of years, would not be considered biotechnology. This distinction emphasises that modern, recombinant DNA based biotechnology is not just a more powerful version of existing technology, but represents something new and different; for instance, theoretically, recombinant DNA biotechnology allows the taking of virtually any gene and express it in any organism. For example, the genes that make crimson colour in plants and put them into guinea pigs to make pink pets, or, the genes that help arctic fish survive the freezing temperatures and put them into food to increase the amount of time it can grow before it freezes. Biotechnology combines disciplines like genetics, molecular biology, biochemistry, embryology and cell biology, which are in turn linked to practical disciplines like chemical engineering, information technology, and robotics. Biotechnology can also be defined as the manipulation of organisms to do practical things and to provide useful products. One aspect of biotechnology is the directed use of organisms for the manufacture of organic products (examples include beer and milk products). For another example, naturally present bacteria are utilised by the mining industry in bioleaching. Biotechnology is also used to recycle, treat waste, clean up sites contaminated by industrial activities (bioremediation), and produce biological weapons. There are also applications of biotechnology that do not use living organisms. Examples are DNA microarrays used in genetics and radioactive tracers used in medicine. Red biotechnology is applied to medical processes. Some examples are the designing of organisms to produce antibiotics, and the engineering of genetic cures through genomic manipulation. White biotechnology also known as grey biotechnology is biotechnology applied to industrial processes. An example is the designing of an organism to produce a useful chemical. White biotechnology tends to consume less in resources than traditional processes used to produce industrial goods. Green biotechnology is biotechnology applied to agricultural processes. An example is the designing of transgenic plants to grow under specific environmental conditions or in the presence (or absence) of certain agricultural chemicals. The term blue biotechnology has also been used to describe the marine and aquatic applications of biotechnology, but its use is relatively rare.
Systems Biology	Systems Biology is an interdisciplinary field which addresses biological problems using computational techniques. The field is also often referred to as computational biology. It plays a key role in various areas, such as functional genomics, structural genomics, antibodies and proteomics, and forms a key component in the biotechnology and pharmaceutical sector.

SUB-FIELD	DESCRIPTION
Clinical Trial Capability	A clinical trial is a comparison test of a medication or other medical treatment (such as a medical device), versus a placebo (inactive look-a-like), other medications/devices, or the standard medical treatment for a patient's condition. Clinical trials vary greatly in size: from a single researcher in one hospital/clinic to an international multicentre study funded by a pharmaceutical company with over 100 participating hospitals on several continents. The number of patients tested can range from fewer than 50 to thousands. In a clinical trial, the sponsor first identifies the medication/device to be tested. Then the sponsor decides what to compare it with (one or more existing treatments or a placebo), and what kind of patients might benefit from the medication/device. If the sponsor cannot obtain enough patients with this specific disease/condition at his/her own location, the sponsor assembles researchers at other locations who can obtain the same kind of patients to receive the treatment. During the clinical trial, the researchers recruit patients with the predetermined characteristics to participate, administer the treatment, and collect data on the patients' health for a defined time period. (These data include things like vital signs, amount of study drug in the blood, and whether the patient's health gets better or not.) The researchers send the data to the trial sponsor, who then analyzes the pooled data using statistical tests.
Biotechnology Services	Outsourced services that are provided to specific companies to enable them complete various Biotechnology operations or research.

7.2
KEY TRENDS IN LIFE SCIENCES

The dynamics of Life Sciences has been almost as dramatic as those of the ICT sector in that it has attracted significant amount of hype and capital and followed a trend almost equivalent to that of the ICT sector[65].

In essence, Life Sciences combines physics, biology, chemistry and technology that affects the discovery and development of products for healthcare and the wellbeing of individuals founded on the toolsets to enabling visualisation and understandings (genomics, combinatorial chemistry, SNPs, proteomics etc). The Life Sciences area has been impacted by some significant achievements but also some challenges. Almost every achievement arises to be confronted by a challenge. The human genome sequencing has completed, genotyping, SNPs, functional genomes, proteomics are now redefining how visualisation and discovery are happening.

However, the changes in Life Sciences have led to changes in the structure of the industry. This has been significant since 2002 when acquisitions were plentiful and motivated by;

- the acquisition of innovation (Merck/Rosetta);
- the need for size (SmithKline Beecham/ Glaxo; Pfizer/Pharamacia); and
- the need for market focus (Aventis).

However, the industry has also been changed by a convergence in the industry where the manufacturers of 'traditional' products started to realise that they may be moved to become sub suppliers to the manufacturers of drug delivery devices. Additionally, once size is achieved, the average portfolio of Life Science companies is moving to generic based products at a rate of 15% per annum.

This, aligned with stock market demands for increasing profitability at 12 - 15% per annum is compelling a global search for innovative products and delivery mechanisms.

The internet is redefining information[66], access to information, business models and success factors and products, revenues and profits within the Life Sciences remain positively strong. However, with increased information, Genetically Modified Foods, Cloning, Stem Cells, Gene Therapy are interesting the public, but the debate is fragmented and this produces volatile reactions. Additionally, the changes to the information[67] in the sector are implying significant growth in self-administered healthcare where patients see the opportunity to provide self diagnosis and remedies[68 69].

Due to costs and complexity of modern Life Sciences, the industry is seen from two perspectives - extensive restructuring continuing in pursuit of optimal size or innovation and extensive degrees of partnership to reduce costs and extend market reach. It is estimated that the number of large collaborations in Life Sciences has increased significantly since the early 1990s[70]- by a factor of eight.

The changes in Life Sciences themselves are being driven by:

- New technologies including molecular, biological etc;
- An aging and demanding population in USA and Europe;
- Consolidated demand side of Healthcare in critical diseases such as obesity, alcohol consumption etc.; and
- Greater interest in medicine, safety and the wellbeing of individuals.
- A new concept of Applications Biology. It integrates the understanding of cellular components and how they function and when aligned with computational methods it allows for a better understanding and visualisation of complex biological applications and their behaviour. Effectively, it is the beginning of the integration of 'wet' biology with digital biology. At the same time there is a shrinking in market exclusivity between the introduction of medicine and competing innovators. In 1965 exclusivity could be seen to last almost 10 years but by 1999 this had been reduced to almost 0.25 years. Additionally, only three out of 10 new medicines or products actually produced revenues that matched or exceeded average Research and Development costs[71].

In summary, the ability to meet consumer demands, using a strong scientific basis for products with early market access and a strong exposure to a large amount of technologies, ideas and concepts seem to be the only means to allow Life Sciences to create a product pipeline that is dependent on partnerships, but that can be profitable.

65. Burrill & Company
66. See for example Medicineonline.com/YourDiagnosis.com
67. Cyber Dialog/Market Drivers
68. Future Health Trends - An Overview/National Leadership Network
69. Trends 2006/Top Trends in Health/Swan
70. Bioworld Financial Watch, American Health Consultants
71. Grabowski, Vernon 'Returns to R&D on new drugs introduced in the 1980s.

7.3 PRIVATE SECTOR

The Life Sciences private sector in NI consists of approximately 60 companies that had, in 2005, a combined turnover of some £290m, and employ in the order of 3920 staff. Twenty-eight of these companies have an identifiable R&D capability, and in 2005 allocated some 612 staff and £33m to this.

The following table presents the company names and business descriptions associated with the companies grouped in this capability sector. The full list of companies in this sector is presented in Appendix 3 alongside the companies in all other sectors.

TABLE 7.2: LIFE SCIENCES COMPANIES IN NORTHERN IRELAND[72].

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Medical Devices and Diagnostics	The creation, design or manufacture of an instrument, apparatus, implement, machine, implant, invitro reagent or other items for correction of recognised clinical conditions.	This includes a range of companies varying significantly in size. These include Almac - Almac Diagnostics, Anser Laboratories, Biocolour[73], Biopanda Diagnostics, BioSearch NI, Fortress Diagnostics. Amtec Medical, Andor Technology, Armstrong Medical Services, Avalon instruments, Bluescope Medical Technologies, Haemoband Surgical, HeartScape Technologies, Heartsine Technologies, Morris Consulting, Orthodocs, ST&D, Tru-Corp, Tyco Health Care (UK) manufacturing. As the global market for medical devices and diagnostic devices will continue to grow, this offers a significant economic impact to NI.	4		3

72. The allocation of companies to sub-fields is aligned with the NI Life & Health Technologies Sector – BioBusiness Northern Ireland
73. Queens Award in 2006

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Pharmaceuticals	The creation, manufacture and distribution of substances with solid, living and non-living organisms that produce a change in function with medicinal properties. This encompasses drug composition and properties, interactions, toxicology, therapy and medical applications.	This is the largest sub-field of the sector in terms of employment however there are fewer companies in this sector and the cost pressures are significant. The companies are Almac – Almac Sciences, Almac – Pharma Services, Galen, Ivex Pharmaceuticals, Kiel Pharmaceuticals, Nicobrand, Norbrook Laboratories, Victoria Pharmaceuticals, Warner Chilcott. The economic potential of this sector will lie in the development of pilot/prototype capability as the cost advantage of NI is disappearing.	3	3	
AgriBiology	Veterinary products	This sub-field is driven by one large company in NI and that is Norbrook laboratories, which appears to have significant product engineering and product capabilities. Globally, this market will continue to grow as animal disease becomes more into focus.	3	3	
Medical Disposals	Disposable instruments, devices and materials that are used within medical and surgical procedures.	Traditionally, medical disposals are the most cost competitive aspect of this sector. NI has a number of companies in this sub-field including Clonnallon Laboratories, Shiraz Medical, TG Eakin. As the globalisation forces take hold of this sector, it is unlikely that NI will retain the industry in its present state.	2	4	

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Biotechnology	Refers to recombinant DNA based and/or tissue culture based processes. Biotechnology combines disciplines like genetics, molecular biology, biochemistry, embryology and cell biology, which are in turn linked to practical disciplines like chemical engineering, information technology, and robotics. Biotechnology can also be defined as the manipulation of organisms to do practical things and to provide useful products.	Biotechnology is the newest sub-field of development in NI and is a critical aspect of the future of Lifesciences. The companies here include Diabetica, Fusion Antibodies, Gendel, Randox Laboratories, Xenosense.	4		4
Systems Biology	Systems Biology is an interdisciplinary field which addresses biological problems using computational techniques. The field is also often referred to as computational biology. It plays a key role in various areas, such as functional genomics, structural genomics, antibodies and proteomics, and forms a key component in the biotechnology and pharmaceutical sector.	This capability exists in the university structure only with some minor capability in industry. However, this will drive the sector for the remainder of this century and exploitation pathways for this capability must be found. Please see university capability listed below.	4		2
Packaging	The provision of packaging formats to the sector	Sepha Ltd, Boxmore, Perfecseal,	3	3	
HealthCare Informatics	The provision of ICT solutions or embedded solutions to the sector.	i-Path Diagnostics, IQ Solutions, Tomcat systems, ContacQ	3	3	

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Clinical Trials		There is a highly competitive capability in Clinical Trials whereby companies are offering effective supply chain solutions that ensure an effectiveness and efficiency to clinical trailing. Almac Clinical Services, Medevol Clinical Services, MDS Pharma Services and Biokinetic Europe are examples of this capability. This capability will stretch across into the food industry with claim substantiation in the future.	2	4	
Biotechnology Services	The provision of outsourced innovation or operational services for the Life Sciences sector.	Outsourcing is very new to the Life Sciences industry however, in the search for ever increasing innovation capabilities and capacities it is a rapidly growing aspect of the sector. The developments by Almac Pharma Services, BioSearch NI and Almac Sciences (chemistry services) provide direct evidence of this capability.	3	3	

SELECTED COMPANIES

The following section presents in more detail eight of the most significant companies in this sector in terms of a combination of R&D spend, turnover and number of employees. As can be seen from Table 7.3, these companies together account for some 63 % of turnover, 60% of employment and 65% of identifiable R&D spend in the sector.

Almac Sciences
Almac Sciences is an amalgamation of five related businesses and is a world leader with regards to the research, development and delivery of pharmaceutical services. Competencies range from drug discovery through clinical trials to the commercialisation of the end product. Whilst it keeps most R&D activities in-house, Almac Sciences has strong linkages to QUB.

Randox Laboratories
Randox specialises in the development and production of diagnostic equipment and test kits for laboratories. Its latest developments are based around the use of protein biochip technology for multiple simultaneous analyses and it has the world's first protein biochip manufacturing facility. With regards to research cooperation, Randox does not have extensive links with external organisations (either academic or commercial) as it largely keeps this in-house.

Norbrook Laboratories
Norbrooks primary focus is in the development and production of value-added off-patent pharmaceuticals in the veterinary field, although there is an increasing focus on medical products. As such they have significant competencies with regards to reverse engineering, clinical trials and drug regulation. They do not cooperate at present with other companies or universities in NI.

Almac Diagnostics
Almac Diagnostics is split into two divisions, the first of which is Genomic Services and provides an all-inclusive gene expression and bioinformatics service to academia, biotech and pharmaceutical companies. These services include analysis of unique disease specific cancer arrays. The second division is that of R&D, which focuses on the development of new tests for improving the diagnosis and treatment of cancer.

Bio-Kinetic Europe
Specialise in the design and undertaking of Phase one clinical trials. They have no real in-house R&D capability as the clinical trials they undertake are integrated in to the respective R&D projects of their clients. They do, however, have some cooperative undertakings with UU, QUB and Sligo Institute of Technology.

TG Eakin
Specialises in the development and manufacture of high quality skin protection products for global export.

Tyco Healthcare
Manufacture a variety of products including; needles and syringes, surgical products for the treatment of incontinence, covers for thermometers and plastic containers for the disposal of needles and syringes. They have very limited R&D capability as this is mostly addressed within the companies US operation.

It is also important to note that within the Life Science sector in NI, there are also a number of interesting and innovative smaller companies, and again a summary of a selection of these is presented below:

Heartsine
Were set-up in 1999 and specialise in the manufacture of medical devices, specifically innovative defribulators. They collaborate with UU and the RVH on R&D initiatives.

Diabetica
Diabetica were spun out from the Diabetes Research Group of UU and specialise in innovative diagnosis and treatment of diabetes and obesity.

TABLE 7.3: LIFE SCIENCES COMPANIES

COMPANY NAME	TURNOVER (£000)	TOTAL TURNOVER AS % OF SECTOR TURNOVER	R&D SPEND (£000)	TOTAL R&D SPEND AS % OF SECTOR R&D SPEND	NO. OF EMPLOYEES	NO. OF EMPLOYEES AS % OF SECTOR EMPLOYMENT	R&D STAFF	FULL-TIME R&D STAFF AS % OF SECTOR TOTAL
Almac Sciences (includes Almac-clinical)	27,000	9.3%	8,500	25.8%	420	10.8%	160	26.1%
Randox Laboratories	39,642	13.7%	6,500	19.8%	438	11.2%	136	22.5%
Norbrook Laboratories	84,462	29.1%	3,647	11.1%	1,007	25.7%	78	12.7%
Almac Diagnostics	735	0.3%	1,308	4.0%	24	0.6%	18	2.9%
Bio-Kinetic Europe	1,569	0.5%	1,079	3.3%	28	0.7%	20	3.3%
T G Eakin	10,032	3.5%	406	1.2%	165	4.2%	4	0.6%
Tyco Healthcare	21,710	7.5%	n/a	n/a	270	6.9%	n/a	n/a
Totals	**185,150**	**63.1%**	**24,246**	**65.2%**	**2,352**	**60.0%**	**416**	**68.0%**

Fusion Antibodies
Was established in 2001 as a spin-out from QUB and specialise in the investigation of the use of therapeutic antibodies for the treatment of cancer.

Sepha
Established in 1980 and specialise in the manufacture of equipment for blisterpacking, deblistering and leak testing.

Private Sector capability
In summarising the core capabilities of the NI private sector in the field of Life Sciences, it is the case that definite strength exists with regards to the following:

- Clinical Trials;
- Medical Devices and Diagnostics;
- The emerging Biotechnology sector.

It is also the case that in terms of scale the private sector is dominated by three main companies; Almac, Randox and Norbrook and these companies do not engage, to any real extent, either with each-other or the smaller life science companies.

7.4 PUBLIC SECTOR

The primary source of public sector capability in Life Sciences lies within the Research and Development directorate of the NI Health and Social Services Central Services Agency, which was established to promote, co-ordinate and support R&D within the field of health and social care. This directorate has published a 'Research for Health and Wellbeing Strategy 2007 – 2012' in early 2007 and this drives the overall programme.

The strategy outlines that the directorate has a dual strategic and operational role with, at a strategic level the office providing an overall strategic direction for Health and Personal Social Services (HPSS) R&D and liaises with national statutory bodies and health-related organisations including the Department of Health, whilst at an operational level supporting a wide range of R&D initiatives from education and training to direct commissioning. In total, the budget of the office is approximately £12m per annum and the emphasis on knowledge, innovation and partnership permeates the strategy.

The R&D strategy of the office is based around five strategic elements priorities which are:

- Developing and enabling infrastructure;
- Building research capacity;
- Funding R&D;
- Supporting innovation by translating R&D into practice; and
- Ensuring patient and public involvement.

The primary element of this strategy is Recognised Research Groups and this is summarised below:

The Recognised Research Groups (RRGs), which are intended to enhance good quality research, while creating a more vibrant research culture, with increased multidisciplinary working and co-operation. These RRGs are the central strand of HPSS R&D policy, complementing and supporting the other eight strands and integrating the whole of HPSS R&D strategy. Currently there are seven such RRGs (see list below) and these account for some 50% of the offices funding:

- Child Health and Welfare;
- Vision;
- Diabetes, Endocrinology and Nutrition;
- Cancer;
- Trauma;
- Infectious Diseases;
- Neuroscience and Mental Health.

In addition to these RRGs, the R&D office has also created the following capability:

- NI Clinical Research Support Centre (CRSC) - The CRSC was established as a key component of the HPSS R&D strategy, with an important role to play in capacity building and infrastructural support for the promotion and conduct of high quality clinical and health services research. It provides advice, support and training to individuals undertaking research of value to HPSS and can provide assistance with regards to a number of elements including; research question refinement, research design, statistical advice, feasibility and costing, data management services, clinical trials services, grant applications, project management, regulatory requirements and IP management.
- NI Clinical Research Network (NICRN) – The NICRN has been created in line with the objectives of the UK Clinical Research Collaboration. It is made up of a central support centre which provides; methodological expertise, data management capability, coordination of IT, maintenance of disease registers, coordination of network monitoring, development and provision of training, provision of administration support, contract negotiation support and acting as the point of contact for the rest of the UK.
- Topic specific clinical research networks (TCRNs) will have several components, each of which will contribute unique but overlapping functions, all of which will be crucial to the overall success, not only of the individual network, but the wider NICRN. These local networks will lead, support and promote research in each topic area. It is envisaged that the research portfolio will include a range of multi-centre nationwide studies as well as some pilot and/or local/non-nationwide studies.
- The Experimental Cancer Medicine Centre (ECMC) is jointly funded by the R&D office and Cancer Research UK. It is one of 14 such centres in the UK and is located at Belfast City Hospital. Their general aim is to improve the quality of cancer care by integrating and sharing the knowledge and resources of the scientific and clinical staff at each of these centres. In the case of the Belfast centre, its primary focus is with regards to early phase clinical trials, biomarkers for prediction of response and toxicity, and the application of functional imaging in the monitoring of responses to normal therapeutic agents.
- The NI Longitudinal Study (NILS) provides a dataset that links demographic health and social care information that can be used as a basis for a variety of research projects. The first of such projects undertaken addressed:
    - Mortality;
    - Population mobility;
    - Population migration and health inequalities;
    - The link between birth rates and mothers of different ages.
- The All Island Co-operative Oncology Research Group (A-ICORG) supports initiatives to improve cancer care, research and training throughout all of Ireland. It is co-funded by the Health Research Board in the Republic of Ireland and the R&D centre in NI;
- The Nucleic Acid Extraction Centre (NAEC) works in clinical genetics and provides expertise in the extraction and storage of DNA and RNA. It stores nucleic acid, blood and tissue samples and is using state-of-the-art control procedures in addition to ICT solutions that allows for the storing and accessing of data.

7.5 ACADEMIC SECTOR

Within the academic sector there is also a well developed and diverse set of capabilities with regards to Life Science in both universities, and this is summarised in the Table 7.4.

With regards to FE the following table lists the courses related to Life Sciences that are currently available. It shows that in total some 470 students are enrolled in these, at this time, and that Human Biology and Pharmacy Technicians are the most popular.

TABLE 7.4: SUMMARY OF CAPABILITY IN THE HE SECTOR IN THE DOMAIN OF LIFE SCIENCES

NO.	INSTITUTION/GROUP	LOCATION
1	NI Technology Centre	QUB
2	Polymer Processing Research Centre	QUB
9	Molecular Biology Research Group	QUB
12	Cancer Research and Cell Biology Group	QUB
13	Centre for Vision Science	QUB
15	Innovative Molecular Materials	QUB
16	Synthesis and Biological Organic Chemistry	QUB
32	Medical Polymers Research Group	QUB
33	Clinical and Population Sciences	QUB
34	Oral Sciences and Health Care	QUB
35	Respiratory Medicine	QUB
37	Maternal and Child Health Group	QUB
38	Evaluation of Complex Healthcare Interventions	QUB
39	Molecular Therapies	QUB
40	Pharmaceutical Science and Practice	QUB
44	Cancer and Ageing	UU
45	Diabetes	UU
46	Human Nutrition and Dietetics	UU
47	Vision Science	UU
48	Bioimaging	UU
49	Biomedical Genomics	UU
50	Microbiology and Biotechnology	UU
51	Stem Cell and Epigenetics	UU
52	System Biology	UU
53	Health and Rehabilitation Sciences Research Institute	UU
54	Nursing Research Institute	UU
57	Medical Informatics Recognised Research Group	UU

NO.	INSTITUTION/GROUP	LOCATION
66	Bioceramics and Tissue Engineering Group	UU
67	Biosurfaces	UU
68	Electrodes and Sensors Group	UU
70	Plasma and Nanofabrication Group	UU
73	Nanotec NI	QUB/UU

TABLE 7.5: SUMMARY OF CAPABILITY IN THE FE SECTOR IN THE DOMAIN OF LIFE SCIENCES

SUBJECT CODE OF COURSE	TOTAL	LOCATION
Clinical Medicine	21	Lisburn
Clinical Dentistry	9	Fermanagh
Human Biology	118	BIFHE, East Tyrone, NDA
Pharmacy	61	Fermanagh, Omagh
Pharmacy Technicians	118	BIFHE, Newry & Kilkeel
Nutrition/Dietetics	57	Armagh, East Antrim
Nursing	68	East Down, Newry & Kilkeel, North East
Others in Medical Technology	13	Newry & Kilkeel
Microbiology	5	Lisburn
Sum	**470**	

7.6 OVERALL SECTOR CAPABILITY MAPPING & CONCLUSIONS

The Life Science capability in NI is impressive and significant, however, this remains fragmented between Academic Research, Public Sector Research and Private Company Research.

Private Sector

The private aspect of the sector remains dominated by three leading companies - Almac, Norbrook and Randox, who have little interaction with the rest of the sector in Northern Ireland. Their success is based on their own capability to supply their markets - quickly and efficiently. Their product capability aligned with a 'silent' capability in their supply chain of solutions is also noteworthy. This domain of the sector becomes relatively small once these companies are excluded, and although excellent capability is detected, this remains relatively small is scale, which is a threat to those companies and further enhances the fragmented nature of the sector[74]. Within the private sector, there are clear capabilities:

Medical Devices and Diagnostics

Here, small NI companies show significant technical capability in creating innovative solutions based on collaborations with the universities and other research centres, however the scale of this capability remains an issue. There remains excellent capability based on Advanced Materials and Computational Capability;

Pharmaceuticals

Here, some large players have a number of operations within NI. These operations tend to be production orientated and therefore extremely cost sensitive. The real capability in these companies is borderline competitive, which implies significant ongoing pressure on costs and margins;

Medical Disposals

There are a number of disposable companies in NI. These companies provide supplies to the medical industry, however the companies were attracted to NI when it was a relatively low cost environment. These conditions have changed somewhat and have affected the ability of these companies to embrace more significant technology capability and add further value to their products. These companies will experience commercial difficulties otherwise;

Biotechnology

NI shows a high degree of innovation and entrepreneurship in this area. The company size tends to be small however and scale once again threatens the companies here;

Clinical Trials

NI has captured highly competitive capability in Clinical Trials – particularly early stage. These companies have developed product capabilities that are constantly updated but can be readily replicated and controlled.

Public Sector

The public sector capability is driven by the work of the DHSSPS. This unit benefits from having a dual remit of health and social care and therefore has a R&D directorate which promotes and supports R&D within the HPSS. This R&D tends to span both healthcare and community/social care. This does provide some additional 'end-to-end' capability.

There are a broad range of self-contained R&D projects which are supported by the directorate and some of these range from pure research groups to education and training, career development, information dispersal etc. The R&D Strategy is focussed on wellbeing and health but seems to be disconnected from the other companies in the sector in NI.

Academia

The Academic part of Life Sciences in NI is filled with significant capability, albeit sometimes small in scale. However the strength of the sector in Genomics and diseases (cancer), Human Nutrition and Diet including the emphasis on food, vitality and nutraceuticals and other diseases such as Diabetes. The capability of Systems Biology is not fully exploited in NI. The key academic areas of focus are:

- Vision (and the implications of vision);
- Immunology;
- Drug formulations and associated technologies;
- Systems Biology;
- Bioimaging;
- Epidemiology; and
- Tissue engineering as a platform for regenerative medicine.

However, the research in the sector tends to be fundamental in nature and this drives limited exploitation opportunities. This implies that any meaningful commercial research is exported outside of NI to leading companies in the UK or Europe and the USA. The upshot of this situation is that the sector therefore has long critical mass innovation. It is worthwhile to comment that R&D in this sector is considered stronger in NI than in the Republic of Ireland, however, it has more exploitation capability. The net 'drain' affect of this situation is that NI will lose key researchers to other geographies unless this is reversed.

74. The significant efforts of BioBusiness NI in commencing to pull the sector together should be noted however. This is certain to assist in creating clustering affects.

7.7
A SUMMARY OF LIFE SCIENCES IN NORTHERN IRELAND

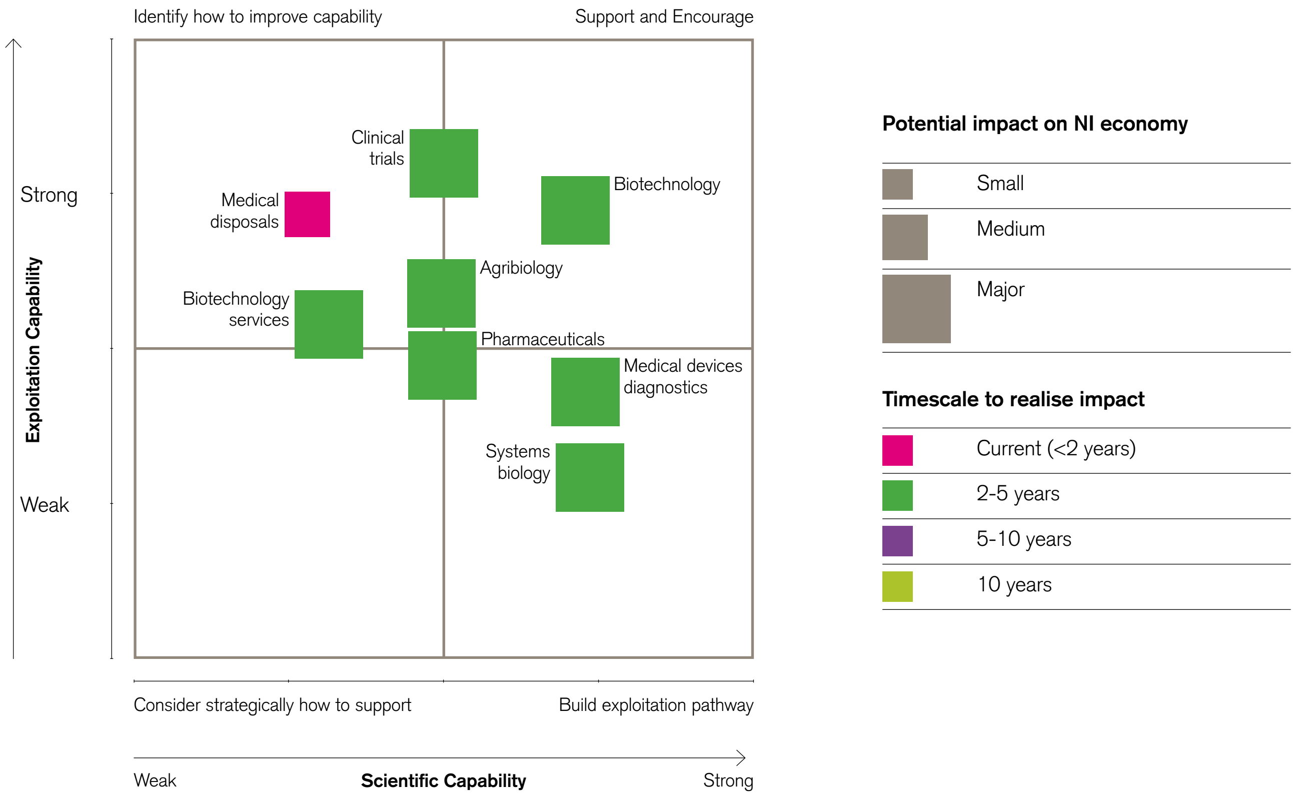
The summary position of Life Sciences in reflected in Figure 7.1. There is much capability within Life Sciences however this capability is clearly fragmented between Academia, the private sector and the public research agenda. There is little interaction and relatively little discourse although capability in all of these sub-fields in highly competitive. Hence, the anchor companies such as the indigenous large companies and the international players create relatively small demand within the sector in NI. This damages emerging capability.

Within the sector, there is limited recognition of the cross-over of capability to other sectors such as Life Sciences (Genomics, Systems Biology etc) that they can contribute to. Equally, there is relatively little cross-over with other sectors such as Advanced Materials and Advanced Manufacturing where there is real capability that can advance the sector in NI.

In certain instances, competitive capability is small in scale and this can create issues concerning the development of that sub-field within NI. The links to universities could alleviate this situation but there appears to be a mismatch with some exceptions.

The major players within the sector do not communicate or interact in any meaningful way leading to an isolation of capability that could be used for other purposes.

FIGURE 7.1: LIFE SCIENCES CAPABILITY IN NI



ICT

8

8.1 ICT

Information Communications Technologies (ICT) is defined as the combination of manufacturing and services industries that support the capture, transmission and electronics display of data and information. This is a sectoral definition and excludes industries that are underpinned by ICT developments such as medical devices etc.

ICT is a broad term that refers to both an enabling technology and a sector within itself. However, it is clear that to maximise the impact of ICTs in any economy, it must move towards becoming a formal cluster[75].

8.2 SECTOR DESCRIPTION

The NI ICT sector has achieved some growth in the past ten years. It now employs almost 11,000 people and has a student population of 24,000. However, these 11,000 employees are spread across 750[76] companies, implying that the majority of companies remain relatively small and supply-based to the local public sector market, where they provide a combination of capacity and some capability resources. By comparison, the Republic of Ireland ICT Cluster employs 115,848 personnel with 1,317 companies in nine sub-sectors[77].

The existence of growth in the NI ICT environment has been primarily achieved through a combination of cost competitiveness and an emerging business policy environment. The quality and quantity of skills available augmented this fact[78]. However, the progress of the NI ICT environment positions it behind the formal clusters of leading countries such as the Sweden, the USA, Israel and other UK regions and only slightly ahead of the emerging clusters in Eastern Europe and India[79].

At this point in time, the NI ICT environment looks to be in transition. It is losing the low cost competitiveness position and the emerging critical strategic factor is that the NI ICT environment builds on the existing platform of technical excellence and competency and creates an environment where it is compounding existing value added activities through specific industry and customer focus.

The NI ICT environment is a relatively recent development compared to developed environments in leading ICT countries such as the USA, the Republic of Ireland[80] and some parts of the UK. The NI environment developed from an outsourced base (most other leading countries environments have come from a Research & Development base) and has overcome inherent barriers of geography and size to become a net exporter of ICT products and services. Traditionally, the NI ICT environment has benefited from a moderate policy platform and an excellent skills base.

A feature of the sector is the existence of both FDI and Indigenous companies within the sector. The NI ICT environment is only becoming export oriented as it has traditionally been focussed on the government market from a services perspective. Both the FDI and indigenous aspects of the NI ICT environment have been influenced by a number of drivers.

In evaluation of this sector in NI, the following sub-fields and definitions have been used. This categorisation is based on market type and the skills required.

75. European Innovation Index 2006
76. OCO Consulting
77. PA Consulting – The Irish ICT Cluster (2004)
78. NI has thirteen university research centres in ICT with specific and excellent focus. The quality of graduates from the universities is highly regarded.
79. The source of this analysis is a report completed on Global Clusters published in 2005. Whilst there has been some progress in NI in 2006, it is unlikely to overcome this positioning.
80. This cluster is considered to be forty years old

TABLE 8.1 ICT SUB-FIELDS AND DESCRIPTIONS

ICT SUB-FIELD	DESCRIPTION
Application Software	Application Software is defined as programs that help the user accomplish tasks: for example, word processing programs, spreadsheet programs, or FTP clients. The Application Software sub-sector includes the following subsets: Bespoke software Systems integration Other business applications software Kitting and logistics software eGovernment applications
Product Software	Software 'products' that are sold and replicated individually or as part of larger solutions around the world. Mobile Telecommunications (including network management) Security Content management software Financial software Healthcare software Enterprise software
Digital Content	Digital Content is defined as content or material that is provided in a digital format. It includes eLearning, Games, Digital Television (DTVGF), Animation and Post Production, and Special Effects (SFX). Digital Content is characterised by the fact that the digital medium is driving convergence between formerly independent industries. For example, ICT might once have been seen as separate from Media and Entertainment but the convergence of these sectors is driving the development of new products and services.
Hardware and Systems	Hardware and Systems refers to the physical devices that drive the ICT sector and the systems software that is typically embedded within the hardware to make it operate. This is a broad category that refers primarily to what is termed 'manufacturing' – either assemble to order, assemble to schedule, build to order or turnkey systems. The sub-sector includes: Fabrication and Logistics/High Value Added Fabrication and Logistics/Medium Value Added Fabrication and Logistics/Low Value Added IC Diffusion (as in Intel, Analog Devices) Computer and peripheral systems with local product development Other embedded systems Process Control Systems including testing
IC Design	Microelectronics Design is defined as the design of materials, circuits and new device structures for the ICT sector. It is the strategic research and development that focuses on identified technology bottlenecks and challenges with the purpose of creating new technology platforms, building blocks and intellectual property to drive the next generation of ICT products and applications.

ICT SUB-FIELD	DESCRIPTION
IT Services	The IT Services sub-sector is defined as companies that provide IT functions with a focus on specific solutions for customers based on a mixture of hardware and software. The commercial models vary within this sector and the range of services covers both mature and developing services including: Package Implementation Application Maintenance Internet Service Providers Application Service Providers Business Service Providers Business Process Management Services
Support Services	Support Services relates to the support functions of ICT companies independent of the production of products and services. This includes: Shared services centres; Back office functions e.g. payroll, accounting, finance, tax; Front office functions.
Mobile Telecommunications	This sub-field deals with Wireless Technology only. It should be noted that telecommunications software has already been excluded from this sub-sector and included under applications software.

8.3 KEY TRENDS IN ICT

The ICT sector is moving towards a global supply chain as it seeks both new markets and new innovations that will sustain existing markets. This change sees the centre of gravity of the ICT sector move from specific locations to a global supply chain[81]. To continue to operate effectively within the ICT sector will mean that all clusters will have to work together in the future.

Application Software will continue to drive the ICT sector globally and this will be underpinned by a developing IT services offering that is commercially and technically robust. However, throughout this environment the availability of high quality skills is the critical success factor. The issue relating to the quantity of skills available is becoming less critical internationally. However, the debate surrounding the quality of skills is coming to the fore. This is shifting the policy focus away from the initial education and training required to drive increased supply, and towards the continuing learning required to underpin the quality and fit of the skills of ICT professionals.

The ICT sector is becoming more integrated into the fabric of industries and society. The result of this is that the sector is becoming more industry and customer focused as it has recognised that true value added and cost management decisions are best articulated in the context of industry and customer demand. This is a compelling change in FDI companies globally and it will also determine the future of start-ups and existing local companies. Whilst the concept of industry and customer focus is relatively easy to articulate, it is complicated by the fact that industries and customers are becoming more global and are driving standards and procedures to optimise their own operations.

New standards and innovations are changing the structure of the ICT industry. Software is starting to drive change and IT services are becoming more important as an underlying foundation to the sector. As the ICT sector changes, skills and capability remain the fundamental driver and means of achievement. The policy environment is also changing dramatically for the ICT sector. ICT regulation in itself is changing due to liberalisation and imposed regulations. Additionally, labour regulations, in particular from Europe, can change the dynamics of the NI labour market.

81. The concept of a global supply chain implies that there will be multiple locations of both supply and demand within the global ICT sector and that these will work of combined products and services from all existing locations.

8.4 PRIVATE SECTOR

TABLE 8.2 ICT SECTOR[82] - KEY INFORMATION

ICT SUB-FIELD	EMPLOYEES	TURNOVER (£000s)	R&D EXPEND (£000s)
Application Software IT Services Product Software	5,037	285,731	14,971
Product Software	464	16,089	230
Hardware and Systems	425	68,705	0
IC Design	N/A	N/A	N/A
Telecommunications	2,940	441,427	401
Total	**8,866**	**811,952**	**15,602**

The NI ICT sector is dominated by the Telecommunications and Software (both application and package software) sub-sectors, representing 53% and 34.3% of sector turnover respectively. Significantly, R&D expenditure as a % of turnover across the ICT sector is only 1.9%, with the Software sub-sector representing over 95% of entire sector R&D expenditure. Table 8.2 provides key information on ICT sector.

The entire sector is characterised by a small number of large MNCs, some significant indigenous companies, as well as a large number of small companies. The analytical breakdown of the sector is demonstrated in Table 8.3.

82. Source: DETI Statistics 2005

TABLE 8.3 ICT CAPABILITY IN NI

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Application Software	Creation of software for a specific purpose on a 1:1 basis (i.e. limitied reuse and licensing)	Strongest part of the ICT sector in NI and driven by the single biggest customer – Government sector. Companies in this space include AMT-Sybex, Asidua, BT, HP, Fujistu Services, CSC, Fern Computer Services, Finisco, Fionn, Gazer Technologies, Invision, IT Alliance, Siemens Business Services, Modcoms, Momedisys Limited, Raytheon, Vision Consulting etc. This sub-field is driven by capacity only and specific requirements articulated by clients – or inhouse organisations.	2	4	
IT Services	IT services covers Shared Services, Offshoring, Nearshoring and Infrastrcucture services.	BT, Bytel, Consilium, Core Systems, Cover.net, Finisco, Fionn Technologies, Memsis, NITEC, Northbrook Technologies, Stream Synstar, Unite, UTV Internet, ICS Computing. There are large variations in these companies in terms of size, scale of operation etc.	2	4	
Digital Content	Digital Content that covers internet content, digital media, etc.	There are a number of companies in this space that provide local services to local enterprises and business. There are some generated content management solutions but no real product development. Companies include Internet Business Ltd, TiBus, Streamon.net.	2	2	
IC Design	N/A	N/A			

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Product Software	Creation of a functional product that requires configuration or minor adaptation to meet requirements. Such a product is sold a large number of times, in a variety of markets, due to its depth of that market. This market is very different to the application software market although some of the skills are similar (at a technology level)	Product software is less capacity dependent, but requires deep market insight. In NI, there are a number of key areas: eCRM, which has companies such as Kainos, Amacis, Datatactics, Ion Technologies, Lagan Technologies Integration such as Invision, Interval Software, Meridio, Nisoft, Singularity. Serpico Software, Swan Labs Ltd. Financial Services products such as Wombat, SAP Research CEC. Retail with VME Retail Systems. Healthcare products such as Axis Three, Clinisys Oncology, CanDo Interactive, Steria, Tomcat Systems Oil and Gas solutions such as 80VER8 and Biznet Solutions. Specifically, these companies tend to be small, however some have grown and the development of product software capability (and research into same) must be a critical factor for the NI ICT sector. This sub-field offers the greatest impact in terms of employment and economic value added as it drives the entire ICT industry.	3	3	

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Hardware & Systems	Combination of processors, sensors, actuators, 'intelligence', hidden computers and deployment which have intensive interaction with an uncertain environment. The characteristics of the Hardware and Software co-design with high degrees of dependability, low power, power harvesting. The new markets are personalised devices that are user centred and adapt to preferences.	There is a growing development of embedded solution companies in NI. These companies range from Ceva, Bluechip Technologies (distribution), Goodrich Control Systems, Sanmina-SCI[83], Andor Technologies and others that incorporate the latest software models with hardware solutions. The range of application of these devices is from construction to medical technologies.	4	3	
Telecommunications	Telecommunications industry is experiencing significant change that allows for new models of revenue sharing and introduction of new players to the industry with responsive solutions to meet market or function needs.	There is a strong niche of telecommunications software companies within NI. These companies work throughout the Telecommunications OSS structure and include back office functions etc, which integrate with new models of revenue sharing. For example, Aepona, Andronics, Atlas Communications, Black Box Communications, Clarity Telecommunications, Kingston, Mobility Data Solutions, Mobile Cohesion, Openwave,and NTL. This can be a strong area of growth for NI.	2	4	

83. Note this facility closed in June 2007 during the completion of this exercise. It is included here for completeness.

TABLE 8.4 LEADING NI ICT COMPANIES BY TURNOVER[84]

RANK	COMPANY	EMPLOYEES	TURNOVER (£000s)	R&D EXPEND (£000s)
1	BT plc	2,548	370,339	0
2	Sanmina-SCI[85]	349	62,601	0
3	NTL Group	142	49,979	0
4	Northbrook Technology	1,472	42,130	0
5	Northgate Information Systems	806	37,732	0
6	Fujitsu Services	379	32,813	0
7	Merlin Interactive Ltd.	250	19,000	99
8	Kainos Software	164	11,025	0
9	Stream International (NI)	397	10,936	4
10	Lagan Technologies	107	9,950	1,745
TOTAL		**6,614**	**646,505**	**1,848**
As % of Sector		72.4%	77.6%	11.8%

TABLE 8.5 LEADING NI ICT COMPANIES BY R&D EXPENDITURE[86]

RANK	COMPANY	EMPLOYEES	TURNOVER (£000s)	R&D EXPEND (£000s)
1	Openwave Systems	111	7,464	2,274
2	Lagan Technologies	107	9,950	1,745
3	Meridio[87]	147	11,209	2,770
4	Mobile Cohesion Limited	30	38	2,770
5	Ceva	15	1,172	976
6	Aepona	81	6,513	818
7	Singularity	92	7,500	736
8	Texthelp Systems	26	2,069	552
9	Consilium Technologies	84	6,895	396
10	Andronics	14	549	381
TOTAL		**707**	**53,359**	**13,418**
As % of Sector		6.6%	5.5%	68.9%

84. Source: DETI Statistics 2005
85. This facility had a reduction in force in 2006 (100) and a further reduction in 2007 (complete closure - June 2007)
86. Source: DETI Statistics 2005
87. Please note that a subsequent note from Meridio updated the DETI 2005 statistics

Tables 8.4 and 8.5 show the leading companies in NI by turnover and R&D expenditure.

The key information to note about the top 10 ICT companies in NI by turnover is that:

- They represent 72.4% of full time employment in the sector;
- They represent 77.6% of sector turnover;
- The top nine companies only represent 0.6% of sector R&D expenditure; and
- Only three of the top 10 are indigenous companies, albeit that one company (Northbrook) is now 100% owned by a US company.

However, despite the level of turnover and employment generated by the top 10 ICT companies, they invest a disproportionately small amount in R&D. This fact is likely to have a major impact in NI's ability to generate real value from companies in the ICT sector.

Table 8.5 illustrates the contrast in statistics when R&D expenditure is considered.

The key information to note about the top 10 ICT companies in NI by R&D expenditure is that:

- They represent 68.9% of sector R&D expenditure;
- They represent only 5.5% of sector turnover, and 6.6% of sector employment; and
- Eight of the 10 companies are indigenous.

A small number of mid-tier companies (by turnover) represent almost 70% of R&D expenditure in the sector. 12 of the 119 companies in the sector are spending over 100% of their turnover on R&D, with a further nine companies spending over 50% of their turnover on R&D. All of these companies are indigenous, which reflects the significant level of investment in R&D required by local companies to make an impact on their respective markets. It also highlights the lack of local R&D investment by MNCs.

KEY COMPANIES

Based on the information provided above, a number of companies have been selected as representative of the some of key ICT companies in NI. A summary of these companies is provided in the following sub-sections.

Sanmina-SCI

At Sanmina-SCI's Lisburn plant, the main focus of its activities is precision enclosures assembly and metal fabrication. The Lisburn enclosures facility specialises in low- to medium-volume manufacturing for the data-storage, high-end computing, semiconductor and industrial markets, offering you fast-track prototypes to help introduce new products to market quickly and efficiently. The facility also delivers world-class painting and plating services, welding, volume mechanical and electrical assembly, tool forming, full-system integration and testing. However, although it declared a turnover of £62.6m in 2005, it only employs 349 people at the facility. The facility has subsequently had problems and reduced the workforce in 2006 and in 2007 announced the closure of all activities in NI.

Northbrook Technology

Northbrook Technology specialises in delivering high-quality, low cost technology and business solutions to its parent company, the Allstate Corporation. Northbrook plays a strategic role in developing, transforming and maintaining the various technology platforms used within Allstate. Essentially, Northbrook offers off-shore IT development and support to Allstate in its day-to-day business, looking after the different systems that Allstate needs to run. The development environment is IBM mainframe/midrange/PC with all the associated technologies.

Northbrook has a second facility in Magee College Campus. The Software Research Park there provides the necessary infrastructure and access to research personnel, resources and graduates. It also has a third facility in Strabane, which employs 70 staff working on a mix of call centre technical support and other back office administrative work for Allstate. Northbrook also has alliances with a number of bodies such as Momentum and the Centre of Excellence.

Northgate Information Systems

Northgate Information Solutions is a market leader of software applications and outsourcing solutions to the public safety, local government, education and human resources sectors and is also the largest HR and payroll application supplier in the UK. Its main presence in NI is due to its acquisition of Sx3 in 2005. Northgate has three major divisions focused on the group's core business areas: Northgate HR; Northgate Public Services; and Northgate Managed Services.

Kainos Software

Kainos is a privately held company and was one of NI's first campus companies, established in 1986 as a joint venture between Fujitsu and the Queen's University of Belfast Business Incubation Unit (QUBIS). Kainos specialises in developing mission critical business systems servicing clients in financial services, public sector, retail and utilities across Ireland and the United Kingdom.

Lagan Technologies

Lagan Technologies provides software solutions to governments in Europe and North America. Lagan's portfolio of solutions for government now encompasses: Customer Relationship Management, Customer Contact Centre and Case Management solutions for Central & Regional Government, Case Management for Human and Social Services solutions, Shared Service Centre solutions, and Single Non Emergency Number solutions.

Openwave Systems

Openwave Systems is an independent provider of open software solutions for the communications and media industry. Openwave software solutions are designed to enable customers to accelerate ARPU by rapidly launching value-added communication, information and entertainment services across networks and devices, and comprise a broad range of solutions including content delivery, messaging, music, video, and location.

Meridio
Meridio is a provider of enterprise Document and Records Management (eDRM) software, engineered for Microsoft .NET platforms. It's a privately owned company founded in 2001. Its investors include ACT Venture Capital, Polaris Venture Partners, QUBIS Limited, and Invest Northern Ireland. Meridio was built around the Products Division of UK-based software house Kainos Software Limited and the Document Management and Process Division of Teamware Group – a Fujitsu subsidiary. Meridio operates an indirect sales model as most eDRM solutions are linked with Process Optimisation projects.

Aepona
Aepona is a leading provider of application-led products and expert services to telecommunications operators globally, allowing them to rapidly deploy profitable new services across fixed-line, mobile and SIP/IMS networks. Aepona possesses a combination of expertise in both telecoms infrastructure and IT, and its solutions have been chosen by Tier 1 operators such as France Telecom/Orange, KPN, Sprint, E-Plus, Vimpelcom, Eircom and Bridge Mobile Alliance. Aepona's solutions enable operators to adopt new business models, combining externally-hosted with network-resident services to unleash the full power of their networks.

Singularity
Singularity markets a range of component based client server applications utilising Windows technology. It competes in the global market and is a Microsoft solutions provider with full TICKIT and ISO 9000 certification.

The company's second TCS Programme with the University of Ulster's School of Computing and Mathematical Sciences and School of Art and Design, was established to improve the computing of the design and development functions in the company. They were transformed and new design and prototyping teams were established, who now work together in product development, to ensure that products are 'right first time.' Singularity's new capabilities streamlined the software lifecycle and attracted new business based on prototype development. The company has also increased its product range through the introduction of human-computer interaction (HCI) design services to external software clients.

Texthelp Systems
Texthelp Systems is a software house based in Antrim, which specialises in assistive technology. Texthelp has developed a range of software products designed to assist individuals to improve their reading and writing abilities. Texthelp's products include Read&Write, Browsealoud and Lexiflow, which are software tools for people in the fields of government, education and special needs.

Andronics
Andronics provides global two-way data solutions for monitoring and control of remote assets. The company has been widely recognised for its technical innovation and commercial success in telemetry applications. Its software contributes to the smooth management of water, effluent, process and energy networks in both the public and private sector.

8.5
ACADEMIC SECTOR

TABLE 8.6: SUMMARY OF ICT CAPABILITY IN THE HE SECTOR

NO.	INSTITUTION/GROUP	LOCATION
58	Computer Science Research Institute (NIKEL (58), NICeB (59) and CSPT (60))	UU
5	ECIT-Electronics Communications and Information Technology	QUB
20	Knowledge and Data Engineering	QUB
78	eScience Centre	QUB

Research partnerships with private sector companies are still small in scale, but extremely interesting in content, at present. For example, the work in the Belfast e-Science Centre (BeSC), within Queen's University Belfast, is the regional focus of expertise, knowledge and experience in Grid technology. The BeSC is collaborating with industrial partners to sponsor and manage a number of projects such as GeneGrid (A collaborative industrial e-Science R&D project with Fusion Antibodies and Amtec Medical to provide a system for the analysis and mining of the digital data from the human genome) and OpenRiskGrid (a project developing grid technology for First Derivatives, a leading financial services software company based in Belfast.)

Equally, the work in ECIT, which is based on integrated collaboration, conducting blue-sky research and industrial research. There are also hot-housing and incubation facilities to encourage and support the establishment and development of new companies. Companies such as Xilinx, Andor, Octec, OMMIC and TDK are already working within ECIT. This innovation model is of great interest and is a model being followed elsewhere around the world in ICT clusters.

With regards to ICT capability in the FE sector, the following table lists those courses that are currently available throughout NI. It shows that there are at present almost 20,000 enrolled in IT related courses throughout NI, with in excess of these studying Information Technology.

TABLE 8.7: SUMMARY OF ICT CAPABILITY IN THE FE SECTOR

SUBJECT CODE OF COURSE	TOTAL	LOCATION
Computing Science	137	BIFHE, Castelreagh, Lisburn, North East
Computer Studies	1,100	BIFHE, Castelreagh, East Antrim, East Tyrone, Fermanagh, Lisburn, Newry & Kilkeel, North Down & Ards, North East, North West, Omagh, Upper Bann
Data Processing	47	Castlereagh, East Antrim
Applied Computing	136	Fermanagh, North East, North West
Software Engineering	241	BIFHE, Causeway, East Down, Lisburn, North Down & Ards, North West
Software	19	Castlereagh, East Down, Lisburn
Systems Analysis & Design	92	Limavady, Newry & Kilkeel
Programming	60	Castlereagh, Causeway, North Down & Ards, Upper Bann
Computer Education	4,480	BIFHE, Castlereagh, Causeway, East Antrim, East Down, East Tyrone, Lisburn, Newry & Kilkeel, North Down & Ards, North East, North West, Omagh, Upper Bann
Information Technology	10,258	All
Information Systems	118	Castlereagh, East Down, Fermanagh, Lisburn, Omagh
Applied Information Technology	253	East Antrim, East Down, Fermanagh, Limavady, North East
Others in Computing	2,043	Armagh, BIFHE, East Down, East Tyrone, Fermanagh, Lisburn, Newry & Kilkeel, North Down & Ards, North East, North West, Omagh, Upper Bann
Sum	**18,984**	

8.6 OVERALL SECTOR CAPABILITY MAPPING & CONCLUSIONS

The NI ICT sector, as defined in this report, is relatively strong and growing. It has missed a number of ICT generational issues which assisted the development of other sectors, however, there is a strong blend of growing indigenous companies as well as large MNC companies in the sector.

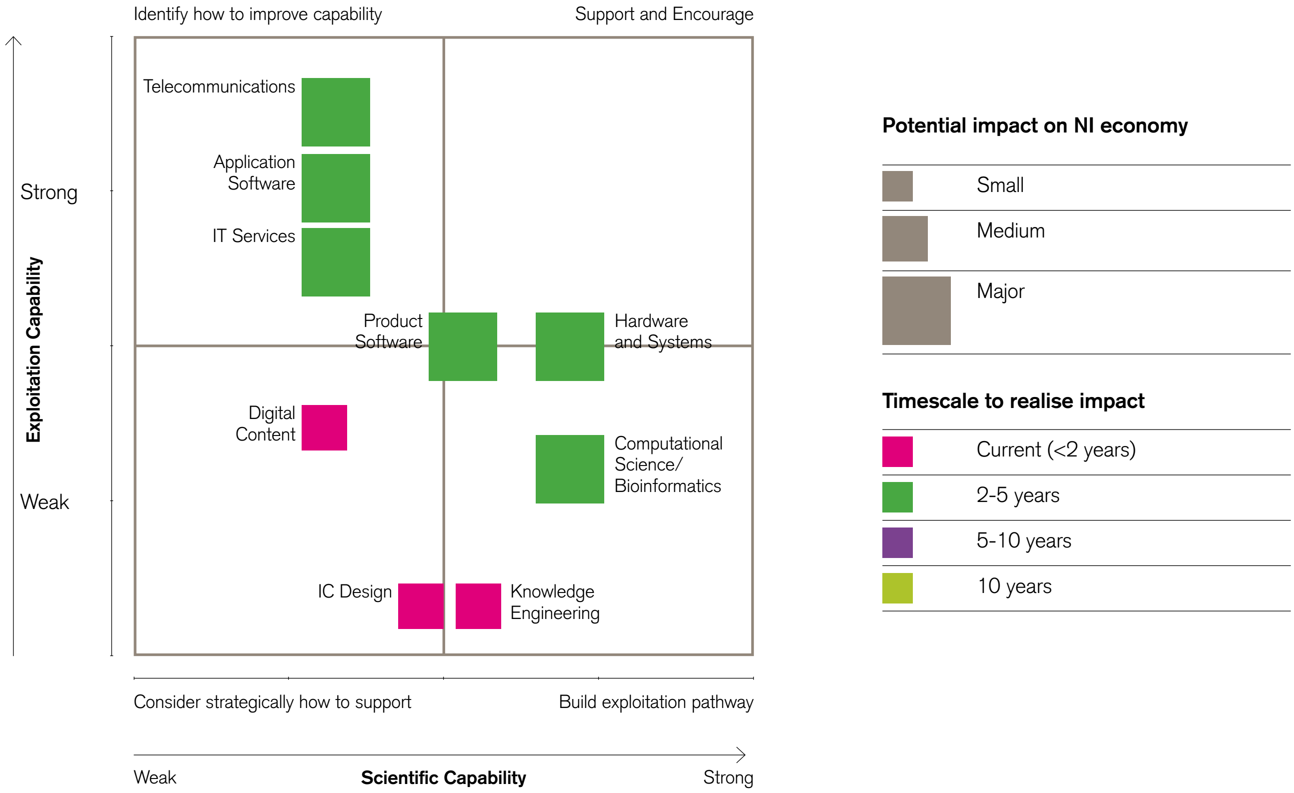
There is some heavy investment by indigenous companies in the latest technology and research but in general, this is low across the sector as a whole. Additionally, there has traditionally been a moderate level of academic research, recent investment in ICT research facilities (e.g. ECIT) should 'bear fruit' over the coming years and recent developments such as the involvement of TDK in ECIT and SAP in Grid Computing should advance capability in these critical areas.

Figure 8.1 below provides a summary of the NI ICT sector's exploitation capability and its scientific capability. It highlights that in some ICT sub-sectors (e.g. Application Software, IT Services, Product Software) it has a strong exploitation capability even though some of its scientific capability is weak. Similarly, in sub-fields such as Bioinformatics and Application Software it has weak/moderate exploitation capability, yet it has a strong scientific capability.

The key message from this analysis are: NI does not have an ICT cluster at this point in time. The journey to developing a cluster is 10/12 years and should be considered. However in the interim, the platforms of the cluster can be developed showing short term and medium term impetus;

There are also significant disconnects between education, skills and exploitation requirements. This issue is also misunderstood between all parties – education and knowledge is provided in universities, skills are developed and training in companies or further experience centres. Exploitation requires the immediate use of

FIGURE 8.1 SUMMARY OF ICT CAPABILITY IN NI



education and skills when provided;

There are some highly competitive capabilities in the exploitation arena and these clearly lead to new short term opportunities – nearshoring, product software and application software in telecommunications, financial services for example;
There are limited capabilities in the hardware and systems aspect of the sector in NI. The technology capability identified in this is relatively new. Centres such as ECIT are important developments. There is a need to manage the alignment of such centres with industry within NI. The presence of TDK and others does not necessarily guarantee economic impact and this has to be openly tackled;

NI in ICT will always be a 'net importer' of capability in ICT as it is not possible to develop all its own capability. This implies that the growth of the sector is based on collaboration with other centres – an integral aspect of ICT Clustering. There are limited views on how NI is currently collaborating with other ICT centres and this should also be addressed in the short term to allow the sector to attain critical mass and acquire new experience in areas such as product software etc.

The skills agenda
During the latter half of the 1990s and the early 2000s, there were widespread claims of ICT worker shortages internationally. More recent international analyses[88] have tended to suggest that the extent of the shortage was not as great as had been claimed. There had been a rapid increase in demand for ICT professionals, and there had been evidence of labour market tightness. However, except in narrow areas, labour market indicators, such as the rate of increase in pay, had been broadly in line with other professional occupations, suggesting that ICT professional shortages had been no more severe than for other comparable occupations. Industry internationally appears to have bridged the potential gap in supply by recruiting more people with non-ICT qualifications than previously.

To the extent that current trends and forecasts are a reliable guide to the period to 2015, international ICT labour markets are unlikely to become as tight as in the late 1990s, unless as a result of a very significant decline in student interest in ICT disciplines in developed countries. On the demand side, best estimates are that the rate of growth in ICT markets will be significantly lower, which will restrict demand for new ICT professionals to a level lower than the peak experienced in the late 1990s. On the supply side, countries such as India are increasing their supply of ICT professionals rapidly, with the intention, in large part, of substituting for ICT professionals located in developed countries.

Under these circumstances, the quality of skills, and the extent of the match between those skills and industry needs, will be crucial determinants of the success of export-oriented ICT industries, particularly those that are unable to compete on the cost of labour.
Even in the early 2000s, when most of the international policy focus was on the quantity of skills available, issues to do with the quality of skills and their match with industry needs were important. For example:

- Germany had significant unemployment among ICT professionals with dated skills.
- Much of the inward investment by major European companies is driven by shortages of specific skills and competencies in their home countries, rather than general shortages of ICT skills, or significant cost considerations.

With issues relating to the quantity of skills available becoming less critical internationally, issues relating to the quality of skills are coming further to the fore. This is shifting the policy focus away from the initial education and training required to drive increased supply, and towards the certified continuing learning required to underpin the quality and fit of the skills of existing ICT professionals. Organisations such as the OECD are now arguing that the main issue of concern for policy makers and companies should now be the gap between the current skills of some ICT workers and those sought by companies[89].

Implications for Northern Ireland
The skills aspect of NI becomes very relevant. Rough projections of demand and supply of graduates in computing and engineering within this current study suggest that the supply of computing and electronic engineering graduates available from the higher education sector is likely to fall short of ICT sector opportunities. As these are the primary technology disciplines in which substantial numbers of graduates are required, the projected shortage has the potential to constrain the sector's growth if alternative sources of skills cannot be found. The alternative is to take other graduates through certified conversion programmes (at Masters level) to alleviate this position.

However, it is likely that NI will have to again draw on significant volumes of skills from other countries. Inward migration from other EU countries will play an important role in this. However, the best sources of some skills will be outside the EU, in countries such as the US, India and Eastern Europe. It will be important that the sector should have access to these sources of skills, both through inward migration and through the establishment of subordinate operations in these countries. Inward migration by students, who may remain in NI after graduation, may also have a significant role to play in compensating for reductions in the number of NI students interested in pursuing ICT disciplines at college.

88. Information Technology Outlook 2002, OECD
89. Information Technology Outlook 2006, OECD

ELECTRONICS AND PHOTONICS

9

9.1 SECTOR DESCRIPTION

Electronics is the design and manufacture of the flow of charge through various materials and devices such as, semiconductors, resistors, inductors, capacitors, nano-structures, and vacuum tubes. All applications of electronics involve the transmission of power and possibly information. Although considered to be a theoretical branch of physics, the design and construction of electronic circuits to solve practical problems is an essential technique in the fields of electronics engineering and computer engineering.

Photonics is defined as the technology of transmission, control, and detection of light (photons). Photonics is the science of generating, controlling, and detecting photons, particularly in the visible and near infrared spectrum, but also extending to the ultraviolet (0.2 - 0.35 μm wavelength), long-wave infrared (8 - 12 μm wavelength), and far-infrared/THz portion of the spectrum (e.g., 2-4 THz corresponding to 75-150 μm wavelength) where today quantum cascade lasers are being actively developed. Just as applications of electronics have expanded dramatically since the first transistor was invented in 1948, the unique applications of photonics continue to emerge. Those which are established as economically important applications for semiconductor photonic devices include optical data recording, fiber optic telecommunications, laser printing (based on xerography), displays, and optical pumping of high-power lasers. The potential applications of photonics are virtually unlimited and include chemical synthesis, medical diagnostics, on-chip data communication, laser defense, and fusion energy to name several interesting additional examples.

9.2 KEY TRENDS IN ELECTRONICS & PHOTONICS

To date, the development of the photonic and electronics market has been hampered by the fact that most integration technologies are specific for the devices for which they have been developed. The market for these devices is usually not large enough to justify the investments involved in developing a large-scale integration technology that really leads to significant cost reductions. As a result, the penetration of photonic integrated circuits in the optical components market is still small, and it tends to remain modest as long as the prices cannot be reduced drastically. As a result, investment is moving towards the development of generic integration technology that supports the realisation of a broad class of components for application in telecommunications, but also in other applications, like sensors, health care and metrology. Such a technology could address a market which is sufficiently large to pay back the development costs. This is quite similar to what happened in micorelectronics.

In analysing the sector, it is sub-divided into the following fields:

TABLE 9.1: ELECTRONICS AND PHOTONICS SUB-FIELDS

ELECTRONICS/ PHOTONICS SUB-FIELD	DESCRIPTION
Plastics for electronics and photonics	This references the use of polymer materials in the creation of devices that allow for electronic or photonic properties.
Computers and other information processing devices	Computers with associated peripherals that use electronic and photonic devices to operate - PCs, Laptops, etc.
Electricity Distribution and Control	Electricity distribution and control devices that ensure security of supply, safety of use and regularity of services.
Electrical equipment	A machine, powered by electricity that consists of an enclosure, a variety of electrical components and often a power switch and uses electronic or photonic devices internally for regulation, safety or security. Items include major appliances, microcontrollers etc.
Electronics Valves and Tubes	In electronics, a vacuum tube, electron tube (inside North America), thermionic valve, or just valve (elsewhere); is a device used to amplify, switch, otherwise modify, or create an electrical signal by controlling the movement of electrons in a low-pressure space, often not tubular in form. Many devices called vacuum tubes are filled with low-pressure gas: these are so-called soft valves (or tubes); as distinct from the hard vacuum type, which have the internal gas pressure reduced as far as possible. Almost all depend on the thermal emission of electrons, hence thermion. Vacuum tubes were the critical devices that enabled the development of electronics technology, leading to the development and commercialisation of such technologies as radio broadcasting, television, radar, high fidelity sound reproduction, large telephone networks, modern types of digital computer, and industrial process control. Many of these technologies pre-dated electronics, but it was electronics that made them widespread and practical; analogue computers such as slide-rules have become almost extinct due to electronics. For most purposes, the vacuum tube has been replaced by solid-state semiconductor devices such as transistors and solid-state diodes: for most applications, they are smaller, more efficient, more reliable, and cheaper-either as discrete devices or as integrated circuits. However, tubes are still used in specialised applications: for engineering reasons as in high power radio frequency transmitters, or for their aesthetic appeal in modern audio amplification. Cathode ray tubes are still used as display devices in television sets, video monitors, and oscilloscopes, although they are being replaced at various rates by LCDs and other flat-panel displays. A specialised form of the electron tube, the magnetron, is the source of microwave energy in microwave ovens and some radar systems.
Radio, Television and Communications Equipment (including sound and video recording)	Electronics and photonics communications devices that allow for the transmission of visual or audio signals and their representation in the form they were transmitted in.

ELECTRONICS/ PHOTONICS SUB-FIELD	DESCRIPTION
Instrumentation	Instrumentation is an electrical device placed in the field to provide measurement and/or control capabilities for the system. The simplest measurement instrumentation device is a thermistor. A thermistor is very similar to a typical resistor, except that it greatly varies its resistance depending on its temperature. Therefore this device can easily be used for measurement of temperature in the field. Control instrumentation includes devices such as solenoids, Electrically Operated Valves, breakers, relays, etc. These devices are able to change a field parameter, and provide remote control capabilities. Instrumentation plays a significant role in both gathering information from the field and changing the field parameters, and as such are a key part of control loops.
Process Control	Process control is a statistics and engineering discipline that deals with architectures, mechanisms, and algorithms for controlling the output of a specific process. A commonly used control device called a programmable logic controller, or a PLC, is used to read a set of digital and analog inputs, apply a set of logic statements, and generate a set of analog and digital outputs. Larger more complex systems can be controlled by a Distributed Control System (DCS) or SCADA system. In practice, process control systems can be characterised as one or more of the following forms: Discrete - Found in many manufacturing, motion and packaging applications. Robotic assembly, such as that found in automotive production, can be characterised as discrete process control. Most discrete manufacturing involves the production of discrete pieces of product, such as metal stamping. Batch - Some applications require that specific quantities of raw materials be combined in specific ways for particular durations to produce an intermediate or end result. One example is the production of adhesives and glues, which normally require the mixing of raw materials in a heated vessel for a period of time to form a quantity of end product. Other important examples are the production of food, beverages and medicine. Batch processes are generally used to produce a relatively low to intermediate quantity of product per year (a few pounds to millions of pounds). Continuous - Often, a physical system is represented though variables that are smooth and uninterrupted in time. The control of the water temperature in a heating jacket, for example, is an example of continuous process control. Some important continuous processes are the production of fuels, chemicals and plastics. Continuous processes, in manufacturing, are used to produce very large quantities of product per year (millions to billions of pounds). Applications having elements of discrete, batch and continuous process control are often called hybrid applications.

ELECTRONICS/ PHOTONICS SUB-FIELD	DESCRIPTION
Optical Instruments	An optical instrument either processes light waves to enhance an image for viewing, or analyses light waves (or photons) to determine one of a number of characteristic properties. The first optical instruments were telescopes used for magnification of distant images, and microscopes used for magnifying very tiny images. Another class of optical instrument is used to analyse the properties of light or optical materials. They include: • Interferometer for measuring the interference properies of light waves. • Photometer for measuring light intensity. • Polarimeter for measuring dispersion or rotation of polarised light. • Reflectometer for measuring the reflectivity of a surface or object. • Refractometer for measuring refractive index of various materials. • Spectrometer or monochromator for generating or measuring a portion of the optical spectrum, for the purpose of chemical or material analysis. • Autocollimator which is used to measure angular deflections. • Vertometer which is used to determine refractive power of lenses such as glasses, contact lenses and magnifier lens.
Computers	Computers are machine which manipulate data according to a list of instructions which makes it an ideal example of a data processing system. Computers take numerous physical forms. Personal computers in various forms are icons of the information age and are what most people think of as ‘a computer’. However, the most common form of computer in use today is by far the embedded computer. Embedded computers are small, simple devices that are often used to control other devices - for example, they may be found in machines ranging from fighter aircraft to industrial robots, digital cameras, and even children’s toys.

9.3 PRIVATE SECTOR

The Photonics & Electronics sector in NI comprises of approximately 35 Companies that have a collective turnover of £506m and employ 3,114 people. 23 of these companies have identifiable R&D capabilities and invested £14.1m in R&D in 2005. Over 300 staff within these companies are directly engaged in R&D. The sector is dominated by the sub-fields of 'Manufacture of Radio, Television and Communication Equipment and Apparatus' sub-sector, representing nearly 57% of sector turnover respectively. R&D expenditure as a % of turnover across the sector is 2.8%, with the 'Manufacture of Radio, Television and Communication Equipment and Apparatus' sub-sector representing over 62% of entire sector R&D expenditure. Interestingly, the 'Computers and other Information Processing Equipment' sub-sector invests 169% of its turnover in R&D. Table 9.2 below provides key information on ICT sector.

The private sector in NI is characterised by a small number of large MNCs, with a large number of indigenous SMEs. Indigenous companies are focused on niche sectors e.g. sound compression, ceramic and tantalum capacitors etc., there are a small number of companies working on a diverse range of electronic products, but no real area of specialisation identified within region. Major growth areas in the global electronics market present strong opportunities for NI electronics firms.

Tables 9.3 and 9.4 highlights the leading companies in NI by turnover and R&D expenditure, respectively.

TABLE 9.2: PHOTONICS & ELECTRONICS SECTOR[90] - KEY INFORMATION

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Plastics in Electronics and Photonics	Very small sub-field with only 74 employees and relatively small turnover with little or no R&D.	Only one company in this space, Crossbows Optical (a Signet Armorlite Group Company). They manufacture ophthalmic products and the precision machining and forming of glass using relatively modern technology for the design and development of glass moulds. They use progressive, aspheric and atoric products which are sold within the group and to other casters throughout the world. More recently, investments in development of freeform software for back surface progressive lenses incorporating the patient's prescription, for use in laboratories around the world.	2	4	

90. Source : DETI Statistics 2005

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Computers and other information processing devices	Very small sub-field in NI with little or no real impact and turnover. Technology located here tends to be older security technology. 43 employees and small revenue. However, significant R&D is conducted relevant to revenue.	Controlled Electronics Management Systems and InspecVision are the only companies in this space. CEMS has been acquired by Sensormatic.	2	2	
Electricity Distribution and Control	Very small sub-field with relatively low technology being used. Significant turnover due to agency commercial agreements.	JMG Systems	1	2	
Electrical Equipment	Small based company using electronic scoreboard techniques with no real technology. 18 people involved and high turnover due to international sales.	FSL Electronics	2	2	
Electronic Valves, Tubes and other components	Significant sub-field in a NI context with almost 1,000 employees creating significant revenue. R&D spend is just 1% of revenue indicating no real capability. Technology used is relatively recent in some cases and the exploitation channels exist through foreign sales offices.	Elite Electronic Systems (turnkey electronic components), HIVOLT Capacitors (Capacitors), Power Action Ltd, R F Integration Ltd (RF Integration is a 'fabless' manufacturer of RF/Mixed Signal ASIC's for the Wireless and Broadband Communications Markets. Utilises GaAs, CMOS, SOI and SiGe processes from 'best in class' foundries for optimisation of cost/performance for each ASIC. A large library of IP's allows for design flexibility and fast time-to-market. AVX is another player in this sub-field using passive component devices. Mimix Broadband (formerly Celeritek UK) uses NI for power amplifiers.	3	4	

SUB-FIELD	DESCRIPTION	ANALYSIS	SCIENTIFIC CAPABILITY	EXPLOITATION CAPABILITY	
				ESTABLISHED	EMBRYONIC
Radio, Television and Communications Equipment (including sound and video recording)	Largest sub-field with 1,500 employees and significant turnover. However, there is little R&D work conducted in NI and most of the activities are cost dependent manufacturing or services.	Companies in this sub-field include Audio Processing Technology Ltd. (spin off from QUB with world leading compression capability); ADT Europe (reseller with no real capability); Daewoo Electronics UK[91] (component manufacturing); FJ Telecommunications Europe; Glentronics Ltd. (basic equipment); Nortel, Radiocontact.	3	3	
Instrumentation	This sub-field shows the highest degree of capability. Although only employing 320 people, the R&D ratio is significantly higher than the rest of the sector at almost 10% of turnover. This tends to be driven by Andor.	Companies include Acksen Ltd., Andor Technology PLC., Fibre Optic Installation Services, Infineer Ltd. (smart cards), Mindready solutions, Star Instruments, Taran Systems.	4	3	
Process Control	Relatively small sub-field with no real capability other than installation and agency work.	Companies include Integrated Process Control, MCA Systems, E&I Engineering,	2	2	
Optical Equipment	Smallest sub-field with no real capability.	Companies include United Optical Laboratories.	1	1	

91. Operation in NI has ceased.

TABLE 9.3: LEADING NI PHOTONICS & ELECTRONICS COMPANIES BY TURNOVER[92]

RANK	COMPANY	EMPLOYEES	TURNOVER (£000s)	R&D EXPEND (£000s)
1	AVX Ltd	540	80,216	1,119
2	Nortel Networks[93]	526	69,583	4,315
3	Daewoo Electronics[94]	319	56,716	455
4	E & I Engineering	79	15,627	0
5	Flextronics[95] (UK) Design Services Ltd.	66	15,278	86
6				
7	Elite Electronic Systems	206	13,613	0
8	J.M.G. Systems Ltd.	42	2,994	67
9	United Optical Laboratories	53	2,602	0
10	Crossbows Optical Ltd.	74	2,547	276
TOTAL		**1,905**	**259,176**	**262,354**
As % of Sector		82.0%	77.2%	90.4%

TABLE 9.4: LEADING NI PHOTONICS & ELECTRONICS COMPANIES BY R&D EXPENDITURE[96]

RANK	COMPANY	EMPLOYEES	TURNOVER (£000s)	R&D EXPEND (£000s)
1	Nortel Networks	526	69,583	4,315
2	AVX Ltd	540	80,216	1,119
3	Andor Technolgy Plc.	118	677	1,016
4	Celeritek UK Ltd	6	696	598
5	Daewoo Electronics	319	56,716	455
6	Controlled Electronic Management Systems Ltd.	42	216	390
7	Audio Processing Technology Ltd	19	2,195	380
8	Infineer Ltd	29	1,987	343
9	Crossbows Optical Ltd.	74	2,547	276
10	Marturion Ltd.	3	235	135
TOTAL		**1,673**	**214,833**	**8,892**
As % of Sector		67.7%	74.0%	91.1%

92. Source: DETI Statistics 2005.
93. Nortel Networks is no longer present in NI.
94. Daewoo Electronics no longer manufacture in NI, however they were included in the 2005 numbers and therefore are reflected in this database.
95. Flexitronics has ceased operations in Oct 2007 during the completion of this report. This is included for completeness.
96. Source: DETI Statistics 2005

The key information to note about the top 10 Photonics & Electronics companies in NI by turnover is that:

- They represent 82% of full time employment in the sector;
- They represent 77.2% of sector turnover;
- The top 10 companies represent over 90% of sector R&D expenditure; and
- Seven of the top 10 are indigenous companies.

In summary, the top 10 Photonics & Electronics companies generate the vast majority of turnover and employment in the sector, as well as nearly three-quarters of R&D expenditure.

Table 9.4 illustrates the contrast in statistics when R&D expenditure is considered.

The key information to note about the top 10 Photonics & Electronics companies in NI by R&D expenditure is that:

- They represent 91.1% of sector R&D expenditure;
- They are also some of the biggest companies in the sector by turnover, representing 74% of sector turnover, and 67.7% of sector employment; and
- Seven of the 10 companies are indigenous.

In summary, the NI Photonics & Electronics sector has a large number of indigenous companies, with many making significant investments in R&D in order to achieve growth in their respective markets.

Three of the 35 companies in the sector are spending over 100% of their turnover on R&D, with another two companies spending over 50% of their turnover on R&D. All except one of these companies are indigenous, which reflects the significant level of investment in R&D required by local companies to make an impact on their respective markets.

KEY COMPANIES

Based on the information provided above, a number of companies have been selected as representative of the some of key Photonics & Electronics companies in NI. A summary of these companies is provided in the following sub-sections.

Audio Processing Technology
APT was spun out of QUB in 1990 with the help of the QUBSBI. It specialises in developing compression technology for audio transfer technologies over satellite, ISDN and Digital media. The company has grown at a compound rate of about 45% over the last three years, and employs 40 staff. Most of their work is done in-house, though they use contractors from time to time for specialist work. They have to work with contractors overseas as the capability that they require does not exist in NI.

AVX Ltd.
AVX is a large scale electronic components manufacturer. Its Coleraine plant is one of only five R&D facilities globally, and focuses on the production of integrated passive networks. The company has also built the first line, outside Japan (location of its parent company), for a thin tape technology that will be used in the production of small, high-value capacitors.

Elite Electronic Systems
Elite offers Contract Electronic Manufacturing (CEM) services using their state of the art facilities. Its assembly capabilities include PCB, conventional and surface mount; wiring harnesses, fibre optic assemblies, electromechanical and complete systems build. These capabilities include turnkey procurement, manufacture, inspection and full test services.

Andor Technologies
Andor is a significant company in this sector, with its main activities being the development and manufacture of high performance digital cameras. It also develops solutions for light measurement problems. Andor employs over 160 staff and distribute our products to customers in over 40 countries.

9.4 ACADEMIC SECTOR

TABLE 9.5: SUMMARY OF ELECTRONICS AND PHOTONICS CAPABILITY IN THE HE SECTOR

NO	INSTITUTION/GROUP	LOCATION
1	NITC (Northern Ireland Technology Centre)	QUB
5	ECIT: Electronics Communications and Information Technology	QUB
22	Astrophysics Research Centre	QUB
28	Theoretical & Computational Physics	QUB

TABLE 9.6: SUMMARY OF ICT CAPABILITY IN THE FE SECTOR

SUBJECT CODE OF COURSE	TOTAL	LOCATION
Electrical Engineering	488	BIFHE, Castlereagh, Causeway, North East, Omagh
Electrical & Electronic Engineering	484	BIFHE, Causeway, East Antrim, East Tyrone, Fermanagh, Lisburn, North Down & Ards, North East, North West, Omagh, Upper Bann
Electrical Technicians	38	BIFHE, East Antrimt
Others in Electrical Engineering	398	BIFHE, Castlereagh, Causeway, East Down, East Tyrone, Fermanagh, Limavady, Lisburn, North East, North West
Electronic Engineering/Electronics	91	BIFHE, North East, North West, Omagh
Electrical & Systems Engineering	280	Castlereagh, Causeway, East Antrim, North West, Omagh
Electronics & Computer Technology	82	BIFHE, East Antrim
Communications Engineering	75	BIFHE, North Down & Ards
Electronic Servicing	100	Armagh, North West
Others in Electronic Engineering	58	BIFHE
Sum	**2,094**	

With regards to Electronics and Photonics capability in the FE sector, the table lists the applicable courses currently available and shows that there are just over 2,000 people currently enrolled in Electrical or Electronic Engineering.

9.5 OVERALL SECTOR CAPABILITY MAPPING & CONCLUSIONS

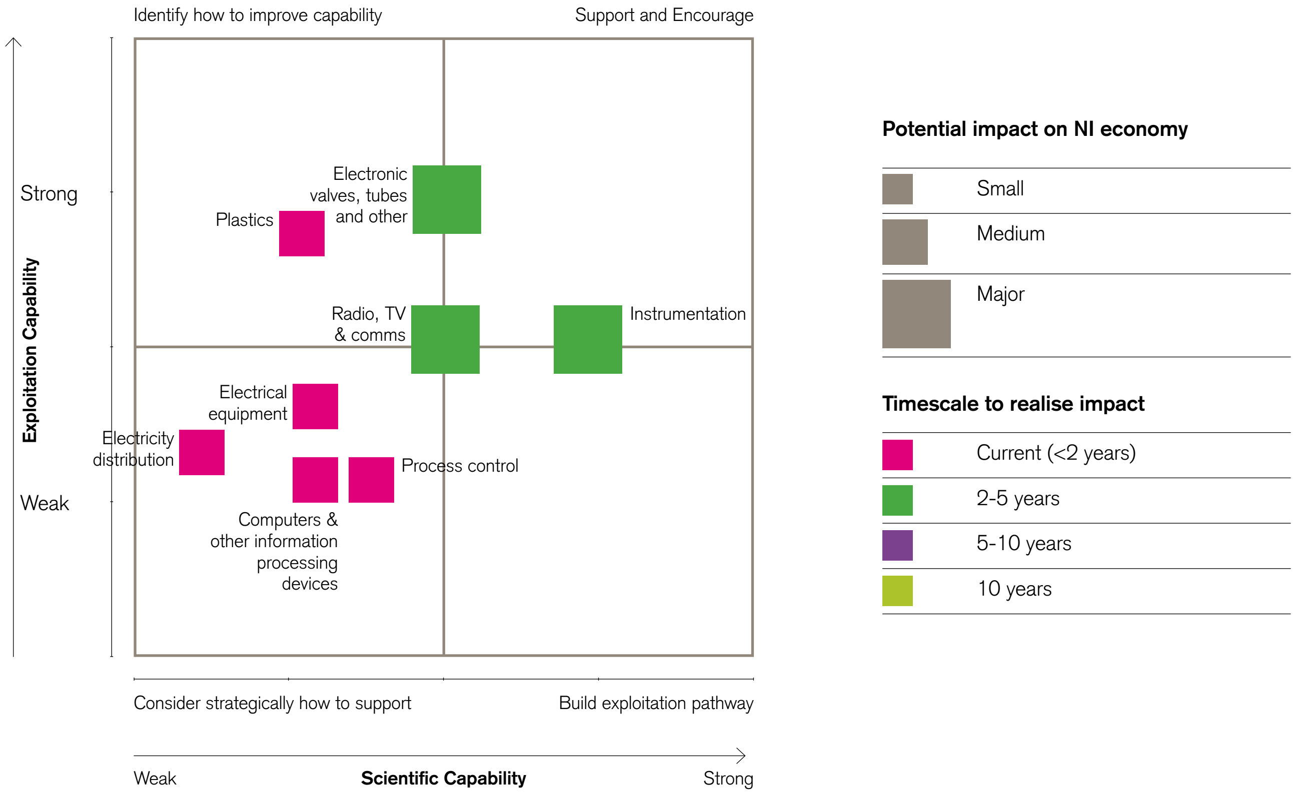
This sector, as defined in this report, is the weakest within NI. There are few real strengths within the sector although a number of indigenous companies such as Andor, Audio Processing Technology and AVX etc are demonstrating significant technology leadership developing exploitation pathways. There is not much depth within the sector i.e. the top ten companies in employment and R&D spend are primarily the entire sector.

Figure 9.1 provides a summary of the exploitation and scientific capability.

In summary, it is worth noting that:

- Developments in this sector are dependent on Advanced Materials capability;
- The capability within the sector itself tends to underpin the activities in sectors such as ICT, Life Sciences, Advanced Manufacturing and as such enable channels to market in themselves;
- There is a broad mix of indigenous and FDI companies in NI and the upper end of scientific capability is being driven by indigenous companies, whereas the upper end of exploitation capability is being driven by FDI companies.
- There remains relatively little supply chain within the market to advance this sector within NI as the capability typically finds markets through other sectors as defined in this report.

FIGURE 9.1: ELECTRONICS AND PHOTONICS CAPABILITY



BENCHMARKING

10

10.1 INTRODUCTION

In order to gauge the current position of NI with regard to its technology capability, it is important to benchmark it against other regions in the UK and the rest of Europe. This chapter evaluates NI's position in relation to these other regions across a number of measures. There is a limited amount of quantitative data available at the regional level (which is what NI is considered as), and thus extrapolations of data are used given these constraints.

Technology indicators measure capability at an aggregate level to allow tracking of changes over time, to inform policy making and also to ensure that these indicators actually drive economic development[97]. In the past ten years, all developed economies have become interested in tracking their capability for technology and innovations. There is significant development in this area with the development of the European Innovation Scoreboard[98], the UNIDO (United Nations Industrial Development Scoreboard), OECD and UK regional comparators.

Technology Capabilities are the results of knowledge produced by scientific and applied research that culminated in new processes, designs, products and consumer goods. From all the indicators of technology measurement, it is clear that this is a complex process but it is worthwhile noting that the bottom line of capability exists in economic matters such as employment, exports and productivity.

In comparing NI, it is important to look at two input indicators for comparison and these are:

- **Regional orientation**
  Historically, NI is not orientated towards high technology intensive industries and capabilities. It possesses a very fine education structure which indicates a high degree of competitiveness however; this rarely makes its way into the exploitation sectors thereby losing economic impact;

- **Technological scoring**
  NI has clearly inherited some advantages from the overall UK position on Technology. However, there are particular characteristics is NI which are preventing the exploitation of much of the capability in the area.

97. OCED 2000/2002
98. www.cordis.lu/itt

10.2 REGIONAL ORIENTATION

High Tech Employment
As figure 10.1 below indicates, the level of high tech employment (i.e. manufacturing and knowledge intensive high tech sectors) in NI is low relative to a selection of other UK and European regions, even when differences in population level are accounted for. When compared to Wales and Scotland, NI has a lower employment level in high tech, and it has also gradually decreased over the last few years.

The following sections highlight some of the probable reasons for employment in high tech areas being relatively low. These reasons mainly relate to the level of investment in R&D and competitiveness, as well as skills and education.

FIGURE 10.1 HIGH TECH EMPLOYMENT

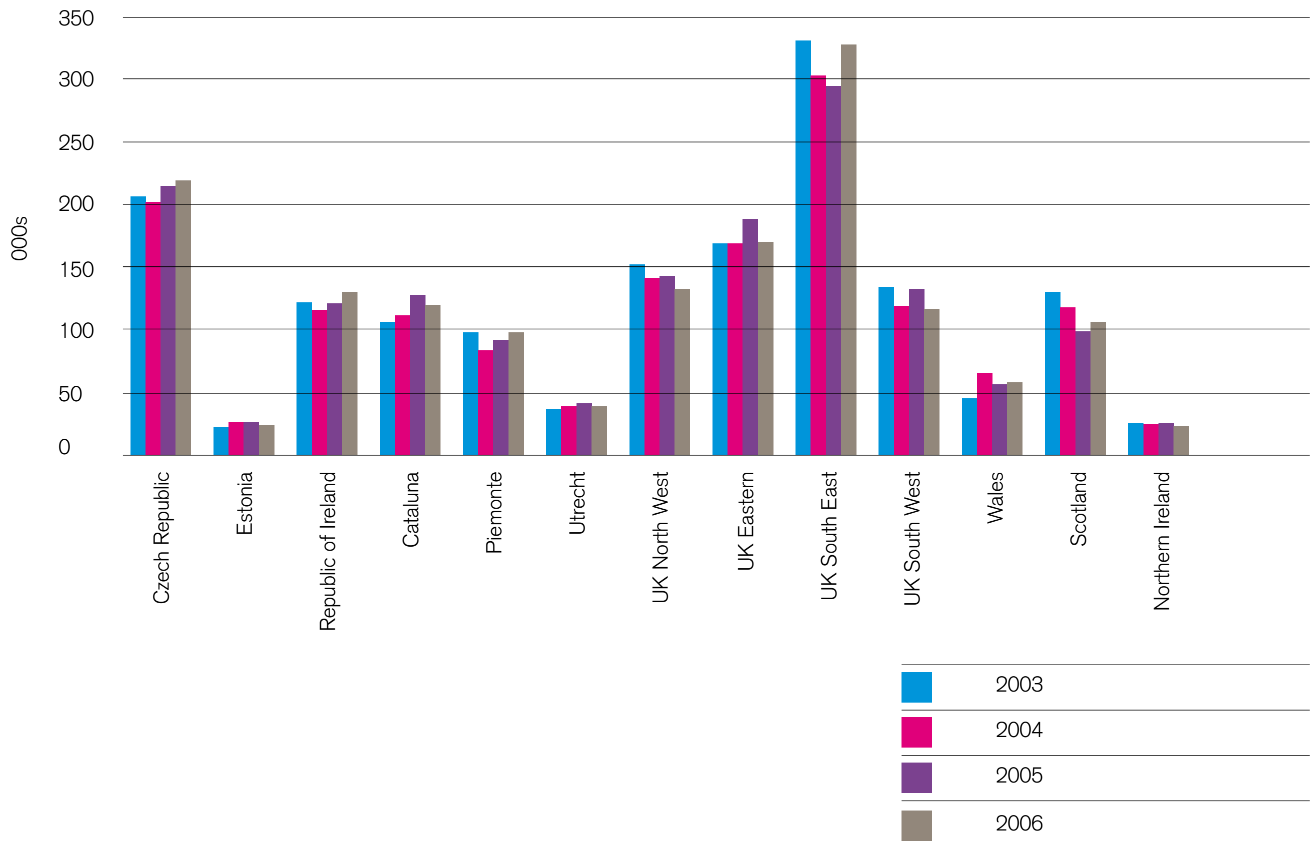
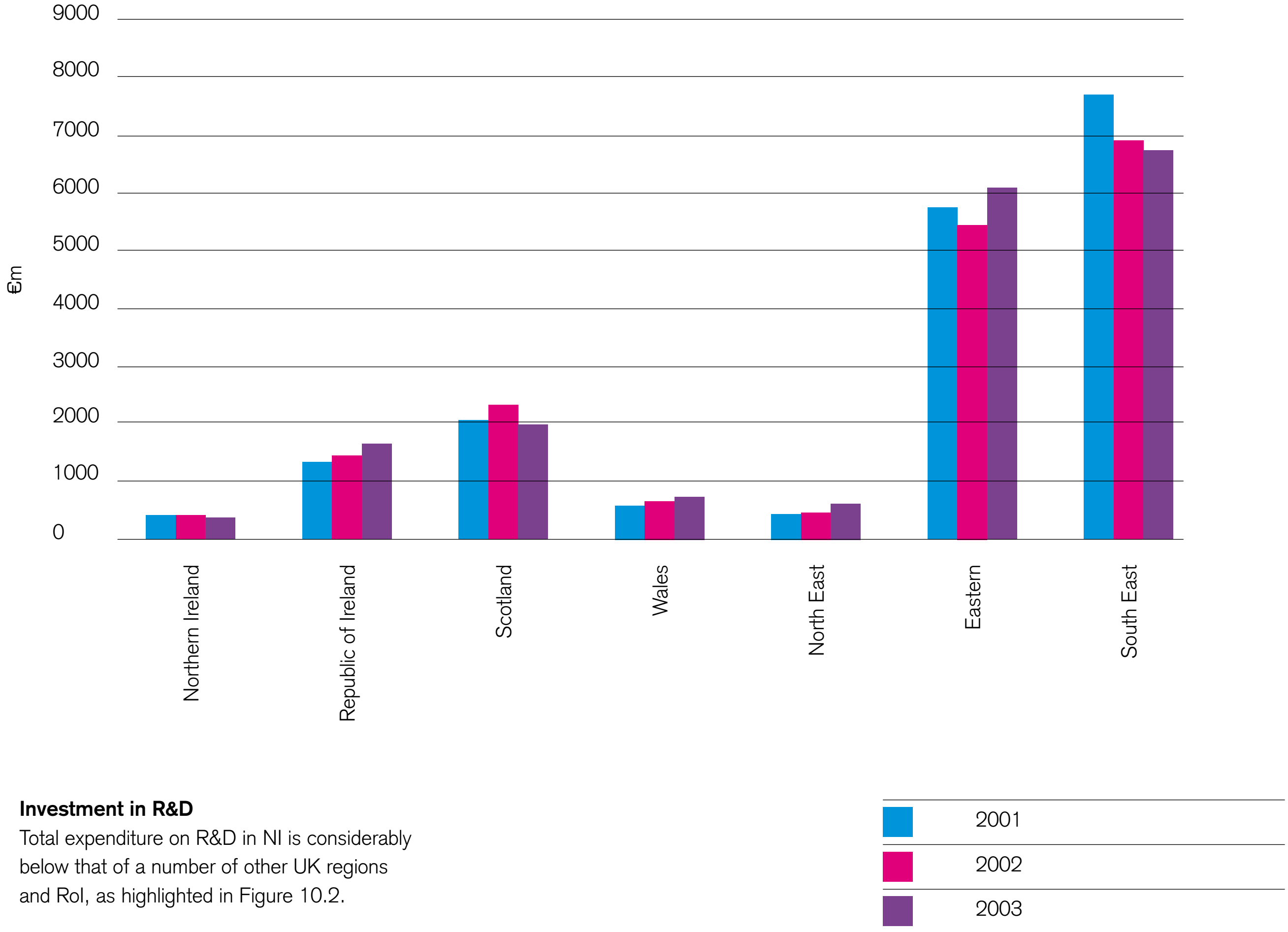


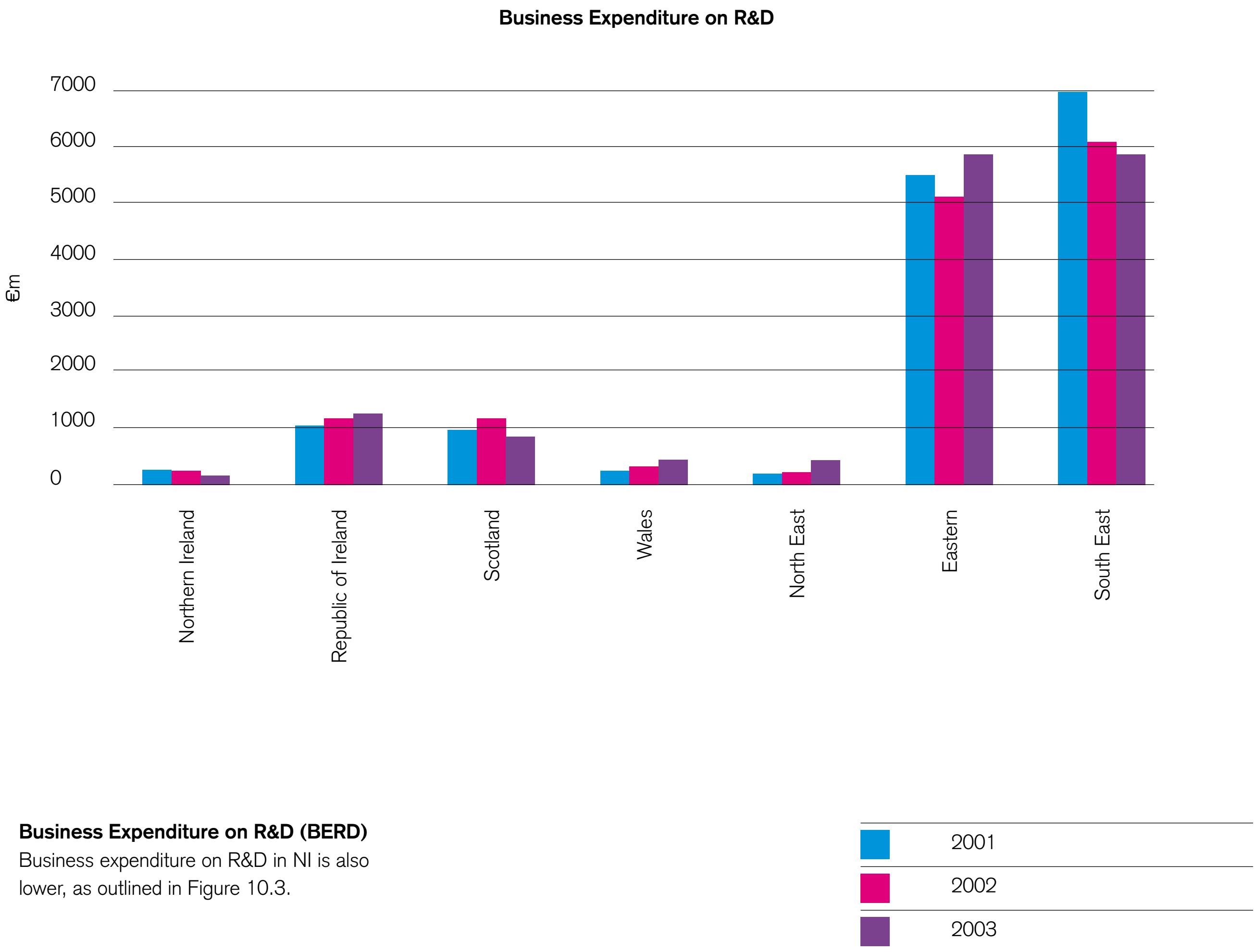
FIGURE 10.2: TOTAL EXPENDITURE ON R&D BY UK REGION



Investment in R&D

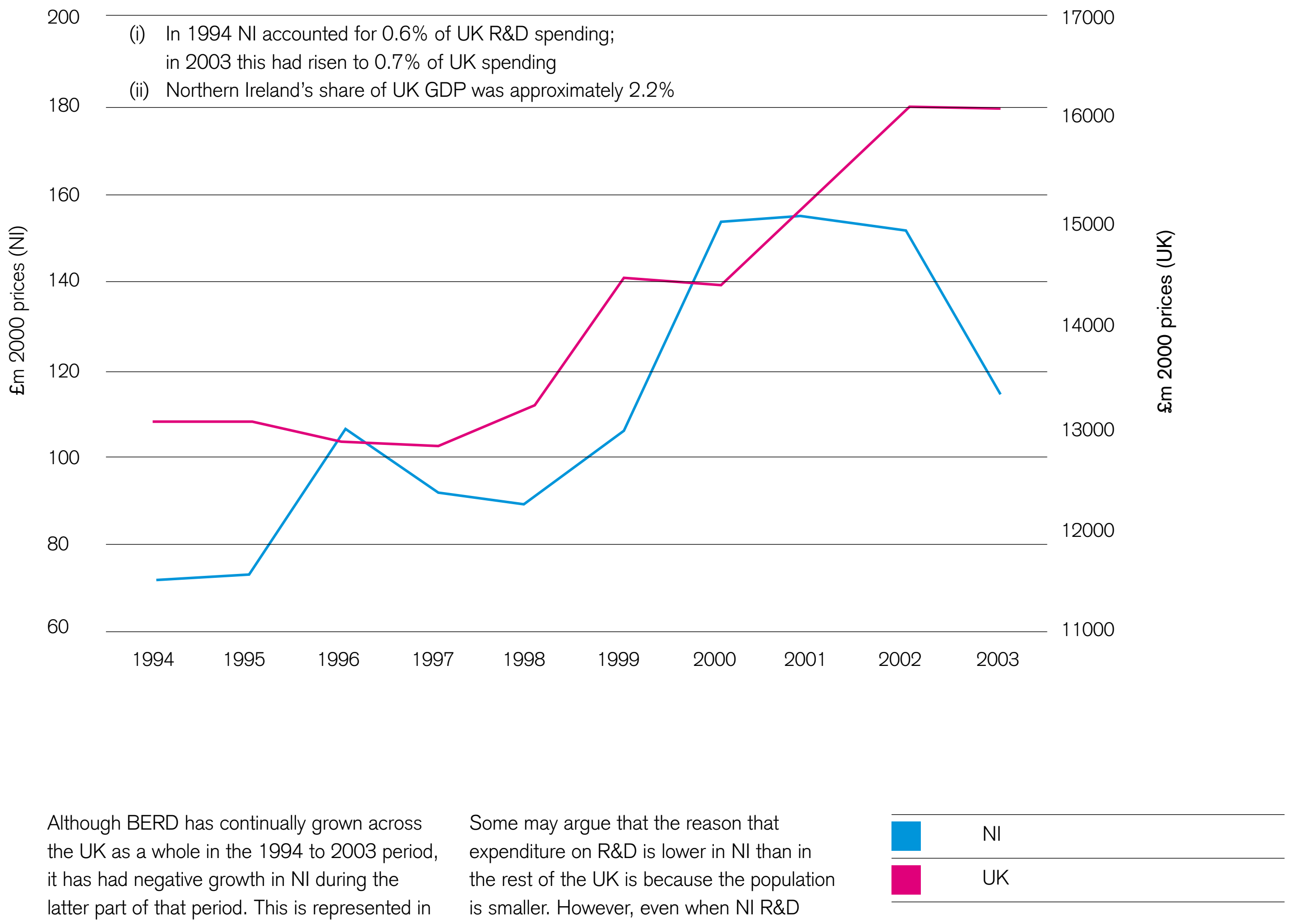
Total expenditure on R&D in NI is considerably below that of a number of other UK regions and RoI, as highlighted in Figure 10.2.

FIGURE 10.3: BERD BY UK REGION



Business Expenditure on R&D (BERD)
Business expenditure on R&D in NI is also lower, as outlined in Figure 10.3.

FIGURE 10.4: REAL SPENDING ON BUSINESS R&D (ALL SECTORS) IN NI & UK, 1994 TO 2003



Although BERD has continually grown across the UK as a whole in the 1994 to 2003 period, it has had negative growth in NI during the latter part of that period. This is represented in Figure 10.4.

Some may argue that the reason that expenditure on R&D is lower in NI than in the rest of the UK is because the population is smaller. However, even when NI R&D expenditure as % of GDP is considered, it is still among the lowest in the UK, as illustrated in Figure 10.5.

Source: NI BERD (unpublished); Business Monitor MA14 (various editions); UK Regional Accounts (2004).
Includes both intramural and extramural R&D.

FIGURE 10.5: REGIONAL R&D EXPENDITURE AS % OF GDP (2003)

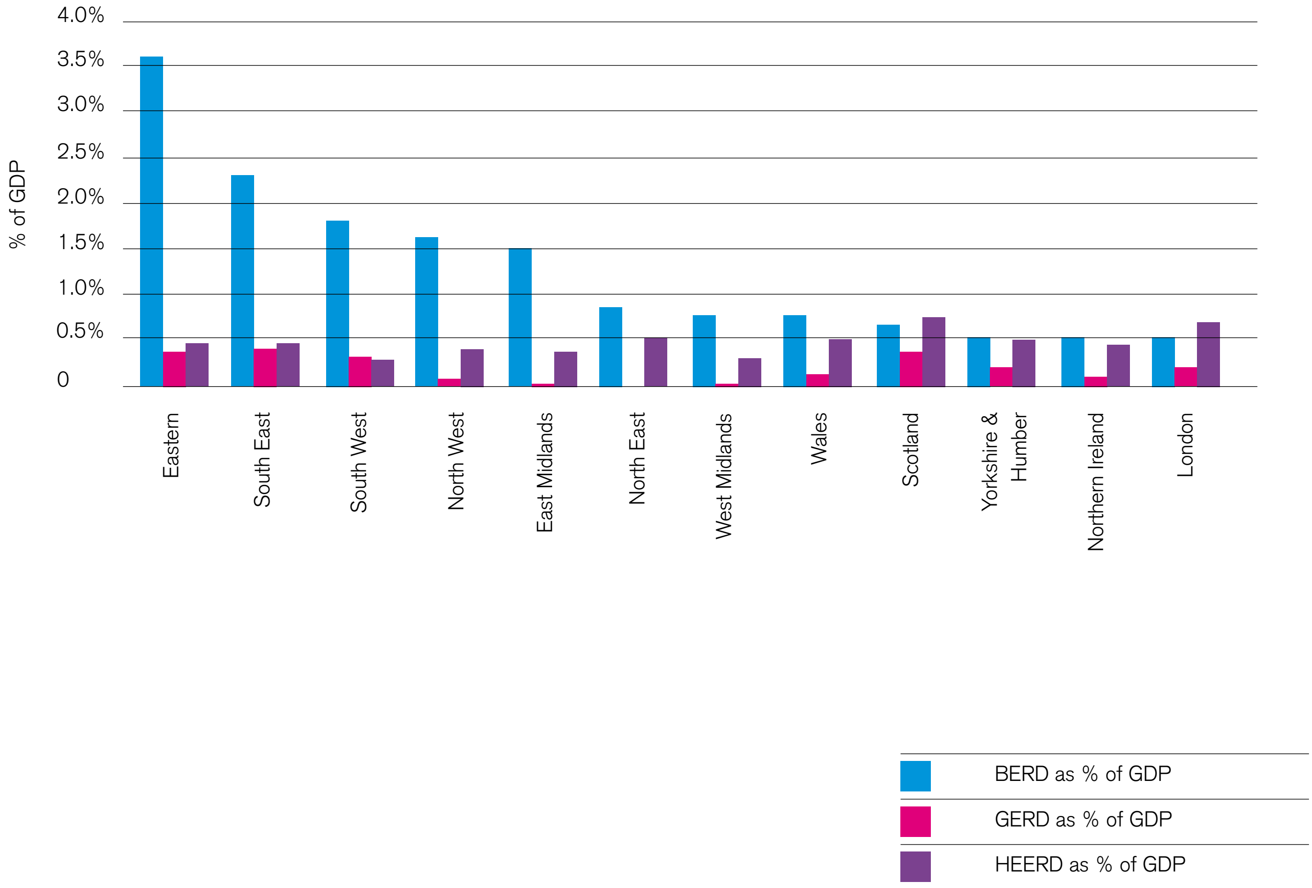
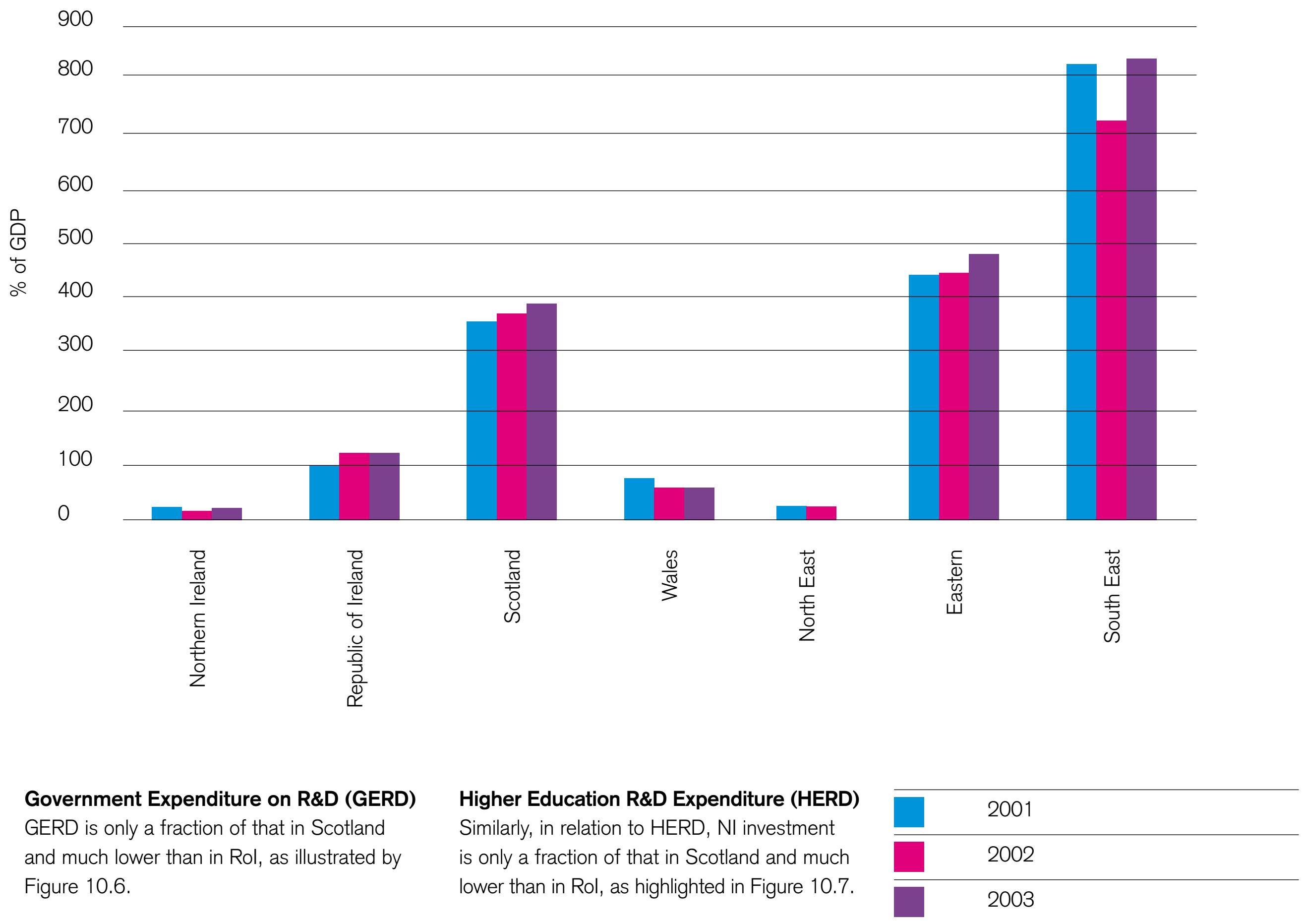


FIGURE 10.6: GERD ACROSS UK REGIONS



Government Expenditure on R&D (GERD)
GERD is only a fraction of that in Scotland and much lower than in RoI, as illustrated by Figure 10.6.

Higher Education R&D Expenditure (HERD)
Similarly, in relation to HERD, NI investment is only a fraction of that in Scotland and much lower than in RoI, as highlighted in Figure 10.7.

FIGURE 10.7: HERD ACROSS UK REGIONS

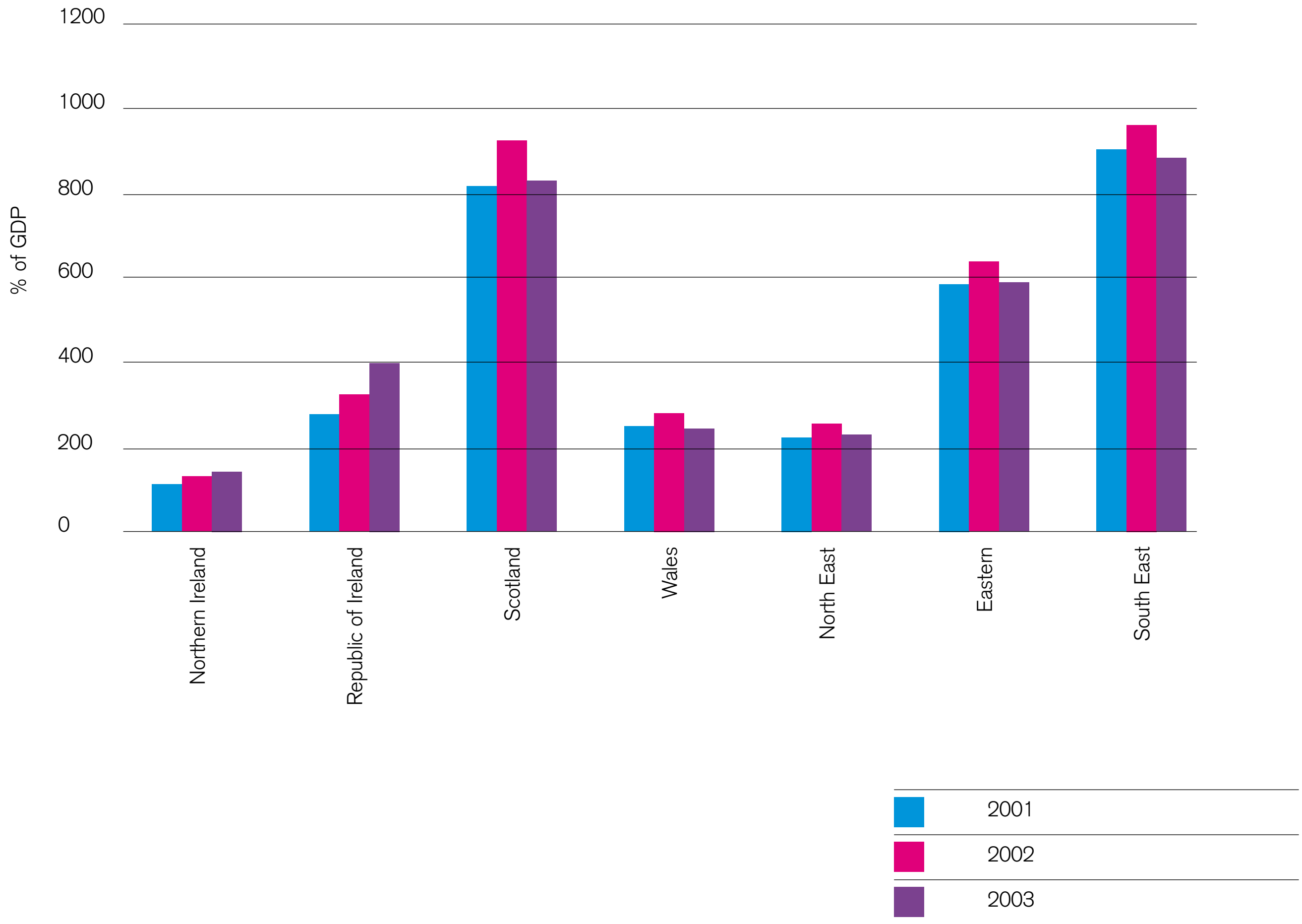
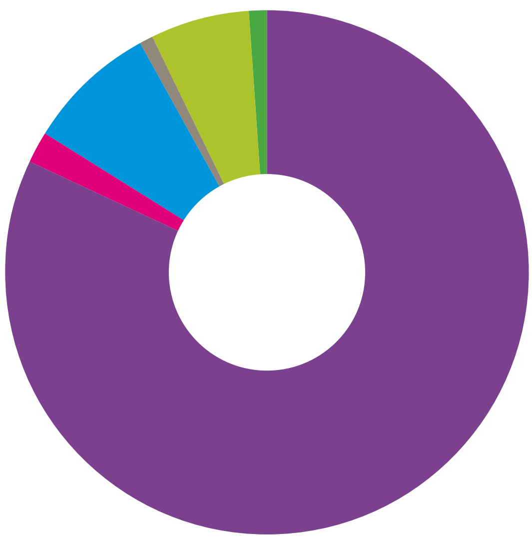


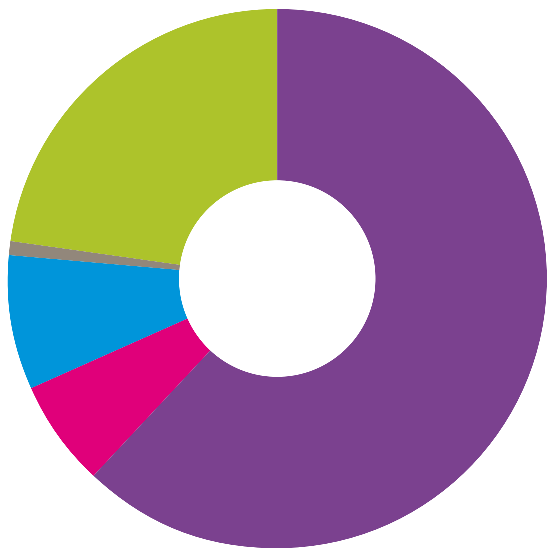
FIGURE 10.8: SOURCES OF FUNDS FOR BUSINESS R&D: NORTHERN IRELAND, UK AND REPUBLIC OF IRELAND (AVERAGE FOR 2001-2003)

NORTHERN IRELAND



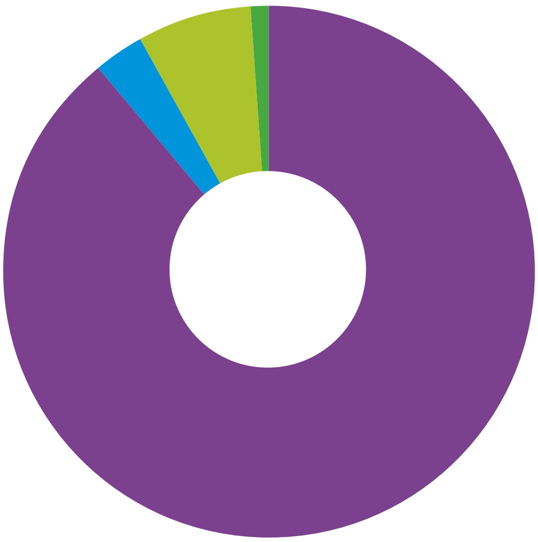
	83% Own funds
	2% Other indigenous firms
	8% Government grants
	1% EC grants
	5% Other foreign
	1% Other national

UNITED KINGDOM



	58% Own funds
	7% Other indigenous firms
	9% Government grants
	1% EC grants
	25% Other foreign

REPUBLIC OF IRELAND (2001 & 2003 ONLY)



	89% Own funds
	3% Government grants
	7% Other foreign
	1% Other national

Private R&D Funding
As indicated in figure 10.8 below, NI has a very low level of overseas funding for R&D compared to the rest of the UK, though it has a similar level to RoI.

TABLE 10.1: UK COMPETITIVENESS INDEX

	INPUTS												OUTCOMES	
	Innovation		Investment		Skills/Education		Enterprise		Business Environment		Economic Infrastructure		Macroeconomic Outcomes	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Baden - Wurtiemburg	200.1	2	97.3	3	104.4	8	208.0	1	115.0	2	128	2	101.5	4
Eastern	207.6	1	80.2	7	106.8	6	74.3	6	91.0	6	104	7	98.3	5
Emilia - Romagna	49.1	7	118.0	2	78.3	11	138.8	4	104.3	4	126	3	113.4	1
Nord-Pas-de-Calais	37.2	11	78.8	9	99.0	9	39.6	10	106.7	3	120	4	93.5	8
Nordrhein Westfalen	89.2	4	93.2	4	98.3	10	206.0	2	94.7	5	187	1	95.8	6
North East	45.9	8	75.9	10	106.5	7	39.5	11	86.5	9	106	6	89.7	10
Northern Ireland	56.0	6	85.3	6	107.7	5	48.7	9	76.3	11	83	11	88.6	11
ROI	40.2	10	142.8	1	108.4	4	156.2	5	180.6	1	110	5	112.4	2
Scotland	79.1	5	79.9	8	121.9	1	51.3	7	87.9	8	93	10	93.6	7
South East	163.1	3	92.3	5	118.2	2	81.8	5	88.9	7	104	7	103.5	3
Wales	45.8	9	69.3	11	110.8	3	51.2	8	83.5	10	95	9	92.0	9
EU15	100.0	-	100.0	-	100.0	-	100.0	-	100.0	-	100.0	-	100.0	-

Competitiveness and Education

Despite the relative low use of technology in NI and although it ranks last out of the sample of UK & EU regions on competitiveness, it ranks 5th on the Skills and Education Index. Tables 10.1 and 10.2 highlight this statistic.

As can been observed in the tables, competitiveness is measured across a number of key variables (e.g. innovation, investment, skills/education etc.), and hence it is a reasonably thorough indication of competitiveness.

Given NI's low ranking in the overall competitiveness index and reasonable score in the skills/education sub-index, it might imply that high quality skills are not translating into better competitiveness. The flight of top graduates from NI to other countries may be a reason for this, among others.

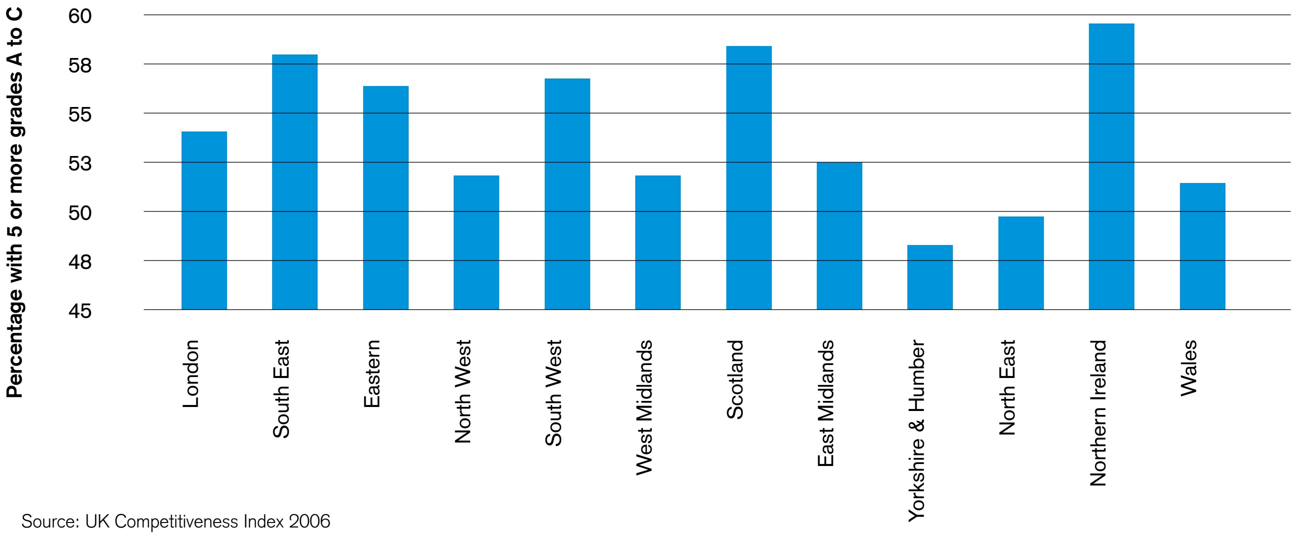
Source: ERINI, The Measurement and Benchmarking of the Competitiveness of Northern Ireland (Oct 2006)

TABLE 10.2: SKILLS/EDUCATION SUB-INDEX

INDICATOR	% OF THE ECONOMICALLY ACTIVE POPULATION WITH LOW LEVEL QUALIFICATIONS		% OF THE ECONOMICALLY ACTIVE POPULATION WITH MEDIUM LEVEL QUALIFICATIONS		% OF THE ECONOMICALLY ACTIVE POPULATION WITH HIGH LEVEL QUALIFICATIONS		SKILLS/ EDUCATION INDEX	
Year	2003		2003		2003		2003	
Source	Eurostat		Eurostat		Eurostat		Eurostat	
Region	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Baden - Wurtiemburg	67.7	4	113.2	8	106.0	7	104.4	8
Eastern	41.6	9	126.9	2	107.6	6	106.8	6
Emilia - Romagna	150.6	1	94.7	10	58.1	11	78.3	11
Nord-Pas-de-Calais	114.2	2	97.0	9	97.5	9	99.0	9
Nordrhein Westfalen	63.1	5	124.7	3	91.0	10	98.3	10
North East	42.4	8	130.0	1	105.5	8	106.5	7
Northern Ireland	61.2	6	118.1	6	110.2	5	107.7	5
ROI	103.7	3	85.7	11	120.5	3	108.4	4
Scotland	41.0	10	113.4	7	139.6	1	121.9	1
South East	30.5	11	121.8	4	131.0	2	118.2	2
Wales	45.0	7	121.0	5	116.7	4	110.8	3
EU15	100.0	-	100.0	-	100.0	-	100.0	-

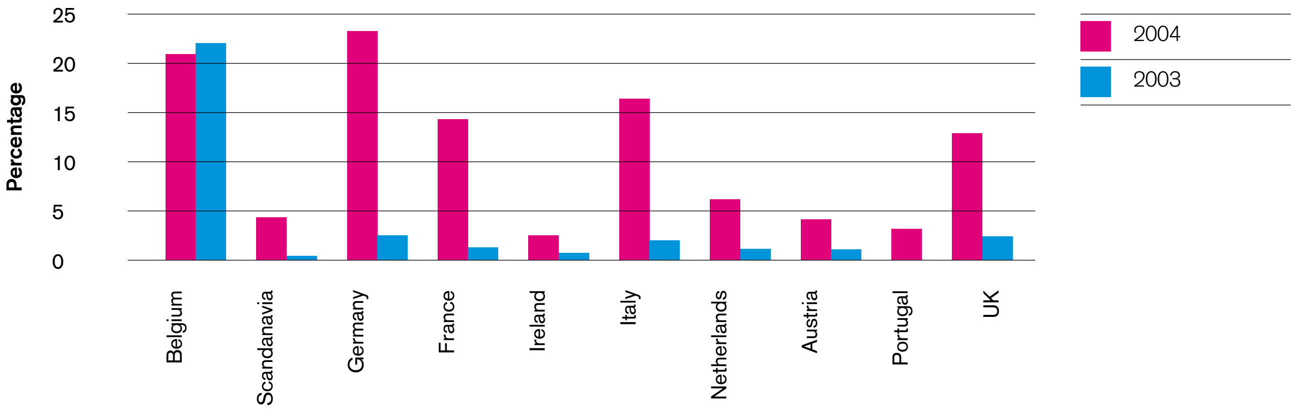
Another interesting fact (along the same lines) is that although NI has the best GCSE results in the UK, it has one of the lowest proportions of knowledge-based businesses in the UK. This is highlighted in figures 10.9 and 10.10.

FIGURE 10.9: REGIONAL GCSE RESULTS (2004)



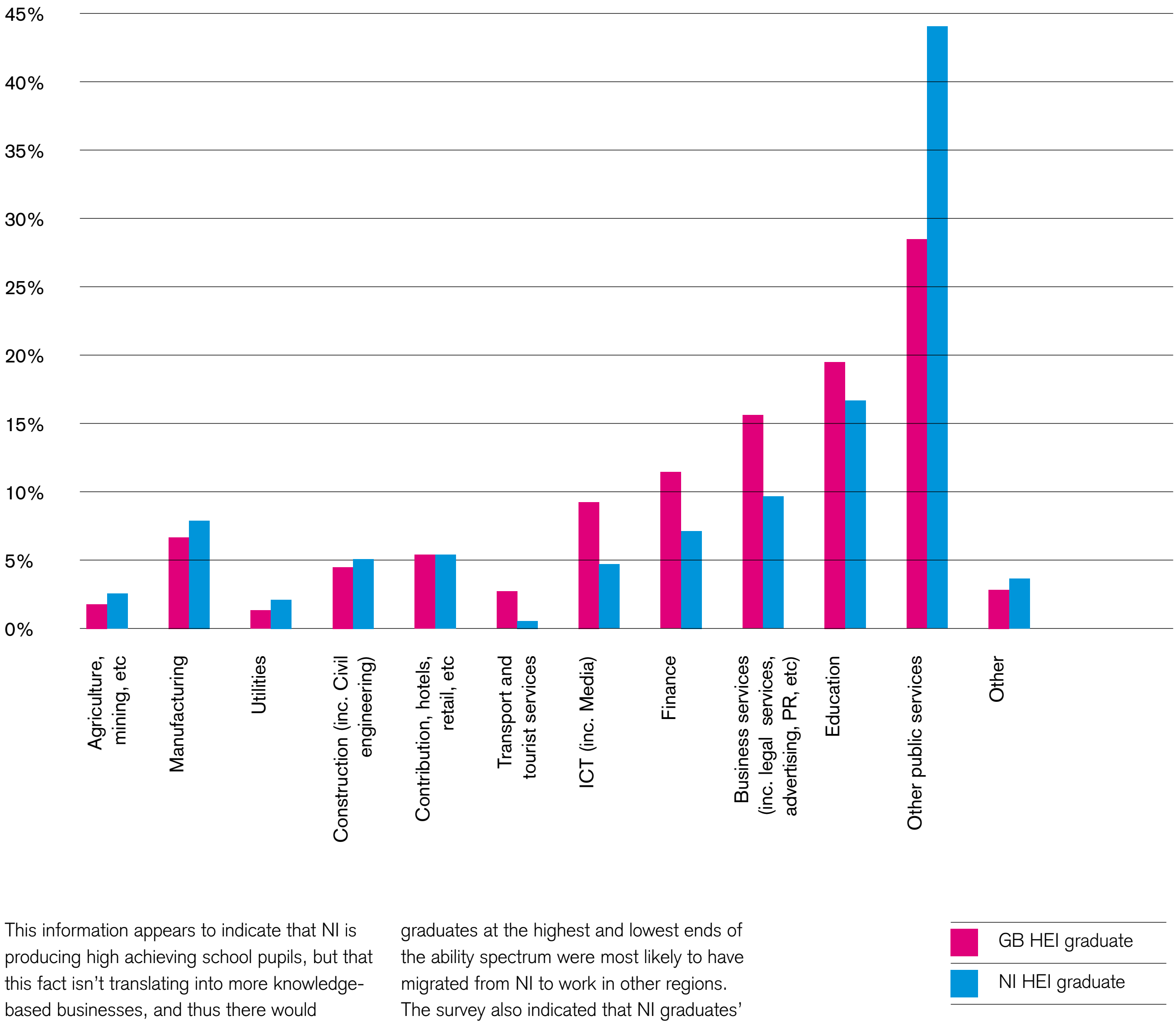
Source: UK Competitiveness Index 2006

FIGURE 10.10: REGIONAL PROPORTION OF KNOWLEDGE-BASED BUSINESSES



Source: UK Competitiveness Index 2006

FIGURE 10.11: SECTOR OF EMPLOYMENT, COMPARING NI HEI GRADUATES AND OTHERS



This information appears to indicate that NI is producing high achieving school pupils, but that this fact isn't translating into more knowledge-based businesses, and thus there would seem to be an issue in harnessing the talent that is developed at school level. A further indication of this is the October 2005 survey by DEL[99] where approximately 15% of 1999 graduates from NI HEIs left NI immediately after graduation. This survey highlighted that graduates at the highest and lowest ends of the ability spectrum were most likely to have migrated from NI to work in other regions. The survey also indicated that NI graduates' earnings are 12-15% below that of the rest of the UK, which would suggest that this is a key reason for the flight of graduates. Figure 10.11 outlines the areas of employment that NI 1999 graduates went into compared with the rest of the UK.

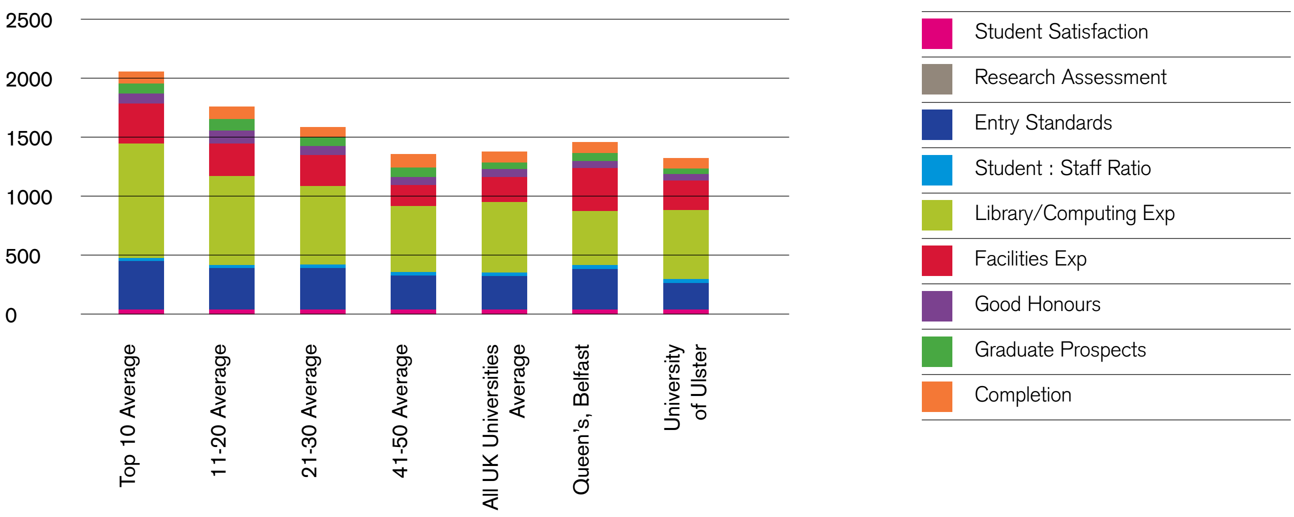
99. 'Northern Ireland's graduates: the classes of '95 and '99'

It's interesting to note that in the ICT sector GB had a significantly higher percentage of graduates than NI, with the opposite being the case with regard to the public sector.

When NI's top 3rd level Educational institutions are rated in the UK context, their performance is moderate as highlighted in the latest UK University league table[100] in figure 10.12.

Although Queen's and University of Ulster are ranked 32nd and 51st overall respectively, they are still only around the UK average and well behind the average for the top 10 Universities. The league table also highlights the fact that Queen's scores poorly with regard to expenditure on Library/Computing compared to the overall average spend of UK Universities. A word of caution: this is a single year snapshot. Items such as major expenditure tend to vary considerably across years though other indicators tend to be relatively constant over considerable periods.

FIGURE 10.12: UK UNIVERSITIES - 2007 LEAGUE TABLE



Source: The Times

100. Source: The Times

10.3 TECHNOLOGICAL FACTORS

There are a number of global comparisons that are relevant to technology capabilities, though all of these are at the country level. Therefore, the data are only provided at a UK level rather than an NI level. In order to develop an NI perspective, we have adjusted the scorings based on other UK benchmarking in NI. This adapts the UK scoring and this then serves to provide a good indication of the performance of many of NI's competitor countries (e.g. Rep. of Ireland, India, Estonia, China etc.) To complete this exercise, we have taken the World Economic Competitiveness breakdown and factored the local NI perspective in terms of the overall UK scoring.

Network Readiness Score
This is an indication of countries propensities and preparation in benefiting from and participating in ICT advancements (i.e. the ability to leverage ICT effectively for improved global competitiveness). It measures the level of ICT development of nations based on a large number of relevant variables. It consists of three main areas capturing:

1. Environment - assesses the degree to which the environment of a country is conducive to the development and use of technology by examining three features:
   - Market: examines the openness of the general business environment for technology developments, taking into account the presence of appropriate capital sources, the degree of business sophistication and innovation potential, and the ease of doing business as well as the intensity of local competition.
   - Political & Regualtory: examines the general efficiency and fairness of public institutions, the legal framework, including specific laws and the extent of protection of IP, and the quality of competition in the sector.
   - Infrastructure: assesses the existence of infrastructure including quality of scientific research institutions, the availability of scientists and engineers and the degree of ICT penetration.

2. Readiness - assesses the capability of citizens, business and government to leverage the potential of technology by examining three factors:
   - Individual readiness: assesses the extent to which citizens within a country are disposed to using technology taking into account the presence of appropriate skills combined with the extent of access to ICT.
   - Business Readiness: examines the readiness of companies to incorporate technology fully into operations and businesses by assessing the presence of trained labour, company spending on R&D and university collaborative R&D, affordability of technology for business and the level of technology imports.
   - Government Readiness: measures the prioritisation of technology by government and the extent to which the government has a clear vision on promoting ICT use and penetration as well as levels of e-government.

With respect to the technological readiness measure from the WEF Competitiveness report, it measures the agility with which an economy adopts existing technologies to enhance the productivity of its industries. To do so, it measures the availability of ICTs and other technologies in the economy as well as the aggressiveness of firms in adopting new technologies from home or abroad (FDI).

NI is performing to a UK national average in this regard; however that average is trailing the leading nations in the work – typically the Nordics and the USA. The gap in this instance is not significantly different however and is something that can be adjusted over time. This chart needs to be seen in the context of existing developments and the competitiveness that these present.

Market Environment Factors
As described above, Market Environment Factors look into critical areas of the 'ecosystem' of technology capability – venture capital availability, taxation, technological readiness to absorb innovations, the intensity of local competition and a relatively subjective judgement on the state of the cluster development. There is a limited supply of VC within NI (much less than available in the UK), whilst the taxation issues remains similar to that in the UK. The key issues in this index for NI relates to:

- Technological Readiness:
  This is measured as the ability of businesses to absorb technology into there operations improving products and competitiveness. NI shows fine exemplars of this however the overall message is one of fragmented operations which undermine the overall capability;
- The Intensity of local competition:
  NI has a small and relatively uncomplicated local market. The issues this raises is that competition does not drive improved performance. There is no key demand which drives excellence and the only form of this can be achieved either through collaboration or through export markets.
- The state of cluster development within NI:
  NI is at the embryonic level of forming clusters in Life Sciences, ICT, Advanced Manufacturing etc. Clusters enable companies to 'punch above their weight' and in NI the fragmentation of the various sectors does not allow for this to happen. There are instances where the expression 'cluster' is used in NI however this is not appropriate as there are few characteristics of clusters at this point in time.

FIGURE 10.13: NETWORK READINESS INDEX

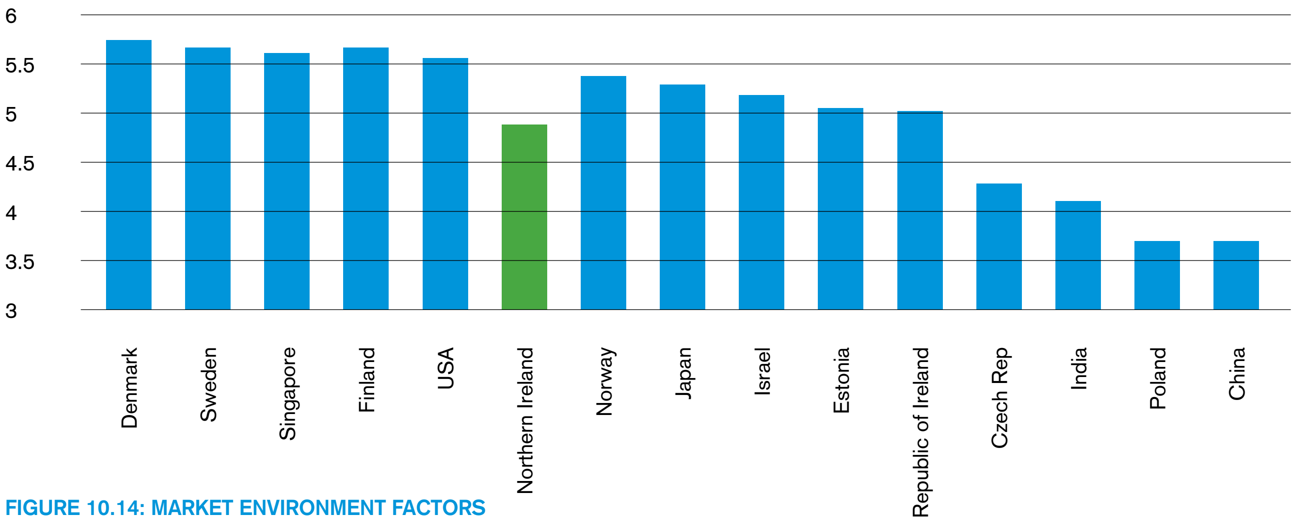


FIGURE 10.14: MARKET ENVIRONMENT FACTORS

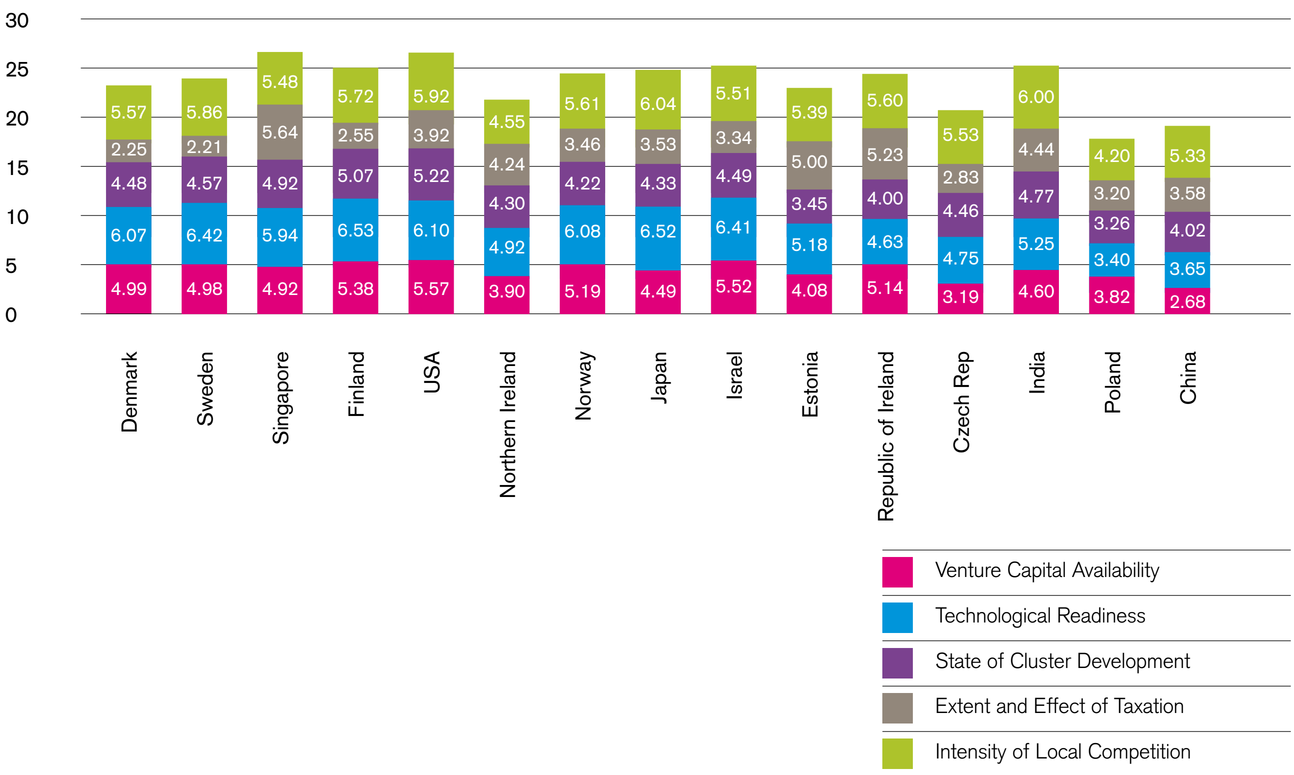
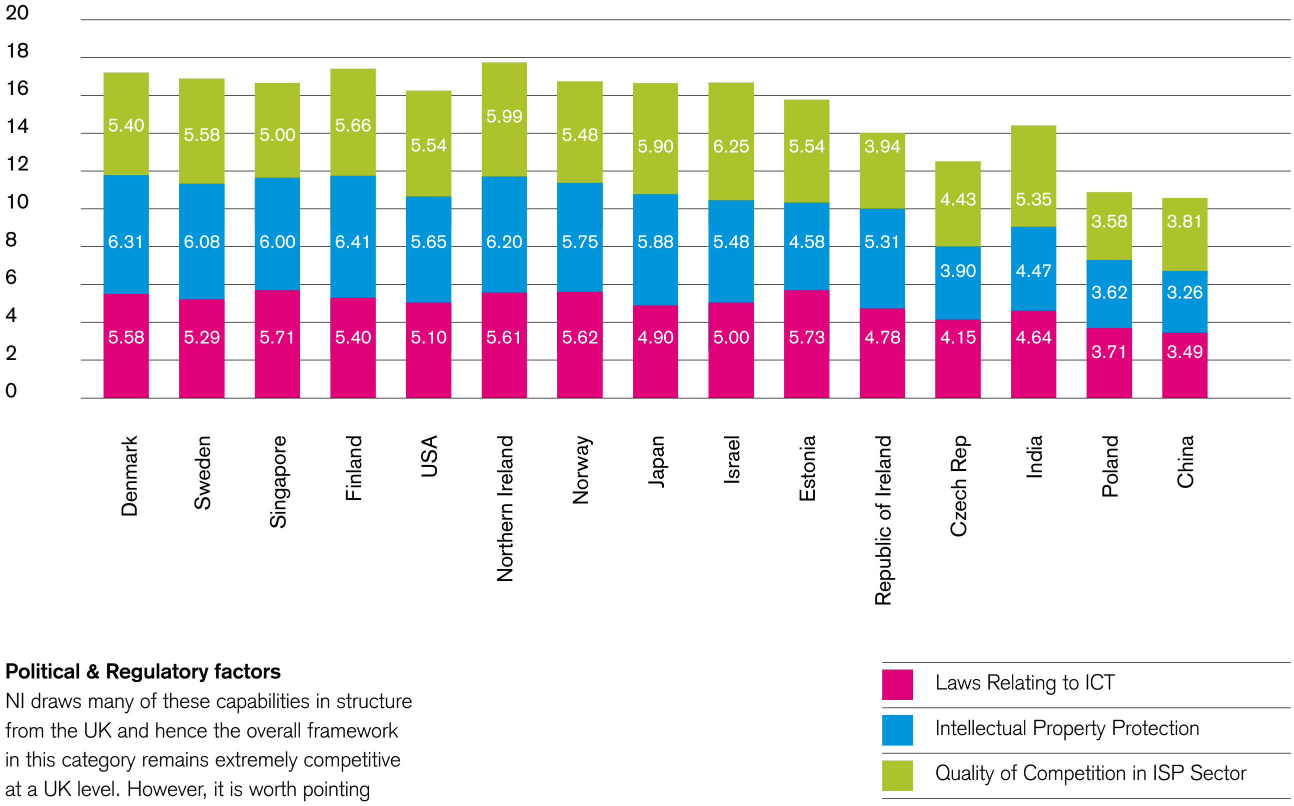


FIGURE 10.15: POLITICAL & REGULATORY FACTORS



Political & Regulatory factors

NI draws many of these capabilities in structure from the UK and hence the overall framework in this category remains extremely competitive at a UK level. However, it is worth pointing out that these measures refer to the existence of structures only; as opposed to their actual implementation.

FIGURE 10.16: INFRASTRUCTURE FACTORS

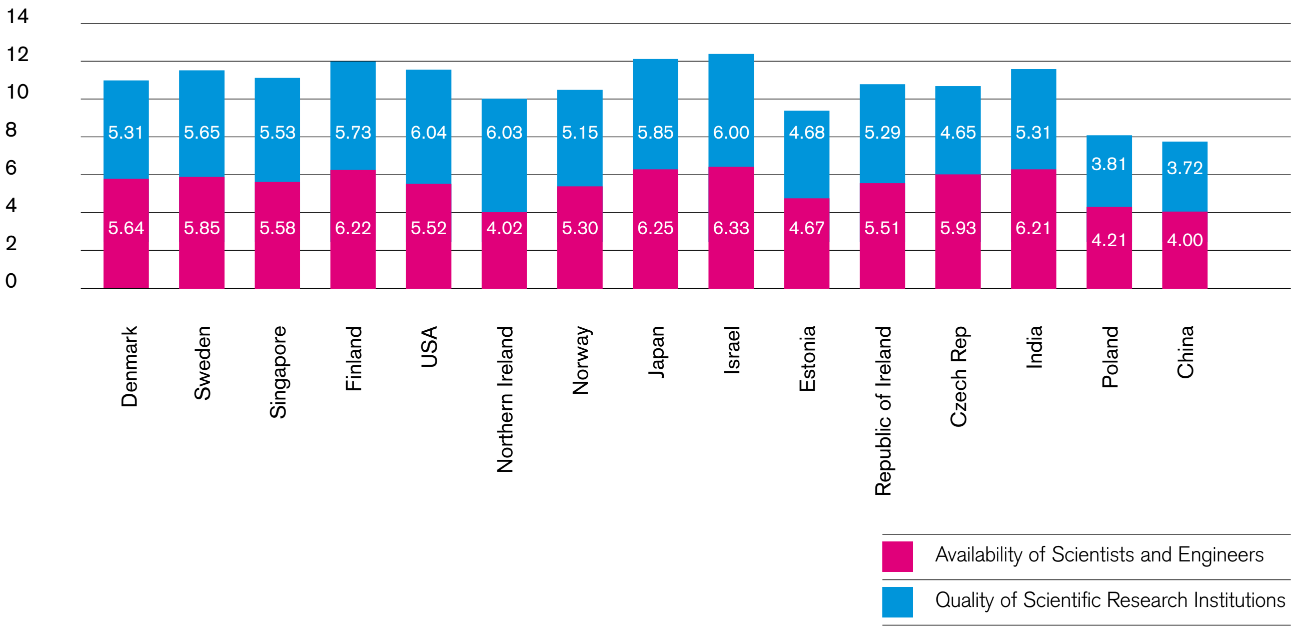
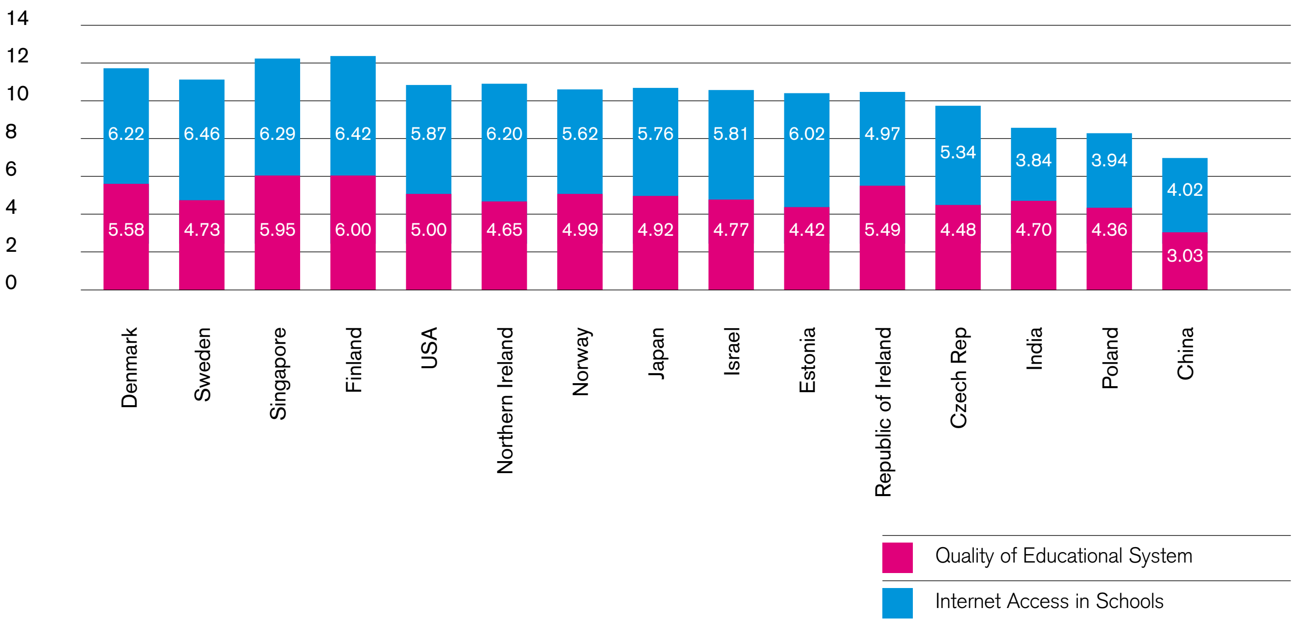


FIGURE 10.17: INDIVIDUAL READINESS FACTORS

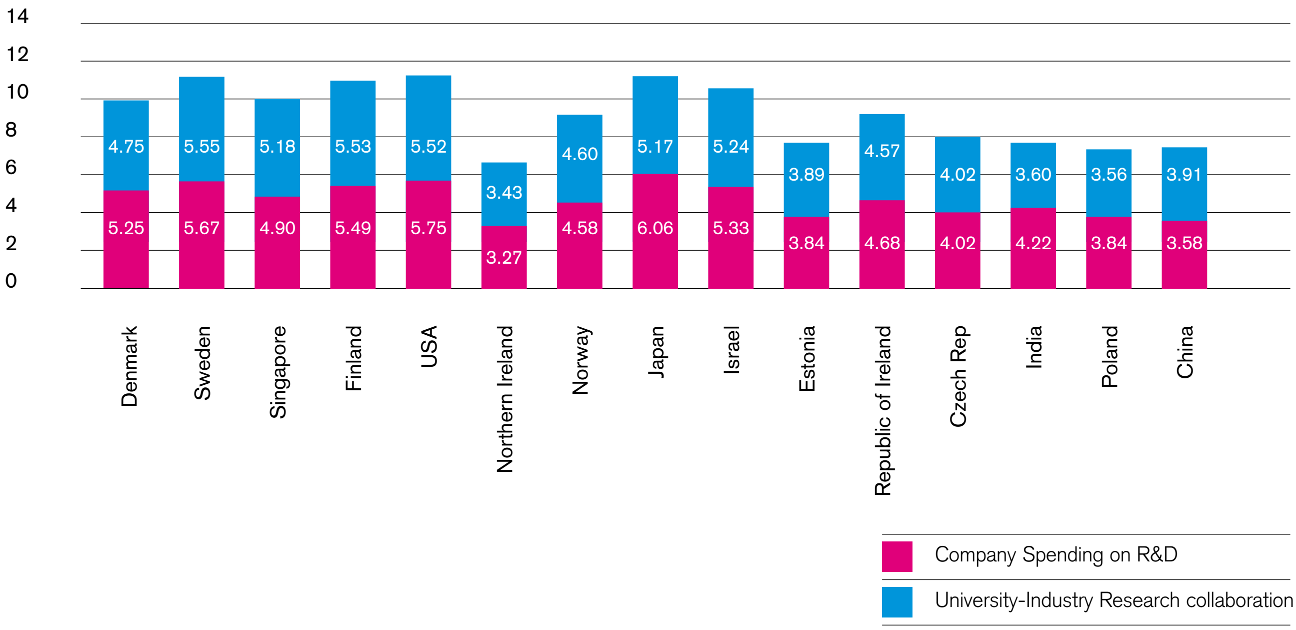


Infrastructure Factors
As a general principle, nothing can happen without infrastructure. In this instance, infrastructure is measured as a feature of the availability of scientists and engineers and the quality of these. The particular situation regarding NI, in this regard, is that historically it has exported these individuals as demonstrated in section 10.2 above. NI leads the UK in the quality of output however the availability appears to be mismatched. The preferences within NI tend to move away from Engineering and Science towards Arts, Law, Accounting etc and this drives a deficit that is difficult to resolve.

Individual Readiness Factors
Individual readiness is attributed to the quality of the education system (very high in the case of NI) and then moves to address the overall access to the internet in schools as a means of determining readiness. What this attribute masks the level of science and technology education in the primary, secondary and tertiary systems. There are no reliable data available on this however, the Nordic countries have instigated significant changes in this area and it would be recommended that NI consider some of these changes such as team work, science experiments etc.

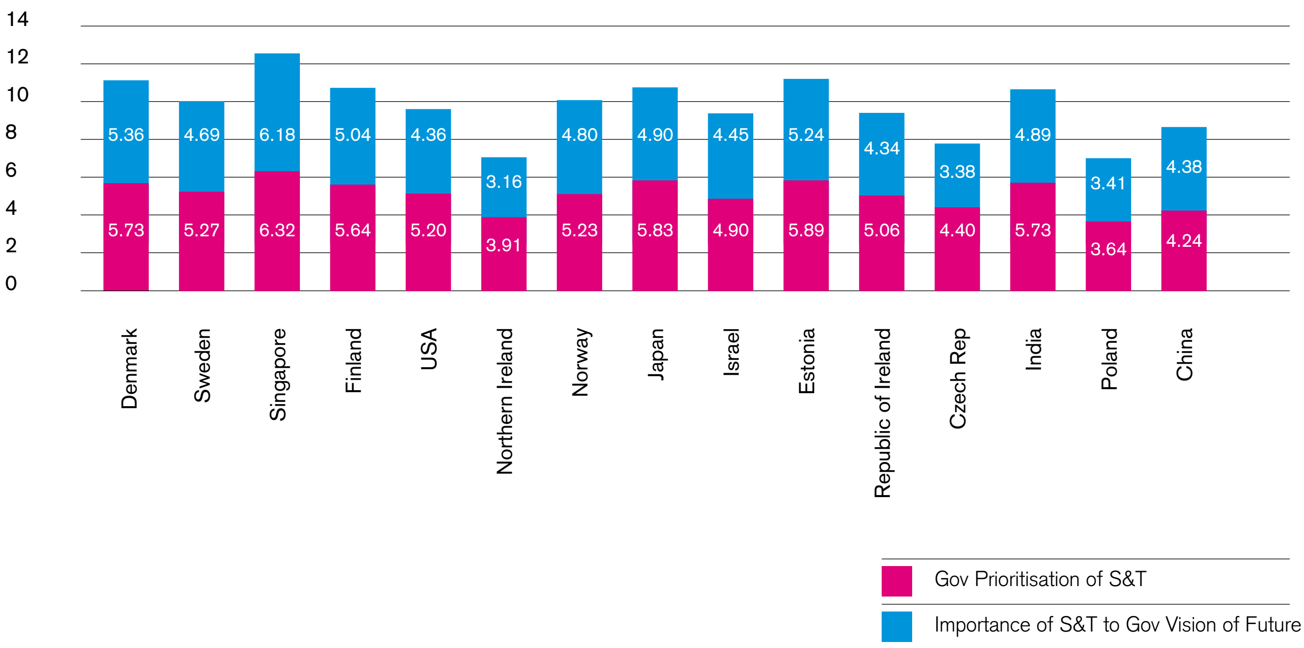
Business Readiness Factors
Business readiness measures, at an individual company level, the spend of private companies on R&D and existing University - Industry collaborations. In both of these categories as illustrated in Figure 10.18 above, it is clear that NI has no real strength in this space at all. The analysis of this capability study demonstrates that R&D is conducted by a handful of companies and primarily in isolation from the research infrastructure.

FIGURE 10.18: BUSINESS READINESS FACTORS



Government Readiness Factors
The final analysis in this chapter looks to Government readiness in terms of the priortisation of science and a specific vision of the future. It is apparent that whilst some work has been completed in this space historically, the MATRIX Panel is the first endeavour to create an environment for science and technology to enable economic growth in NI.

FIGURE 10.19: GOVERNMENT READINESS FACTORS



10.4
SUMMARY OF CONCLUSIONS

In attempting to understand the conclusions from this benchmarking exercise, we have decided to create a Governing Thought on the overall message received and then to subsequently divide the Technology Capability supply chain into five drivers - Innovation Platforms, Knowledge Creation, Innovation and Entrepreneurship, Applications and Intellectual Infrastructure. This is effectively a breakdown of the entire Technology Capability supply chain.

NI possess the key drivers for innovation

It is worthwhile to collate some of the benchmarking information presented earlier in this chapter into Innovation Drivers to see how NI compares internationally. It is worthwhile pointing out at the start that the Nordic countries dominate all of the key drivers for innovation and its exploitation. In this regard, for their size and scale, they surpass the USA, Canada, Japan and the emerging nations of China and India.

Innovation Drivers are considered to be

1. **Supply and Quality of Science and Engineering graduates;**
   As illustrated in Figures 8, 9 and A4 and Tables 10.1 & 10.2 in this chapter, NI is producing S&E graduates with comparable levels of capability at a European and Global level. There is a shortage of PhDs however as these drive the innovation in high technology companies. The Republic of Ireland leads this evaluation at a European level with the Nordic countries very close behind. In terms of NI, it must be pointed out that a high percentage of graduates went into the public sector (45%) compared to all other economies (Figure 10.11).

2. **The provision of tertiary education;**
   NI does provide Tertiary (Figure 10.12, A5) education for all of its population however this is not always availed of. NI finds itself in the mid table positioned with UK, RoI and middle Europe but lagging the Nordic countries who have a tendency to certify and qualify all aspects of their society.

3. **Broadband penetration;**
   Broadband availability and penetration is seen as a critical factor to enable the use of knowledge. NI scores high here and is in the second tier globally behind the Nordic countries who surpass everyone else.

4. **Life-long learning;**
   NI scores highly in Lifelong learning after the Nordic states again. The provisions are clearly in place, however perceptions of uptake remains difficult to measure.

5. **Youth Education.**
   There were no benchmarks to support this other than the regional GCSE results which are extremely favourable to NI (Figure 10.9)

From the data presented earlier in this chapter, NI scores well on almost all of these factors in a European and Global context. In terms of the enabling foundations of innovation, there appears to be a significant platform for NI to develop from.

NI creates knowledge but does not exploit it

Knowledge creation is a step on from the Innovation Drivers and starts to see how knowledge can be created in NI. It does not look to exploitation which is the next step of drivers.

The key aspects of knowledge creation are:

1. **Public R&D expenditure**
   NI scores relatively low in terms of public R&D expenditure at a UK regional level and at a European global level (Figure 10.2 and Figure 10.6). It is certainly not matching the increase in spending of the RoI and other UK regions with the exception of the Northern East of England. It must be said however, that where spending has been made, the quality of output is highly competitive or competitive with significant leading edge outcomes. However, it lags the key old (Nordics) and new (RoI, Belgium) innovators in Europe.

2. **Business R&D expenditure**
   NI scores relatively low in terms of private R&D expenditure at a UK regional level but the gap is not so significant as Wales (and the Northern East are poor in this regard also). At a European level, NI is very weak scoring significantly below European averages (and UK averages). It must be pointed out however that this is supported by the sector analysis earlier in this report which demonstrated that few companies invested in R&D but those that did, were significant spenders and achieved remarkable competitiveness (see individual sector chapters). This would appear to indicate that it is a question of scale in NI (Figures 10.3 & A6).

3. **Share of medium – high/high technology R&D**
   NI scores low on this again. High technology R&D is being conducted in the university system and this in fundamental in nature with some applications being created. In many instances, we noticed that applications were as much for companies that were not exploiting this capability in NI itself (Unilever, TDK etc). In companies in general, only applied research is being conducted (Figure A6) and between academia and companies the interaction level is low (Figure A6). NI does not compare with the Nordics in this regard and at a UK regional level also compare poorly.

In summary, NI has lower levels of spend in R&D but where this does occur the output is significant whether that be in the university system, the professional research organisations (AFBI or DHSSPS) or in companies (Seagate etc). This work is fundamental R&D with applications being also identified. Additionally, although collaborations between companies and professional research organisations in NI are low, the interactions that do occur have been impressive.

NI needs an innovation system that supports new and existing companies in the region using latest technology

This category of comparators attempted to look at how knowledge, once created (irrespective of where it is created), can be channelled into exploitation capability thereby providing economic benefits. There are a number of factors here:

- **SMEs innovating in-house or co-operating with each other**
  This references the number of SMEs with in-house innovation activities. Innovation is defined as the introduction of new products/processes or the combination with other firms (Figure A6). In this regard, NI scores poorly at a UK regional level and at a European level. Most SMEs in NI are driven by cost reduction only and this can occasionally demand process improvement but this is not always evident. Additionally, there appears to be no innovation system in NI and collaboration between companies in similar sectors in poor. For example, in Life Sciences there is almost no collaboration whatsoever between the large indigenous companies and other SMEs.

- **Innovation expenditure**
  This is the total of innovation expenditure for companies in each sector. It includes in-house R&D, external R&D, machinery, equipment etc. The results for NI are relatively poor – sectors such as ICT, Life Sciences, Sustainable Production and Consumption show low levels of expenditure per company and further analysis shows that only a few companies in each sector are investing whereas others are not. It is also clear that some new SMEs in Life Sciences, Advanced Materials and ICT are heavily investing, whereas traditional companies are relatively low.

- **Early Stage Venture Capital**
  Venture Capital investment is private equity for companies. This excludes Management Buy Outs but includes early start seed investment. The UK scores highly on this globally in general but that looks to be entirely focussed on the South East or Midlands. There is little activity in this regard in NI (Figure 10.8) and VC when available appears to come from outside NI.

- **ICT Expenditures**
  ICT is seen as a key enabler of innovation in all sectors. NI scores highly in this regard once the overall Nordic situation is removed. NI scores higher than some other UK regions. It would be deemed that there is sufficient capability in this regard in NI.

- **SMEs using organisational innovation**
  NI performs weakly in this regard also. Time and cost drives a lot of the behaviour in the SME sector and innovation, and when it does occur, it tends to be driven by immediate survival requirements as opposed to a structured organisational change.

Although NI has the factors for innovation in technology, the exploitation is where there is weakness. There appears to be no real innovation system for companies in NI, they are fragmented and although funding and support does exist, this is not always well integrated or connected.

NI needs a significant culture shift concerning high technology and how new capabilities can be exploited

In this aspect of the review of NI capabilities, it is important to look at how technology capability is currently exploited within NI and what key lessons can be learned from the benchmarking conducted.

Employment in the high technology sectors

NI is well behind most European regions in the employment in the high technology classified areas. These are defined as areas whereby R&D services are used to derive new products/processes or where there is a heavy dependency on ICT services.

Figure 10.1 demonstrates how NI compares to other regions in the UK and Europe. This low position is assumed as much due to the investment levels in R&D as the skills and education scoring for NI is extremely competitive. There is a shortage of knowledge based businesses in NI (Figure 10.10) and equally Technology Readiness, the intensity of local competition and a lack of focus on direct market interactions with customers tend to hold NI companies back in this regard (Figure 10.14).

High technology exports

There is a mixed message in High technology exports for NI. These are defined as the total exports that include Aerospace, computers, software, electronics, pharmaceuticals etc. It is interesting to note that NI has highly competitive technology capability in these areas but this is not matched with the exports ratios with the exception of advanced manufacturing (please see individual sectors in this report). This mismatch would need to be addressed for greater economic return. The RoI leads the world, per capita in this scoring.

10.5 NI POSSESS THE KEY TENETS OF A GOOD INTELLECTUAL INFRASTRUCTURE

NI possesses a strong internal infrastructure in terms of laws, regulations and stability to allow for the further exploitation of capability. This can be measured in terms of:

Political and Regulatory Certainty
NI has the political and regulatory certainty to allow it develop into a significant technology based economy (figure 10.15). The infrastructure factors are in place and competitively identified and recognised. The existence of these elements does not however ensure that there is a innovation structure in place to allow the existing capability be merged into economic gain.

10.6 GOVERNING THOUGHT - THE NEED TO CONNECT NI TECHNOLOGY CAPABILITY WITH EXPLOITATION CAPABILITY

The benchmarking of NI concludes that the eco-system for Technology and the innovation it brings is fragmented. The overall net affect is that NI is trailing the rest of Western Europe, the USA and eastern EU in terms of the overall Technology innovation performance.

However, the basic building blocks, of the capability to build a platform for rapid improvement, are already in place in terms of extensive highly competitive capability in R&D, excellent schooling and overall intellectual infrastructure. The 'connectedness' between these aspects appears to be the most critical missing item.

It is worthwhile to point out however, that there are few innovation leaders in the European context – the Nordics alongside Switzerland offer the very best examples. That group of leading innovators is led by European small nations such as Belgium, Italy, Austria, Holland (at a global level the US and Canada are included in this group). This is an important differentiator illustrated by the following point.

CONCLUSIONS

11

11.1 INTRODUCTION

The role of technology in economic growth or industrial growth has been recognised for a significant period of time[101]. The OECD, through a number of reports, has demonstrated that over 50% of THE growth in advanced countries is derived from technology innovations[102]. Furthermore, industrial development is the process of building technological capabilities through learning and then translating that learning into product/process innovations that create employment and income in a course of continuous technological change.

It is therefore important to differentiate the factor that whilst technology capability is the knowledge; skills and experience are necessary in companies to produce, innovate and organise this knowledge into meaningful outputs.

In this report, it has been important to place a broad definition on technology capabilities. Technology capability is the ability to make effective use of technology knowledge in production, engineering and innovation in order to create and sustain competitiveness in price, quality and markets (products or services). This capability therefore allows companies to assimilate, use and adapt new or existing technologies. It also allows companies to create new technologies and to develop new products/processes as markets change. Therefore, technology learning is the process of building and accumulating technology capability. This becomes very important in the context of NI.

In this analysis of NI, we have developed a model for understanding capability in the NI context. This model is based on understanding technology capability as it exists and how this capability is present in the NI environment. This model was evolved over the course of the study as it is apparent that there is a key mismatch within the NI industrial landscape. This mismatch exists in principle between the knowledge creators (universities, public bodies and some individual companies) and the exploiters (majority of companies in each sector). This can be generally classified as an issue of technology transfer but in truth, the issues exists at a number of levels and varies depending on the nature of companies - SME or FDI. This model is demonstrated in figure 11.1

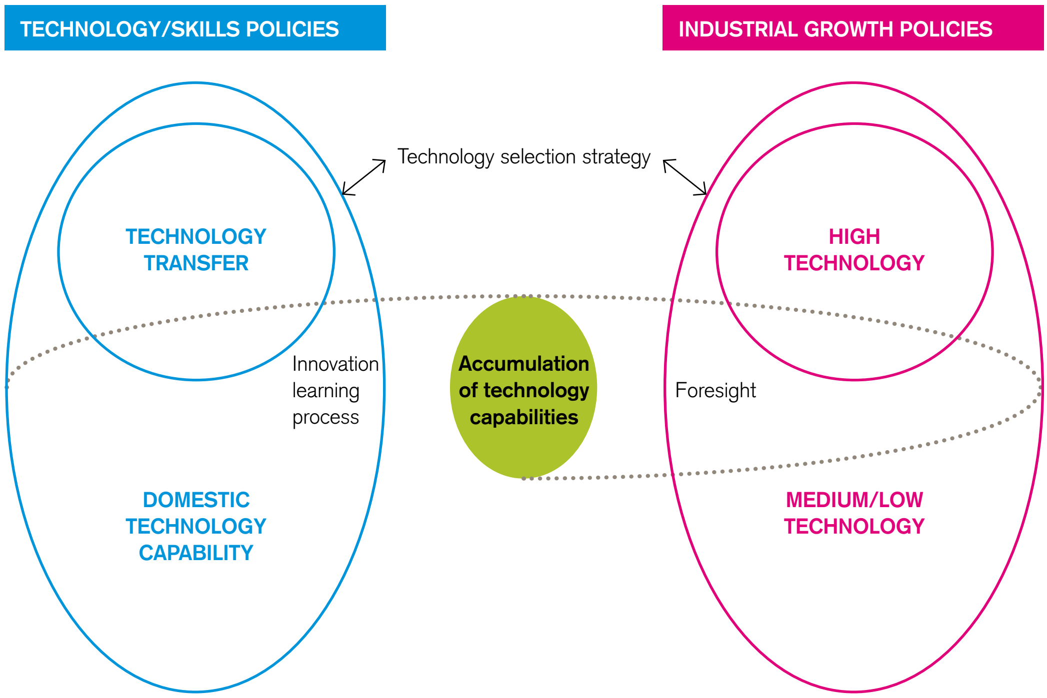
This diagram outlines the twin pillars of the MATRIX work. Industrial growth is developed through the Foresight panels that determine high technology or medium low technology selection areas for the specific sectors in Northern Ireland. The selection of specific technologies is dependent on the analysis of what the sector needs, the existing capabilities within the sector and where new areas can be identified. Clearly this foresight produces the need to derive new industrial policies or to revamp existing ones.

This Capability Study has looked to identify the domestic technology capability by sector. It also however needs to consider how knowledge, irrespective of its source, is transferred to the companies.

In addition, the model looks at the overall innovation learning process and how policies at the technology/skills areas impact on NI. This has been crystallised by the benchmarking exercises also. Whilst the focus of the conclusions of this report are the NI Technology capability, it will also acknowledge the other issues within the overall infrastructure in NI.

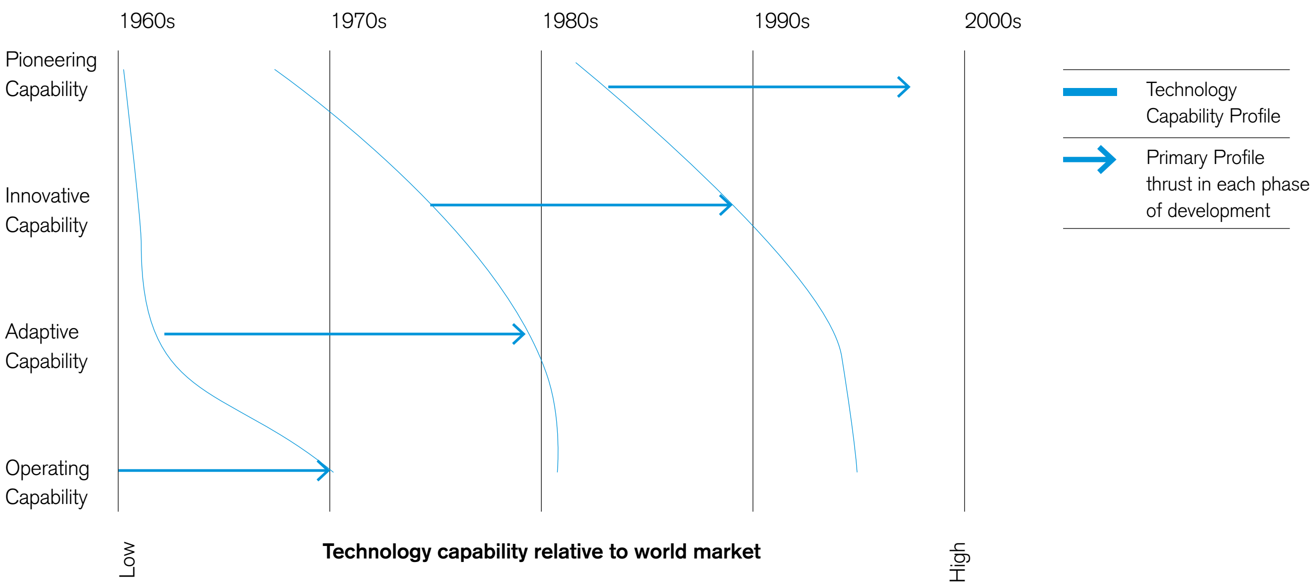
101. Solow 1956
102. OCED/Grossman 1991

FIGURE 11.1: THE ANALYTICAL FRAMEWORK FOR TECHNOLOGY CAPABILITY, TECHNOLOGY LEARNING AND INDUSTRIAL GROWTH IN NORTHERN IRELAND



11.2
NI DOMESTIC TECHNOLOGY CAPABILITIES

FIGURE 11.2: THE PROFILE OF TECHNOLOGY CAPABILITIES IN SINGAPORE OVER THE FOUR PHASES OF THE NATIONAL INNOVATION SYSTEM



The findings in the Technology Capabilities in NI indicate a dichotomy. Normally, in economic development, the exploitation capability exceeds the scientific capability significantly. This tends to be driven by the factors of relatively low cost, incentives etc. As employment rises and economic costs increase there is the pressure to rise up the value chain - in other terms develop technology capabilities beyond the cost depend activities normally conducted. This requires an emphasis on science, technology and higher degrees of innovation using the platforms of exploitation that are already in existence. The key aspect of this however is that the overall direction of the science and technology capability building is related to the existing exploitation base thereby ensuring a high degree of overlap between the new emerging technology capability and the legacy exploitation capability. This provides an accelerate mechanism to exploit the deeper technology capability.

An example of this would be Singapore. It developed its industrial base in waves as indicated in Figure 11.2.

Singapore began as an operator of capability, adapted this capability and then became significantly more and more innovative until eventually it has become a pioneer in various sectors. A similar analysis is developed for Finland, Sweden and the RoI. What is significant behind this analysis is the fact that the companies that were resident through the operating period remain the companies in the innovative and pioneering stages. For example, the pharmaceutical industry no longer produces mass products in Singapore but those same companies are involved in the development and piloting of new products there. Equally, Apple computers in the RoI once manufactured computers but now runs the entire EMEA region from sales to financials with no production capability.

In NI a very different scenario is detected. There is a relatively distinct decoupling between the capability that has been developed and the exploitation of this capability. There are of-course instances where this is not the case but in general, the areas of overlap are much less whereas the breath of areas of highly competitive capability is greater than expected. This appears to indicate effectively two different systems in operation at different paces. Without a tighter coupling, both aspects are in danger; as capability without a chance of exploitation is vulnerable and exploitation with capability is always subject to market costs and market rules.

11.3 THE TECHNOLOGY CAPABILITY IN NORTHERN IRELAND

NI does possess competitive technology capability but this is not always integrated and this is demonstrated in the following table. The table is subdivided into the sectors that were decided upon, which align with the UK technology strategy.

From the analysis of Table 11.1 the key sectors with deep technology strengths in NI are Advanced Manufacturing, Advanced Materials and Life Sciences. ICT and Sustainable Production and Consumption (which includes Energy) are generally strong in terms of employment and hence exploitation. However, the linkages between Scientific capability and Exploitation capability are relatively weak in these sectors;

The developments in Advanced Materials support very much the efforts of Life Sciences and Advanced Manufacturing. The linkages are most apparent in the newer interdisciplinary areas of Advanced Materials - Biomaterials, Nanostructured Materials, and Multifunctional Materials.

Across ICT, Life Sciences, Advanced Manufacturing and Advanced Materials the predominance of Computational Science - in multiple guises - is very important and of growing relevance.

In Life Sciences, the biomedical capability allied to Clinical Trials enables NI to further develop this sector in specific directions whilst the same capability, if transferred to the SP&C sector would significantly enhance the Agrifood business, when coupled with the traditional animal and plant capability in that sector.

From the analysis of these sectors, it appears that it would be preferable to map the capability in Electronics and Photonics into the Embedded Systems capability in the ICT sector. The overlap is significant, based on existing capability.

It is also evident that the exploitation capability in SP&C requires the capability from Advanced Materials (packaging), ICT (toolsets) and Life Sciences (Biomedical) to make further directions into the existing and future direction of that sector.

The coupling of the Advanced Manufacturing sector with the Advanced Materials sector will be of great significance in the further development of both sectors within NI and the integration of the strengths in Life Sciences with Advanced Manufacturing and Advanced Materials will support the further development of medical devices and diagnostics.

TABLE 11.1: SUMMARY OF CAPABILITY IN NI

SECTOR	TECHNOLOGY CAPABILITY STRENGTHS	EXPLOITATION CAPABILITY STRENGTHS	EXPLOITATION CAPABILITY WEAKNESS
SP&C	Animal Welfare Animal Breeding and Biotechnology Plant Breeding and Biotechnology Environmental Technologies	Animal Welfare Animal Breeding and Biotechnology Plant Breeding and Biotechnology Food technology Engineering, Mechanisation and ICT Energy Creation	Aquaculture Fisheries Forestry Plant Production
Lifesciences	Medical Devices and Diagnostics Biomedical Science Biotechnology Computational Science (Systems Biology)	Medical Devices and Diagnostics Biomedical Science Computational Science (Systems Biology) AgriBiology Biotechnology Services Clinical Trials Pharmaceuticals	Medical Disposals
ICT	H/W & Systems (ECIT) Computational Science Knowledge Engineering	H/W and Systems Computational Science Telecommunications Application Software Product Software	IC Design Digital Content
Electronics and Photonics	Instrumentation	Plastics Electronic Valves Radio, TV and Telecommunications	Electrical Equipment Computers and other information processing Process Control

11.4 THE TOP TECHNOLOGY PRIORITIES FOR NORTHERN IRELAND

The evaluation of the existing capabilities and their associated strengths (and relative weaknesses) can be developed further from Table 11.1 into the following analysis in Table 11.2.

Table 11.2 above demonstrates the top technology priorities for the various sectors in NI. These top priorities are where they are a clear, continuous capability in terms of science or exploitation pathways. The extension of these capabilities in the positive directions should lead to significant economic impacts.

There are gaps however within these capabilities and these are also noted. The gaps appear in terms of Scientific Capability (as in ICT for example) and in Exploitation Capability (as in Life Sciences Advanced Materials etc). In many cases however, the overlapping of capability between sectors has to be seen as critical in the development of the economy. The application of Life Sciences techniques to Agrifood and ICT solutions to Agrifood, Advanced Materials and Advanced Manufacturing is essential.

However, the Horizon panels will need to evaluate these issues in further detail to ascertain where exactly the overlaps and relevant focus needs to be.

TABLE 11.2: THE TOP PRIORITIES AND GAPS IN TECHNOLOGY CAPABILITY IN NI

SECTOR	NI KEY CAPABILITY FOCUS	COMMERCIAL SECTOR APPLICATION	MISSING CAPABILITY PERTAINING TO CAPABILITY FOCUS
All	Computational Science/ Embedded Systems	All sectors - Advanced Materials, Advanced Manufacturing, Lifesciences etc.	Applications of Computational Science in Food and Nutrition.
Electronics & Photonics	Instrumentation and Radio TV & Communications.	Integrated into Hardware & Systems in ICT - specifically a focus on Embedded Systems.	Embedded systems design and testing capability with a specific emphasis on scaling.
	Electronics Valves, Tubes etc	Integrated into Advanced Materials - Electronics Materials, Magnetic Materials etc	
Advanced Materials	Rich focus area is the convergence of traditional materials and a focus on the interdisciplinary and multidisciplinary areas of Advanced Materials - Biomaterials, Nanostructured Materials, Multifunctional Materials and Composites.	All sectors from Advanced Manufacturing (Aerospace, Automotive etc), Sustainable Production and Consumption (Food, Packaging and Processing) etc.	Use of Advanced Materials in novel packaging for the food industry; Scaling capability with relevant access to Advanced Materials for NI SMEs; Absorptive capability of the SME sector of Advanced Materials Capability);
Life Sciences	Biotechnology, Agribiology, Biomedical Science, Medical Devices and Diagnostics, Clinical Trials and Pharmaceuticals.	Applications from this sector could be used in SP&C to further develop the Agrifood industry. Equally, Advanced Materials developments are essential for Lifesciences.	Further use of Advanced Materials in Medical Devices and Diagnostic equipment; Exploitation mechanisms for Medical Devices and Diagnostics. No interaction between the major players impacts developments in the market. No cross-fertilisations of knowledge in the sector;

SECTOR	NI KEY CAPABILITY FOCUS	COMMERCIAL SECTOR APPLICATION	MISSING CAPABILITY PERTAINING TO CAPABILITY FOCUS
ICT	Software development with specific applications to Financial Services, HealthCare, Telecommunications and	Emphasis on software development needs to move from application development to packaged software development.	Understanding and development of skills in the the complexities of the global packaged software industry and the commercial model this industry is currently using and will evolve to; There is no real leading software development capability in Northern Ireland;
	Support Services and IT Services;	These need to evolve into a strong near-shoring capability which is enabled by IT services and has applications in Financial Services, HealthCare and Telecommunications.	No real concept of how NearShoring propositions can be developed based on ICT excellence and a model for their exploitation.
	Hardware and Systems	Embedded Systems with a focus on Medical Devices, Security with high value added propositions.	Further work needs to be completed (based on ECIT) to focus on the integration of hardware and software for specific intelligent industrial purposes. It is worth pointing out that ECIT is a tremendous start to this work.
Sustainable Production & Consumption	Environmental Technologies, Animal Health and Welfare, Animal Breeding, Plant Breeding, Food Technology.	Lacks of integration with other industries in terms of packaging etc have limited the development of this sector. The impact of environmental technologies can be significantly augmented based on key global trends in carbon, water, nitrates and phosphates.	Functional Foods, new packaging techniques, new processing techniques, development of alternatives from agriculture needs to be put on an improved format.
Advanced Manufacturing	Design, Simulation and Validation	Used by FDI companies in NI. Significant capability.	Missing entirely in the SME sector.
	Advanced Manufacturing Technologies	Used by FDI companies in NI.	Not used by traditional companies and SME base.
	Lean and Sustainable	Used by FDI companies in NI.	Not used in SME base except in rare circumstances. Extension of Lean capability to Pharmaceuticals;

FRAMEWORK CONDITIONS

IN THIS REPORT, THE FOCUS IS CLEARLY ON THE TECHNOLOGY CAPABILITIES WORK. HOWEVER, AS OUTLINED EARLIER, IT HAS BECOME IMPORTANT TO RECOGNISE THE FRAMEWORK CONDITIONS THAT CHARACTERISE THE NI ECONOMY. FRAMEWORK CONDITIONS ARE THE ELEMENTS THAT MAKE AN ENVIRONMENT CONDUCIVE FOR THE RESEARCH, DEVELOPMENT AND UPTAKE OF NEW TECHNOLOGIES. THEY ARE NOT TECHNOLOGY BASED BUT REFER TO GENERAL ISSUES SUCH AS INCENTIVES, FUNDING, SKILLS ETC. THROUGHOUT ALL INTERVIEWS AND WORKSHOPS CONDUCTED A NUMBER OF FRAMEWORK CONDITIONS WERE CONTINUOUSLY RAISED.

12

12.1
DEGREE OF CLUSTERING

Clusters are geographic concentrations of interconnected companies, specialised suppliers, service providers, firms in related industries, and associated institutions for whom membership within the concentration is an important element of each members competitiveness. A detailed comparison of clusters has been prepared as part of this work and is available in Appendices for review. It would be difficult to see NI as anything but an individual cluster in Life Sciences, ICT, Advanced Materials, Advanced Manufacturing and SP&C. Although the concept of cluster has become generic they are not the same wherever they are found (India, China, RoI, Cambridge etc). They vary based on - Industrial Legacy, Geography, Characteristics, Demographics and Culture.

However all clusters do share some characteristics and follow a particular lifecycle, which supports initiation based on some historical legacy and a constant cycle of rejuvenation. This is illustrated in Figure 12.1.

Significantly, the characteristics of clusters can be summarised as:

- The need for a flexible and responsive framework so that the cluster can thrive and grow in whatever direction it needs to based on market economics;
- The need for linkages in the broadest supply chain between Research and Development institutions with links with industry and a framework that allows for collaboration in an open and transparent manner;
- A financing structure, both private and public, that can be leveraged and used through an entire lifecycle of a company i.e. formation, growth;
- Ability to attract, retain and reward capacity and capability;
- Need for a 'local' demand that provides initial demand and revenue. The concept of demand should be understood to mean both quality and quantity. Quality is more essential;
- Infrastructure that leverages the operation of the cluster without providing additional obstacles;
- Culture - The promotion of risk taking, entrepreneurship, new firm creation.

A detailed cluster model therefore could be described in the following 'cluster model' which has been developed by PA Consulting and is shown in Figure 12.2.

This model demonstrates a number of key attributes in clusters in general. NI needs to complete work in terms of developing the Support Infrastructure, the Relationship Infrastructure, the Investment Continuum, Company Lifecycle Support and People/ Education/Skills. It is recognised that some of these facets are already in place or initiatives are underway to put them into place, but the overall analysis is that the degree of clustering is still at step one to two of the cluster lifecycle (see figure 12.1) and that this needs to be developed structurally to ensure that the economic value from investments in Science and Technology can be realised.

FIGURE 12.1: CLUSTER LIFECYCLE

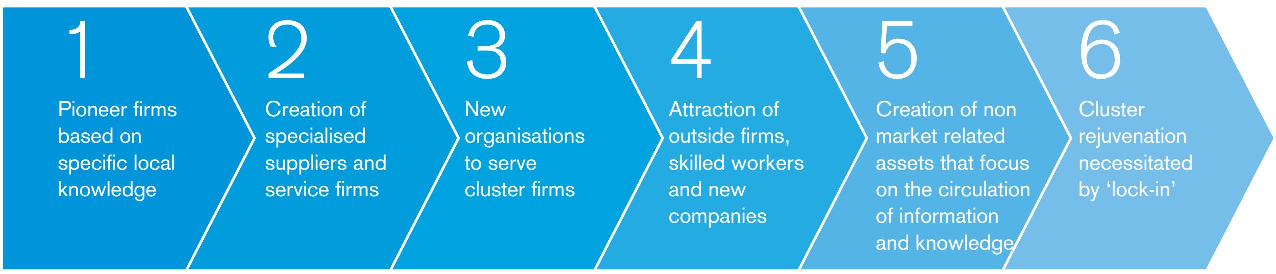
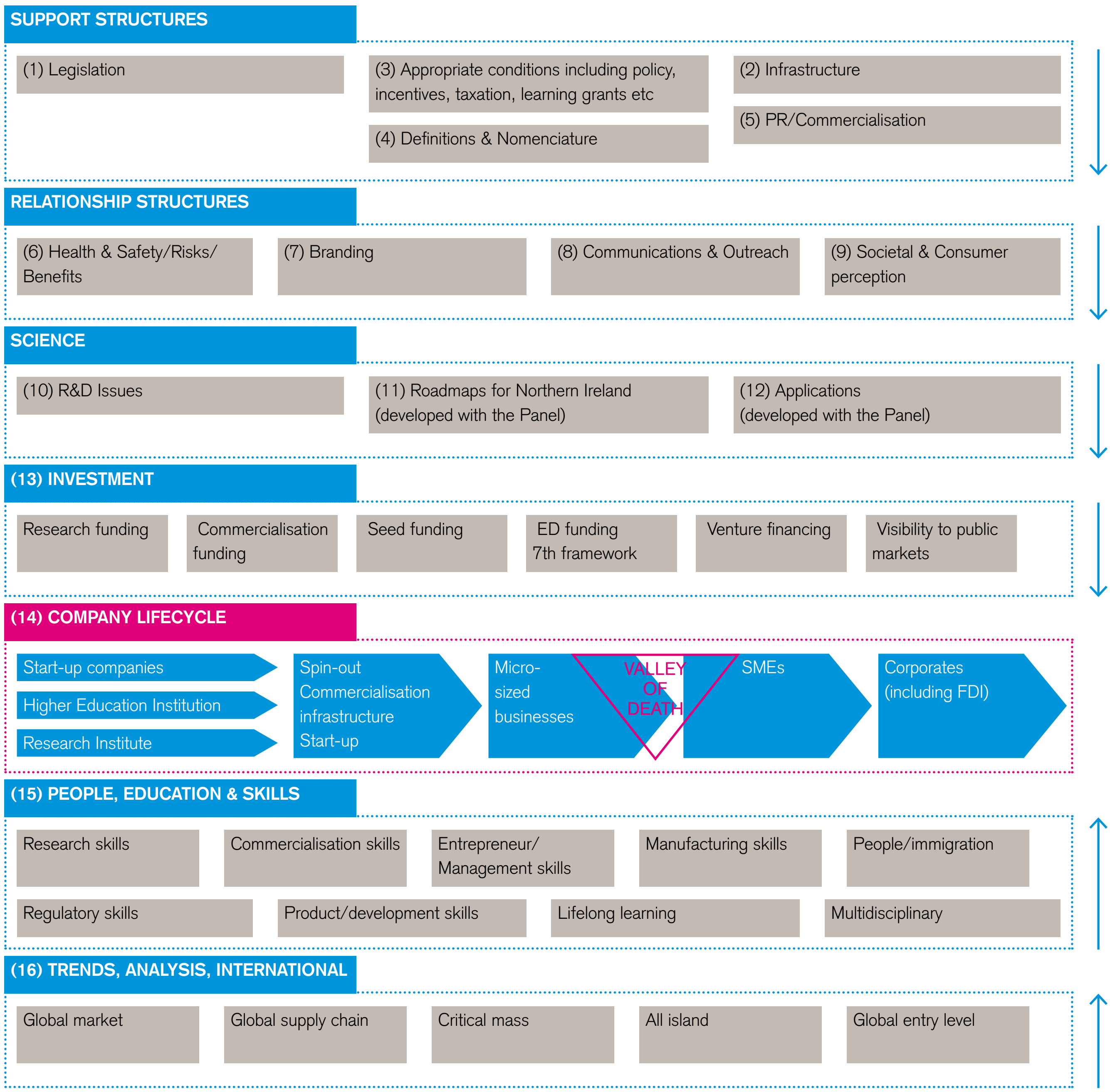


FIGURE 12.2: A STANDARD CLUSTER MODEL



12.2 THE SME ENVIRONMENT IN NORTHERN IRELAND

The industrial landscape in NI is characterised by the predominance of SME companies. Whilst employment and GVA predominance resides with the large FDI players, SMEs companies show a high degree of technology capability and exploitation in a number of the key sectors - specifically Life Sciences, ICT and Advanced Materials where start-ups and spin-offs are using competitive technology capability and seeking market exploitation. In Advanced Manufacturing and Electronics and Photonics the only real capability is demonstrated by FDI companies.

The SME section of the evaluated sectors shows the variation between the innovative ones and the traditional companies. Innovative companies are showing growth (irrespective of sector) in terms of 20 - 50% per annum with increasing spend on developing technology capability. Traditional companies are showing no employment growth and in fact a certain amount of decline. In some sectors, companies indicated that there was no real decision to grow (Sustainable Production and Consumption). In other sectors, aggressive growth targets were outlined and planning was underway to achieve this growth. The evaluation of this is that these issues are heavily sector dependent and fundamentally linked to the technological aspect of the sector. More NI SMEs are now showing export growth with an increase in export to sales ration. However, this again is sub-divided between those that are successful and innovative, creating new products with new technologies and those that are relatively traditional. Compared to UK examples however, NI companies are more likely to export. This is normal for a relatively micro economy where local demand is unlikely to meet market needs. There remain some general parameters however that cause a degree of concern for NI SMEs. These parameters are:

Customers and markets

A large number of firms rely on a few customers for key business. This creates a high degree of dependence and cost pressure[103];

In certain sectors (SP&C, Electronics and Photonics), the top customers effectively determine the product, technology (if applicable) and cost. This tends to drive significant pressure and leave no time or capacity for the development of other capabilities or markets. Generally, this applies because the SMEs are serving the intermediates in the market and therefore being squeezed[104];

The dependence on local market is limited for the more dynamic companies who immediately look to the rest of the UK, the Republic of Ireland and other international markets. These companies tend to seek markets outside of NI to determine growth. The view expressed was that the local market did not always provide the 'quality of demand' that they required[105];

All SMEs encountered are very focussed on responsiveness to customers needs, product quality and the development of an excellent reputation. Companies in the Advanced Manufacturing, ICT and Advanced Materials space were very specific on the need to look at product design, quality, cost, price and responsiveness. However, all of these encountered a 'scaling issue' with specific reference to international markets.

Collaborations

SMEs in NI tend to have relatively low amounts of collaboration. In this study, it was noted that independence of a company was considered an asset. The CBR report of July 2005 seems to indicate a similar trend also with 35% of SMEs have collaborations compared to between 45 - 60% in the UK. Collaborations by themselves can be time consuming without delivering benefits; however prudent selection of these produces significant market amplification, particularly in new markets and this was not always well understood. In certain sectors - Life Sciences, Advanced Materials ICT - collaborations were perceived to be significantly higher;

Skills and Training

The ratio of technologists within the SME sector is approximately the same as the UK or Republic of Ireland[106]. However, in the key sectors of ICT, Life Sciences, Advanced Materials and Advanced Manufacturing most, if not all, companies reported difficult skills categories that they currently employ. This seemed to extend across the skills continuum from the technologists and higher professions to skilled technician resources. Naturally, given the variation of these sectors, this is not easy to address as the skills required are very different. For example, in ICT software. Embedded Systems and Near Shoring operations, skills are missing however these are very different skill sets. SMEs struggle to develop their own skills - they are short of time and other resources. They tend to be looking for the finished product. This is of course different from FDI, where the critical mass allows for time and resources to develop skills;

Products

Product innovations provided some interesting indications. Some SMEs (Advanced Materials, Life Sciences, and Advanced Manufacturing) speak of new products and process innovations to meet customers. It should be noted that typically these companies were dealing with the end customer and not intermediates in a market. Others however, in sectors such as SP&C were more dependent on following the market or taking instructions;

The R&D spend in Advanced Materials, Advanced Manufacturing and ICT match levels in the UK in general. However, all SMEs noted the lack of a full spectrum of financing (no

103. This is supported by evidence from the CBR Report in 2005. This report was a 2004 survey however it is unlikely that the key trends will have altered significantly since then.
104. For example, large retailers 'boss' certain channels and markets.
105. All ICT Companies and Advanced Materials companies interviewed perceived the 'global market' to be there market. In some other sectors, the focus is more local.
106. Expert Skills Group (Republic of Ireland)

Venture Capitalists, limited Banking resources etc) and that innovation costs were too high with long pay back periods as being inhibitors to success. Above all, the lack of innovation capacity was deemed to be most critical. Most SMEs longed for more 'space' to be innovative but needed to mind the day-to-day business.

This is worth further evaluation. The importance of SMEs to R&D expenditure is increasing as demonstrated in this report and further supported by data from DETI analysis which indicates that SMEs are now almost 41% of total R&D. However the increase in importance is coupled with a decrease in the relative contribution of SMEs to R&D in total spend. In other words, more companies are engaged but spending less. Further analysis demonstrates that this is because larger companies are spending more and more (the analysis in this report shows that the top 10 companies in a sector dominate the R&D in that sector - hence SMEs in ICT, Life Sciences and Advanced Materials dominate). It is worth noting however that SMEs are now by this analysis, spending as much on R&D collectively as the FDI sector is. The funding mechanisms for this R&D are predominantly internal to the company or from overseas parent companies. In comparison with the UK regions, NI is leading the increase in funding although it remains from a relatively small base and this has to be continued.

Government Supports

SMEs in NI were not always aware of the full range of funding available to them and this was evident. Most funding seems to come from local government funding (InvestNI) with some smaller participation in EU funding schemes;

Manufacturing firms appear to receive funding, however Advanced Materials or newer companies explained some difficulties. It is difficult to analyse this - it could be a lack of awareness or perhaps some issues relating to the form of funding;

12.3
FDI IN NORTHERN IRELAND

The FDI sector in NI is significant in terms of technology capability and capacity. Companies such as Seagate Technology, DuPont, Bombardier Aerospace, Caterpillar, Allstate (Northbrook), Liberty Mutual, Daewoo, BT, Halifax and Prudential and HCL are the big players in the 640 externally-owned companies in NI. The employment numbers of skills and capable resources are significant - 74,000 by 2005 numbers. More importantly, these companies are bringing and developing significant skills in NI. It must be recognised that the efforts to cultivate these industries is very different from those that are required for the SME sectors outlined above. They role in the Cluster model of Figure 12.4 is different to that of SMEs.

Factors driving FDI performance

The boom year of FDI was 2000. Since then, there has been a falloff in FDI between 2000 - 2004. Additionally, the perception of any developments in that period has been that China has been the chief beneficiary[107]. Certainly China now commands a significant lead in manufacturing with a large, qualified, low-cost and flexible workforce and India has also developed off shoring capability in ICT.

But a more in-depth look suggests a more complex story. Despite the decline in FDI since 1999, its growth over the past 13 years has been phenomenal, averaging more than 17 percent annually. The decline since 1999 is due mostly to the drop in FDI following the boom in huge (one-time) privatization deals in the infrastructure, financial, and petroleum sectors in the 1990s. FDI in other sectors therefore has remained fairly constant[108]. This cyclical effect is confirmed by the much starker 'rise and fall' pattern in FDI flows to fund the infrastructure, financial, and petroleum sectors in the 1990s. FDI in other sectors remained fairly consistent therefore.

China's commanding FDI performance also should be put into perspective. While China accounts for 39% of the FDI to developing countries, it also accounts for almost 30% of the developing world's population. In fact, relative to GDP, China's performance in attracting FDI is good but not extraordinary, with FDI at 3.8% of GDP in 1999-2002.

Nineteen developing countries did better over the same period. China's performance looks even less extraordinary if adjusted for the round-tripping of FDI through Hong Kong (China), which some estimates suggest may account for as much as 30% of total FDI to China.

Broadening the scope of FDI for NI

To start with, the scope of efforts to attract FDI must encompass all sectors and all aspects of those sectors including the R&D base. The tendency in the past was to focus almost exclusively on infrastructure and on efficiency-seeking and tariff-jumping FDI into what can be termed traditional manufacturing.

In the future more and more FDI will be market seeking investment in service sectors as well as investment in offshore services.

Most developing countries continue to restrict FDI in service sectors (for example, India does not allow FDI in retail), yet are ready to waste fortunes to attract efficiency-seeking FDI for manufacturing in an uphill battle against China. There is a general misconception that market-seeking FDI in domestic sectors such as retail yields little development impact. The opposite is true. FDI in retail has been a key driver of productivity growth resulting in lower prices and higher consumption. Large-scale foreign retailers are also forcing wholesalers and food processors to improve.

Tackling FDI microeconomic issues

In addition to broadening the scope of efforts, countries must recognise that the battle for FDI will increasingly be fought at the microeconomic level sector by sector. Of course, foreign investors will continue to insist on basic political and macroeconomic stability, but this should become less important as a differentiating factor. Investors will look increasingly at microeconomic conditions, and what they look for will vary significantly from one sector to another.

The requirements for efficiency-seeking investment in manufacturing are increasingly well understood-low factor costs, a flexible labour market, a small regulatory burden, efficient infrastructure and customs. Less obvious factors include easy access to a competitive supplier base and business service providers.

The global environment for FDI continued to improve from 2004 - 2006. Macroeconomic growth continued, stock prices remained firm and profitability improved. In addition, new players made their presence more strongly felt. Multinational enterprises based in developing or emerging economies became more active acquirers of enterprises in the OECD area and new categories of financial investors, such as private equity companies, allocated large amounts of money to corporate takeovers.

Reflecting this, FDI flows to and from OECD countries increased significantly in 2006, outflows by 29% to USD 1 120 billion and inflows by 22% to USD 910 billion. These are the second highest levels in the history of OECD, exceeded only in the boom year 2000.

As an example to NI, it is important to note some of the developments in FDI across the developed world. Despite high cost, Sweden has seen FDI inflows more than double to USD 28 billion. The increase largely reflects corporate takeovers, with a small number of

107. This has been constantly referred to in all company interviews conducted in this study. This is initially supported by the fact that FDI declined by 26% between 2000 - 2004 and China's share increased to 39%.
108. World Investment Report 2006 - United Nations Conference on Trade and Development.

12.4 EDUCATION AND SKILLS DEVELOPMENT/CONTINUED SUPPORT

investments by UK-based investors accounting for almost half of the total amount, although it also reflects the ability of new companies to invest in markets where technology capability is deemed to be highest and where substantive innovation is available.

The NI education system is unique within the UK in that it has its own curriculum regulations, school funding as well as unique arrangements for Further and Higher Education. However, the challenges facing the science education at all levels are similar to the rest of the UK. Throughout this Capability Study, the uptake of students of science, engineering and mathematics remains an issue. Clearly there is a climate of motivation to change science education as part of the broader aim of social inclusion.

There is no question of the usefulness of science qualifications. Post-compulsory science education is linked clearly to career prospects and earning potential. The Economic Research Institute of NI demonstrated in 2004 that graduates in STI were less likely to be overqualified in their jobs that those of other disciplines within the NI economy. Additionally, the Education and Earning report of 2000 shows something similar in that earnings in S&T have been rising in NI since the 1980s. Larger companies are also involved in this activity with the beginning of placement of PhDs in second level etc. Throughout this study, it was apparent that most people felt that S&T in NI could be coherently managed offering advantages on the rest of the UK.

NI published its Regional Innovation Strategy Think Create Innovate in 2003, a year after the UK wide Investing in Innovation. It sets out an intention to move toward a 'knowledge based economy'. Unlike the UK strategy, it does not mention science, maths and engineering education specifically, only noting that overall achievement at school is high. It aims to 'promote innovation at every level of the NI education system', and sets out that 'education and vocational training deliverers should target resources on developing the knowledge and skills necessary to enhance the selected areas of high promise for R&D and innovation'.

However, the emphasis throughout the strategy is on further and vocational education, with the only specific proposal for schools being a reference to CCEA's curriculum review. It is not yet clear how this will manifest itself. For example, The Department for Education (DENI) Business Plan for 2005-6 includes attainment targets for english and mathematics, but science is not mentioned anywhere in the document. The overwhelming viewpoint in NI is to focus on literacy and numeracy, for natural reasons, however the integration of an exciting science aspect into the curriculum should be possible.

The Department for Employment and Learning (DELNI) Skills Strategy published in February 2006 includes a key target to develop a Skills for Innovation Action Plan by September 2006, in order to be effective in developing the skills needed for an innovative and successful economy in the long term. Skills are defined as the essential elements of literacy, numeracy and ICT; employability skills including team-working, problem-solving and flexibility; and, the specific occupational skills needed by business. These attributes must be strongly endorsed.

The Skills Strategy puts in place an overarching strategy for the development of skills. The four themes that underpin the vision are:

- To understand the demand for skills;
- To improve the quality and relevance of education and training;
- To improve the skill levels of the workforce; and
- To tackle the skills, barriers to employment and employability.

The Skills Strategy also draws together the implementation of the important components of the Essential Skills Strategy, the 'Further Education Means Business' Strategy and the Welfare to Work agenda. A central theme of the Strategy is that it is demand-driven, by the needs of employers, to ensure that the current and future demand for skills is better understood and actioned. An International Skills Expert Group has been established to advise government on projected skill requirements and international opportunities for NI at a strategic level. The work of the Skills Expert Group will be supported by a network of six employer-led Workforce Development Fora, which will provide a view of the skills needs and opportunities at local and sub-regional level. The work of both groupings will provide the information upon which a Regional Employment and Skills Action Plan will be developed, which will recognise and articulate priority-skill needs at regional and sub-regional level. A network of 25 SSCs has been established, whose initial focus will be to establish a comprehensive skills demand and supply analysis of the employers covered by each SSC. The Skills Expert Group and the Workforce Development Fora will be informed by the work of the SSCs and will provide an analysis of the strategic implications of education and training policies on the provision of skills at a regional level. DEL will work with the higher and further education sectors as well as the training sectors to relate provision more explicitly to the information on demand locally, regionally and, where appropriate, nationally and internationally.

NI and Science Skills

The region remains in a slightly better situation than the UK as a whole in terms of post- 16 uptake in science subjects, and has a strong participation and achievement in education overall. This is reflected strongly in the Benchmarking conducted in Chapter 8. Participation of 16-17 year olds in full time education and training is high at around 78% as compared to only 67% in England, and these rates have shown a steady increase in recent years. GCSE and A-level results are traditionally higher in NI than the national UK average.

However, in the uptake of science and engineering, NI follows similar trends to the UK. At A-level, NI consistently enters a slightly higher proportion of its students for science subjects than in the UK as a whole, but patterns of low and declining entries in the physical sciences are the same.

There have been a number of analyses of the percentages of total A-level entries in each subject for 2001-2004[109] in each of the science subjects. However, for students leaving school and entering Higher Education the picture alters. NI's students are less likely than those in the rest of the UK to take up sciences. While the overall proportion studying the selected subject areas is slightly higher among Northern Irish students, this is mainly due to the enormous popularity of healthcare subjects. In any other area, apart from computer science, students are less likely to study sciences than their UK counterparts.

The Horizon Panel work (See ICT and Advanced Materials) indicates that NI universities in physical sciences and engineering have seen a continuing decline in applicants since the 1990s. The situation is taken as a signal of broader problems with the education that students receive at school. In order to maintain student intake relative to other subjects, departments have adapted either by lowering entry requirements or by offering new courses combining traditional scientific content with other areas of study. This can either lead to lower output standards, or to courses becoming highly pressured with less time for personal development and creative or innovative thinking. The current situation is of great concern and is unsustainable if trends continue.

The Further Education sector faces a different range of problems recruiting students into science subjects, as it has struggled to offer qualifications and courses which are seen as appropriate.

NI and the skills that make exploitation possible

In the Benchmarking chapter, the point was made that while NI continues to have high rates of participation in higher education, student migration away from NI continues to persist with up to 30% of NI students moving away to take their degree and not returning. Often the cap on higher education places in NI is blamed on forcing students to study away from the region. However, the evidence presents a different picture:

- The students who leave tend, on average, to be better qualified in terms of 'A' level scores than those that remain in Northern Ireland;
- The vast majority of those that leave do so to secure their first choice course as revealed during the application process;
- Those students who leave NI tend to be drawn much more heavily from the higher socio-economic groups;
- The proportion of NI students leaving NI for a position elsewhere has been declining since 1996/97; and
- The proportion of NI students who study in GB and return after graduation has stayed more or less constant since 1996/97.

While there is emerging evidence that the proportion of NI students leaving the region is declining, the 'brain drain' problem is still significant. Because these students' departure from NI appears to be more out of choice as opposed to being a result of necessity brought about by an inability to secure a place in a NI university, this situation poses particular challenges for the economy.

109. JCQ data

12.5 RECENT DEVELOPMENTS THAT SUPPORT TECHNOLOGY TRANSFER IN NI

Throughout this report it is recognised that Knowledge Transfer activities are the processes by which knowledge, expertise and skilled people transfer between the research base and its user communities to contribute to economic competitiveness, effectiveness of public services and policy, and quality of life. Within NI, the universities, as the largest practitioners of research in the country, have a particularly important contribution in this respect. In this regard, it is worthwhile noting the

Higher Education Innovation Fund
This is the Department for Employment and Learning's funding tool for promoting knowledge sharing and technology transfer. The objective of HEIF is to encourage the higher education sector to increase their capability to respond to the needs of business (including companies of all sizes) and the wider community, with a clear focus on the promotion of wealth creation. The long term aim of this funding is to improve NI's innovation performance as a key element in raising productivity and delivering economic growth. HEIF is supported by INI and DEL and the first round of funding took place in 2004 with £9 million allocated over a three year process. This first round is coming to completion at the time of this report. The HEIF evaluation was completed and a second round of funding has been completed. HEIF reflects wider UK Government policy which supports the establishment of permanent and predicable funding streams for university-based Knowledge Transfer activities thus allowing HEIs to plan and retain key staff.

Higher and Further Education Collaboration Fund - Connected
Connected was launched in 2007 as a pilot to enable the HE and FE sectors identify and meet the knowledge transfer needs of businesses and the wider community in a coordinated and holistic fashion. The programmes runs for three years with a budget of £1 million per annum and will be delivered by Queen's University Belfast and the University of Ulster, in partnership with the Association of Northern Ireland Colleges. This funding complements the existing HEIF in that the core knowledge transfer or 'Third Stream' activities of the Universities are supported. This concept is founded in the Regional Innovation Strategy (RIS) as well as being aligned

Collaboration between the FE sector and the universities is firmly grounded in the recommendations of the Regional Innovation Strategy and is fully aligned with the DEL Skills Strategy (Success through Skills). Although in pilot stage, it is envisaged that this programme would become a permanent structure in the NI innovation landscape.

12.6 TECHNOLOGY TRANSFER IN NI

Nonewithstanding the new initiatives outlined in section 12.5 above, a key finding in this report is the inability to transfer or exploit new ideas and approaches within industry. It is recognised that this may be rectified once the initiatives in section 12.5 are underway and operational (Connected commenced in 2007 only). In general, feedback during this project outlined that Technology Transfer is extremely important to NI business and that this can be achieved in a variety of ways, including the application of greater creativity to business planning, the use of design, the promotion of innovative business practices (especially in smaller SMEs) and through the establishment of cross-sectoral business networks and clusters for firms of all sizes through which to transfer and disseminate knowledge, experience and best practice.

Central to a truly innovative economy is a strong and commercially focused R&D base and the successful exploitation of internationally competitive science and technology by industries focused on future business trends. However, R&D is only one aspect, and increasingly, innovation is no longer seen as the preserve of a small elite of companies working in high-technology sectors and investing in costly R&D programmes. The innovation agenda is relevant for all NI firms, irrespective of industrial sector or size.

In an increasingly competitive global economy, the application of innovation has become a necessary precondition for competitive performance. NI can no longer compete on low wages and costs. Identification and differentiation of regional innovation and R&D capabilities is the basis for economic growth, particularly for small regional economies such as NI that are endeavouring to become more knowledge based.

This report perceives a market failure. Underinvestment in R&D and innovation is due to uncertainties concerning the outcomes and appropriateness of such investments and a degree of government intervention is required to realise the knowledge spillovers that stem from R&D and innovation, thereby resulting in benefits to the economy as a whole[110].

Throughout this study on capabilities, most stakeholders recognised that improving and enhancing NI's overall innovation and R&D performance will lead to increased productivity and prosperity, moving the NI economy up the value-added chain. Failure to do so will, at best, result in moderate economic performance and failure to secure the goal of closing the productivity gap with the rest of the UK. In order to accomplish this, some significant 'framework' issues appear to need to be addressed:

In this study, we show that the proportion of NI firms engaged in innovation increased significantly (see SMEs above). During 2002-2004 around 56% of firms in NI undertook some form of innovative activity - a level similar to the UK average. However, a key determinant of innovation performance is firm size, with large firms more innovative than their SME counterparts. The most significant differences lie in wider innovation, such as changes to business structure, marketing strategy and management techniques. A key challenge for NI is therefore to stimulate innovation within smaller companies. This will mean encouraging SME business growth and overcoming the perception amongst NI business people that innovation and R&D is a cost rather than an investment offering significant long-term benefits.

Although NI's innovation propensity is similar to that of the UK, it is currently ranked eleventh of the twelve UK regions in terms of BERD (please see Benchmarking Chapter 8). A significant step change is required for NI to close the gap and it has been estimated that, in terms of BERD, a further investment of £184 million per annum is needed for NI to converge with the UK average.

NI HERD, at 0.6% of GVA, is above the UK average of 0.4%. It is apparent from all sectors however, that businesses are making adequate use of the R&D being carried out within the HE sector. NI businesses need to become more proactive in exploiting the HE R&D base and in working with HE institutions in more and better collaborative R&D. The ratio of HERD to BERD suggests that NI's innovation system is essentially supply-driven, a common characteristic of lower income regions that have few large indigenous companies. NI must develop the demand side of its innovation system and this needs to be done quickly.

Most companies and institutions visited, outlined high costs as being a primary barrier to investing more in innovation or R&D. Many smaller firms trading in more traditional sectors in NI (SP&C) do not see innovation related activity as an intrinsic aspect of their business planning.

As outlined in the section on SMEs, many NI companies have concerns that government's support programmes are not wholly aligned with the needs of particular business sectors or are too bureaucratic to deliver assistance in the tight timeframes usually associated with R&D-led projects. Greater awareness of the availability of innovation and R&D support programmes (in addition to existing Tax Credits) would be important to develop. For SMEs, some form of tax incentivised investment funding, of a private equity nature, would also be useful.

In many sectors, outside of the top 10 - 15 companies, businesses are often unwilling or unable to carry out effective future planning through horizon scanning 'Foresight' activities. Efforts to promote Foresight planning to NI industries have been made over the past decade, with some success. Firms will continue to be encouraged to recognise that forward planning and horizon scanning is necessary if they are to be in a position to exploit new

110. Search for Spillovers - The RTD Centres of Excellence

business opportunities as they arise. It could be useful to structure this by sector.

In the skills sector in this chapter, there is an open acknowledgment from industry that a broader range of skills is required to encourage innovative thinking as a core skill. Although believed to be an inherent skill, this is a learned management skill reflecting a comprehensive understanding of innovation or enterprise. NI firms tend to under-invest in relevant staff training and offer too few staff development opportunities in terms of innovation and R&D (it is unclear if there is a career path for researchers within NI). It is fully acknowledged that many of these issues are not new and there are already a number of initiatives aimed at addressing many of these issues. These extend from changes in the curriculum and the implementation of the NI Skills Strategy. It is recognised that the development of innovation skills in NI businesses will continue to be a key challenge to be overcome in progressing NI's future knowledge economy and that businesses themselves must lead in the development of these skills, through closer association with the education and vocational training sectors.

The interaction between NI business and the HE-FE sector has grown significantly during the past decade[111], but it is clear from the capabilities mapping that there remains much room for improvement. The universities, in particular, have made noteworthy efforts to open their R&D pipelines to commercial exploitation opportunities. This is demonstrated in the Advanced Materials and Life Sciences sectors in particular. Business, on the other hand, needs to do more to engage with the HE community in a more proactive fashion in order to 'pull' through more and better commercially realisable R&D. From the SME analysis, it is understood that smaller businesses are less likely to have either the capability or the awareness of the possibilities inherent in working directly with universities. However, more connectivity between SMEs and the FE colleges at sub-regional level will be encouraged, firstly to provide the relevant skills to service the needs of local industries, and secondly to create a culture of collaborative working which will ultimately offer a form of brokerage between businesses and the HE-FE sector. In particular, support must be continuously directed to ensuring FE Colleges have the resources to provide business-facing services.

Finally, as discussed in the SME section of this chapter, the absorptive capacity (i.e. the ability of a firm to internalise external knowledge) is also highly important in determining whether an establishment engages in R&D spending. From the evaluation of SMEs, it appears that the lower levels of absorptive capacity within NI actually increase the costs of collaborative technology partnerships between the universities and the companies involved. This 'disconnect' needs to be openly addressed as it is a clear market failing.

111. Search for Spillovers - The RTD Centres of Excellence

ANNEX A
RESEARCH DATABASE

A

A.1 INTRODUCTION

The following tables list and detail the research capability that exists across NI's Higher Education sector that is applicable to the six sectors addressed in the frame of this activity. Where available their most recent Research Assessment Exercise (RAE) scores (those from 2001) are also listed as this provides a useful measure of the extent of their capability. Each research cluster or institute has also been given a unique numerical identifier as the basis for cross-referencing their capability into the main body of the report.

A.2 OVERVIEW OF RAE SCORES

RAE scores are used as the basis by which the quality of research in HE institutes throughout the U.K. is measured. The following table lists the grades attainable in the most recent exercise (2001) and provides an associated description. Note; the results for RAE 2008 will be available in December 2008. The scoring system will have changed, e.g. the highest attainable score is 4*.

TABLE A.1: RAE GRADE DESCRIPTION

GRADE	DESCRIPTION
5*	International excellence in more than half of the research activity submitted, and national excellence in the remainder.
5	International excellence in up to half (11-50%) of the research activity submitted, and national excellence in virtually all (>90%) of the remainder.
4	National excellence in virtually all (>90%) of the research activity submitted, and some evidence of international excellence (approximately 10%).
3a	National excellence in more than two-thirds of the research activity submitted, and possible evidence of international excellence.
3b	National excellence in more than half of the research activity submitted.
2	National excellence in up to half (11-50%) of the research activity submitted.
1	National excellence in none, or virtually none (<10%) of the research activity submitted.

A.3 QUEEN'S UNIVERSITY BELFAST (QUB)

In total there are twenty-one research led schools and some ninety clusters at QUB, however in the frame of this activity we have identified ten schools and some forty-three research clusters to be applicable. Each of these is described, in turn, in the following table.

KNOWLEDGE TRANSFER (BODIES WITH A CLEAR KNOWLEDGE TRANSFER REMIT)

INDUSTRIAL SERVICES - KNOWLEDGE TRANSFER

NUMBER 1: NI TECHNOLOGY CENTRE

NITC is located in a 1600 sq. metre purpose built facility on the Queen's University of Belfast campus. It operates as a practical experience centre dedicated to technology transfer only. The Centre is self-financing with income from industrial services providing 95% of its £2.5 million annual turnover. The remainder is derived from a University grant to support student training and capability building. The full-time staff includes 33 engineers, designers and technicians. The aims and objectives of the Centre are to:

- Provide effective technology transfer to industry and academe;
- Ensure maximum use of today's technology today;
- Provide a centre for good practice in CADCAM technology;
- Operate an effective product and process development centre for local small/medium enterprises;
- Keep key industrial staff aware of new technology;
- Prepare engineering students for industry.

The Centre has a number of Divisions providing services in the following complementary areas:

Automation.
There is a design consultancy for Special Purpose Machinery and Electro-Magnetic Compatibility (EMC) characteristics of new products or processes;

Design.
There are CAD/CAM/CAE facilities that are used for research and for teaching purposes;

Manufacturing
There are Advanced Manufacturing Technologies used within the facility. The facilities extend to

- CNC Programming and turning;
- 3 Dimensional Milling;
- Electrical Discharging Machining;
- Measuring and Digitising;
- Robotics - handling and assembly.
- Product Design and Development:

This centre encourages and assists the uptake of modern product design and development techniques in all sectors of industry. It utilises local expertise in complimentary areas and integrates them into a unique facility capable of addressing industry's product development issues at a range of levels.

- Computer aided design and analysis
- Data exchange
- Product design
- 3D animation and rendering
- Rapid prototyping
- Rapid tooling
- Reverse engineering (3D scanning)

The centre assists local companies (almost 200 to date) in becoming more competitive by enabling them to reduce their product development cycle times. By facilitating access to expertise and prototyping resources individuals and companies of all sizes can use the same modern techniques employed by leading manufacturers. Significantly, there are a range of prototyping technologies on site:

- Stereolithography (3D-Systems SLA 250);
- Fused Deposition Modelling (Stratasys FDM1600);
- Vacuum Casting in polyurethane using silicone tooling;
- CNC machining (including continuous 5-axis milling); and
- Secondary processes for converting stereolithography models into full engineering prototypes in a variety of materials.

QUEENS UNIVERSITY BELFAST

INDUSTRIAL SERVICES - KNOWLEDGE TRANSFER

NUMBER 2: POLYMER PROCESSING RESEARCH CENTRE (PPRC)

The PPRC was established in 1996 with the aim of providing expertise and facilities to improve the research and development capabilities of the plastics processing industry at home and abroad. As a result of having state-of-the-art facilities and access to vast expertise the centre has received substantial funding for its research projects.

The PPRC builds on well established expertise at Queen's in rotational moulding and polymer extrusion by extending into complementary research areas of injection moulding, blow moulding and thermoforming. A comprehensive testing and analysis facility, to service industrial requirements and support research projects forms an integral part of the Centre.

The PPRC provides the expertise and facilities required to undertake fundamental and applied research in polymer processing, reflecting the priorities of the plastics industry. It covers all aspects of polymer processing including studies on: morphology, micro-structure, process control, rheology and physical properties.

The technical capabilities of the facilities are immense and much of the equipment is cutting edge including the Arburg injection moulding machine and Gas Assisted Moulding technology. This equipment, combined with extensive MoldflowTM software capabilities, have made the PPRC a 'one-stop-shop' for the injection moulding industry. Many of the centres labs also have such cutting edge equipment.

In the area of Thermoforming, success in initial investigations into the forming of polypropylene, coupled with significant financial support from local industry has recently led to the award of a major EPSRC grant.

The Rotational Moulding Research Centre is regarded as the world's leading research facility in this subject area and It has developed many important patented products and processes that have revolutionised the rotational moulding industry. One such product is the Rotolog process controller, which significantly improves product quality and reduces cycle time. Processes have also been developed to improve internal and surface pinholing, previously considered to be unavoidable defects in rotationally moulded products.

QUEENS UNIVERSITY BELFAST

INDUSTRIAL SERVICES - KNOWLEDGE TRANSFER

NUMBER 3: KNOWLEDGE TRANSFER CENTRE

The Knowledge Transfer Centre was established in Queen's, in 1993, to provide a focal point and support for the promotion of technology transfer activities, in particular to increase the involvement of small and medium sized enterprises (SMEs) in innovative collaborative projects through Knowledge Transfer Partnerships. Since then, the Centre has supported over 200 Partnerships and is now the top Centre in the UK.

Knowledge Transfer Partnerships offer a unique way of allowing companies to realise their core strategic objectives. The company employs, through a university, a recently qualified graduate to manage challenging projects central to the development needs of participating companies. The company gets the latest know-how available at a reasonable price, whilst the graduate gets valuable experience managing a strategically important project.

The Knowledge Transfer Centre is managed by Technology Transfer & Innovation Ltd on behalf of the Department of Trade and Industry (DTI) and 10 other Government Sponsors. These include among others; DEFRA, Department of Health, The Economic and Social Research Council, The Engineering and Physical Sciences Research Council and Invest NI.

Current projects include;

- To design, develop and implement a manufacturing process for a certified product to allow the company to compete in the expanding fire retardant glass market.
- To improve the design and navigability of a portal site, which will enhance the company's ability to sell and support its online products, as well as integrate the online side of the business with the company's core activities.
- To design and develop SVG front end for existing Java based airline Flight Crew applications.

QUEENS UNIVERSITY BELFAST

INDUSTRIAL SERVICES - KNOWLEDGE TRANSFER

NUMBER 4: QUESTOR

The QUESTOR Centre is an exciting and dynamic international environmental research co-operative that serves a select membership made up of environmental regulators and environmentally responsible companies, ranging in size from large multi-national corporations through to forward looking SMEs. QUESTOR provides member organisations with a highly focussed environmental research programme, delivered by a multi-disciplinary staff at world class environmental research institutions.

Questors areas of expertise include:

- Remediation technologies (water, soil, air)
- Water/wastewater treatment processes (biological, chemical, physical, thermal, plasma)
- Environmental genomics
- Environmental monitoring and analysis
- Waste management and recycling
- Environmental modelling (emissions, odour, noise, dust, air quality)
- Pollution prevention (‘Green chemistry’)
- Environmental communication
- Renewable energy, including bioenergy (particularly energy from waste)

Established in 1989, the QUESTOR Centre is Europe’s only Industry/University Co-operative Research Centre (I/UCRC). QUESTOR has been formally linked to the NSF Programme since its formation in 1989. The centre provides member companies and organisations with environmental research programmes focussed on their specific needs. In addition the Centre has developed a unique model for the transfer of technology and knowledge to member organisations and for the commercial exploitation of research in general. The QUESTOR Centre is now an international multi-University Centre with a network of member companies and organisations that decides both the direction of the research effort and the specific research projects that are funded. Dublin City University became the first partner institution with Queen’s University in November 2005, and the Stevens Institute of Technology joined in 2006. QUESTOR is currently negotiating with other potential academic partners in Australia, Canada, Europe and South Africa.

QUESTOR also has an Applied Technology Unit (ATU) that offers a range of services to several hundred clients for the past 16 years.

The three main service areas include;

- Environmental monitoring with results interpretation and support.
- Technical Support
- Product Development

QUEENS UNIVERSITY BELFAST

RESEARCH AND DEVELOPMENT (INSTITUTIONS WITH AN R&D REMIT AND MAY POSSESS SOME KNOWLEDGE TRANSFER CAPABILITY)

The Institute of Electronics, Communications and Information Technology (ECIT)

ECIT was established in 2003 to commercialise world-level expertise in a variety of enabling digital communications technologies at the School of Electronics, Electrical Engineering and Computer Science at Queen's University Belfast.

The institute's 14,000 sq m headquarters building houses state-of-the-art laboratories, offices and one of the largest RF (microwave and millimetre wave) anechoic chambers in Ireland. It is staffed by 120 academics, senior research staff, post-doctoral fellows, research students and administrators. Among them are 40 highly qualified industrial and academic researchers recruited from around the globe. In addition, TDK - the Japanese electronics company - has located a six person R&D unit in the new building. Its four research clusters cover the following:

NUMBER 5: HIGH FREQUENCY ELECTRONICS CIRCUITS

ECITS division is one of the largest groups of its kind in the UK and Ireland. Research at its state-of-the-art laboratories is focused on developing novel generic solutions to advanced problems associated with wireless front-end technology.

The lab has cutting edge equipment for; vector network analysis, on wafer probing, on-chip temperature measurement; noise measurement, and vector signal analysis.

This work covers many related aspects ranging from custom high performance gallium arsenide and sub micron silicon integrated chips to self adapting antenna solutions, monolithic packaging strategies as well as analytical and computational electromagnetics. The major research projects aligned with these areas of activities aim to provide associated enabling solutions for next generation mobile wireless products.

There are a number of research projects running at the moment including:

- Low cost antenna arrays and added functionality front end technology
- Non-linear device modelling and MMIC circuit design
- Advanced electromagnetic material development
- Liquid crystal phase shifters

QUEENS UNIVERSITY BELFAST

THE INSTITUTE OF ELECTRONICS, COMMUNICATIONS AND INFORMATION TECHNOLOGY (ECIT)

NUMBER 6: SYSTEM ON CHIP

The research aspiration of the SoC Architectures and Programmable Systems cluster is to challenge the widening technology and data processing gap that exists for emerging and future services and applications of converging information and communication technologies. The research is targeting the creation of novel SoC architectures, SoC design methodologies, and programmability of systems that will meet the real-time computational and flexibility demands of current and future systems.

The SoC research cluster is involved in collaborations with various universities i.e. University of Manchester, University College Cork, University of California as well as a number of specialist electronics companies including; Communications Security Group - Germany, Conexant Systems Inc - Belfast, Salex SES - UK, US and Italy and Gedae Inc - US. Major fields of research are:

- Cryptographic research
- Architectures for Video and Signal Processing
- Network Processing

QUEENS UNIVERSITY BELFAST

THE INSTITUTE OF ELECTRONICS, COMMUNICATIONS AND INFORMATION TECHNOLOGY (ECIT)

NUMBER 7: DIGITAL COMMUNICATIONS

The Digital Communications Group conducts research into advanced networks, digital signal processing, programmable systems and networks, radio communications, telecommunications software and wireless networks. The research covered by this cluster is wide and varied and aims to leverage the huge opportunities of digital media to enhance the quality of life for people.

Areas of current research include;

- Programmable routing strategies for multi-hop wireless networks
- Advanced wireless networking functions
- Solutions for streaming media on future programmable IP networks
- Bio-medical signal processing
- Multiple-input multiple-output (MIMO) wireless communications
- Co-operative (relay), sensor and ad hoc networks
- Hardware accelerated IP packet classification for terabit networks
- Ultra-wide-band wearable smart antennas

QUEENS UNIVERSITY BELFAST

THE INSTITUTE OF ELECTRONICS, COMMUNICATIONS AND INFORMATION TECHNOLOGY (ECIT)

NUMBER 8: SPEECH AND VISION

The Speech and Language Processing Group conducts research into speech modeling, speaker modeling and dialogue modeling to advance the design of robust spoken language systems.

Applications include speech control of household devices, mobile phones and PDAs as well as speech-driven access to remote information. Applications being addressed by this work are video surveillance for defense and civil security (CCTV); image verification and validation for the broadcasting industry; and tumour definition for radiation therapy planning and cancer diagnosis.

The research carried out in the speech and vision cluster can offer real benefits to the everyday user, such as enhanced security via voice recognition operated locks. The group is exploring the use of audio-visual speech recognition, in which lip-tracking is combined with analysis of the acoustic signal to further improve recognition accuracy. Other future security benefits could come from enhanced video surveillance technologies developed here including an artificial vision system that will cue a human analyst when it detects something of interest in the video. To that end, a system for moving object detection and tracking (ModTrack) has been developed as a research enabler.

QUEENS UNIVERSITY BELFAST

SCHOOL OF BIOLOGICAL AND FOOD SCIENCES (RAE GRADE 4 - BIOLOGICAL SCIENCES)

NUMBER 9: MOLECULAR BIOLOGY RESEARCH GROUP

The primary focus of the Molecular Biology Research Group is that it provides a broad platform of fundamental and applied expertise in the biosciences, including: molecular biology; cell biology and cell signalling; microbial biochemistry and genomics; stress metabolism; bioremediation; parasite biology, physiology and therapeutics; protein biochemistry, expression and engineering; peptide/protein modelling and synthesis; nucleic acid structure and function; bio imaging.

The Molecular Biology Research Group has a large team of research staff whose areas of expertise are wide and varied including; parasite ultrastructure and neurobiology, parasite drug resistance, structure and function of nucleic acids, protein engineering and molecular modelling, genetics of micro-organisms, stress mechanisms and responses in microbial cells and ecosystems, cell biology, cell signalling and receptors.

This diverse array of interests, ranging from protein modelling, through microbiology to parasite control, is linked by common approaches within the molecular biosciences that are aimed at exploiting the ongoing genomic, transcriptomic/proteomic revolution. The group has a wide range of strong international linkages and the molecular microbiology component is heavily involved with QUESTOR.

QUEENS UNIVERSITY BELFAST

SCHOOL OF BIOLOGICAL AND FOOD SCIENCES (RAE GRADE 4 - BIOLOGICAL SCIENCES)

NUMBER 10: AGRI-FOOD AND LAND USE

Agri-food is increasingly operating in a global market for production, processing and distribution. In addition, the importance of sustainability in relation to environmental quality, particularly for rural areas, is of increasing concern. Nutrition, diet and health, chemical engineering, biomedical sciences, biochemistry, environmental planning and management and economics are areas that need continuing research to achieve a sustainable and profitable future for N. Irelands Agri-food sector.

Research carried out in this institute concentrates on three complimentary themes;

Food Safety
Which concentrates on Drug research, Toxin Research and Microbiology

Human Nutrition and Health
Which has concentrated on food processing and anti-oxidant activity generation, food and nutritional metabolomics, the development of therapeutic metabolomics.

Rural and Environmental Economics
Research in this sector has been in the fields of urban land use and economics and management, economics and valuation of environmental health safety and risk and methodological research in environmental valuation and application of economic experiments to environment and land use.

All research is undertaken in the institutes newly (2006) built facilities.

QUEENS UNIVERSITY BELFAST

SCHOOL OF BIOLOGICAL AND FOOD SCIENCES (RAE GRADE 4 - BIOLOGICAL SCIENCES)

NUMBER 11: ECOLOGY AND EVOLUTIONARY BIOLOGY

The Ecology and Evolutionary Biology team covers a wide and varied field of research including; Ecology, Ecophysiology Animal Behaviour, Molecular Ecology and Conservation etc. This diverse range of interests is linked by common approaches including the integration of theoretical, laboratory and field investigations.

Research facilities include the QUB Marine Laboratory at Portaferry, which hosts C-Mar, the Centre for Marine Resources and Mariculture. C-Mar was instrumental in a recent project to re-introduce the European flat oyster (Ostrea edulis) to its native habitat of Strangford Lough. Strangford Lough historically supported a productive native oyster fishery but a combination of over-exploitation and neglect meant that the fishery had ceased to exist as a commercial entity around 1900. Broodstock were also collected to be sent to Seasalter hatchery for production of 100,000 spat. Experiments on best culture sites, methods and conditions were be carried out. This data will enable C-mar to judge the success of the restocking programme (in 1996-1997) and will provide baseline data to assess the success of this current restocking programme in the future. This is typical of the research carried out by C-Mar.

QUEENS UNIVERSITY BELFAST

SCHOOL OF BIOMEDICAL SCIENCES (RAE GRADE 5 - CANCER STUDIES)

NUMBER 12: CANCER RESEARCH AND CELL BIOLOGY GROUP

The Centre's aims in experimental medicine are to drive the development of phase I and II trials, to facilitate the translation of pre-clinical ideas into the clinical arena and back, and to co-ordinate the collection of clinical samples. Two Cancer Research UK first-in-human (FIH) phase I trials, the first such studies in cancer on the island of Ireland, have recently completed in Belfast and have lead to the development of phase II programmes. Another promising FIH phase I study exploring nanotechnology drug delivery has just opened and will add to increasing activity in early clinical trials.

This cross faculty and multi-disciplinary group has over 300 clinical and basic researchers who are committed to the highest quality of research excellence. Their focus is to develop new avenues for the prevention, diagnosis and treatment of cancer.

The range of activities spans investigators from many disciplines ranging from Chemistry and Mathematics to Pharmacy to basic Molecular Cell Biology, Molecular Virology, Immunology and Parasitology to clinical disciplines such as Pathology, Haematology, Surgery and Oncology. The group have used SPUR funding to set up core technologies which are state-of-the art units for providing critical infrastructure support for the programmes and also are available to Academic staff outside the CCRCB and are potentially available to workers outside the University.

QUEENS UNIVERSITY BELFAST

SCHOOL OF BIOMEDICAL SCIENCES (RAE GRADE 5 - CANCER STUDIES)

NUMBER 13: CENTRE FOR VISION SCIENCE (CVS)

CVS research is multidisciplinary in nature, with an integrated mixture of approaches ranging from basic cell and molecular biology, pathophysiology of disease, genetic analysis, protein chemistry, patient-based investigation and clinical trials.

The primary research focus of CVS is on major sight-threatening diseases of the retina. Retinal degeneration and retinal vascular diseases represent the major causes of blindness in the United Kingdom. Most current studies are concentrated on conditions such as diabetic retinopathy, proliferative retinopathies, age-related macular degeneration and single gene degenerative disorders, a focus which is further narrowed by the fact that all these diseases share aetiological features and neovascular complications. Within this unified theme are embodied laboratory-based cell and molecular studies in parallel with genetic, epidemiological and other clinical approaches, each of which is directly related to elements within at least one of the other disciplines. There is also an active programme in the area of visual disability and rehabilitation. The Centre for Vision Sciences has recently refurbished a 1000 square metre, £3M ophthalmic research facility at the Royal Victoria Hospital, which incorporates state-of-the-art cell biology laboratories, sophisticated molecular biology facilities, a microscopy suite and histological services. The centre has cell culture facilities, a dedicated radioisotope laboratory, patch-clamp and calcium microfluorimetry rigs, flow cytometry, confocal microscopy, transmission electron microscopy, 2-D SDS-PAGE, HPLC, mass spectroscopy, image analysis suite, bioinformatics workstations and real-time PCR

QUEENS UNIVERSITY BELFAST

SCHOOL OF CHEMISTRY AND CHEMICAL ENGINEERING (RAE GRADE 4 - CHEMICAL ENGINEERING)

NUMBER 14: CENTRE FOR THE THEORY AND APPLICATION OF CATALYSIS (CENTACAT)

CenTACat undertakes multidisciplinary research involving chemists, physicists and engineers with a common interest in understanding the fundamental principles that underpin clean energy production, clean organic chemistry, and environmental protection.

The core competencies in CenTACat, range from computation (the application of density functional theory and computational fluid dynamics) through synthesis (inorganic and organic chemistry) and kinetic evaluation (physical chemistry and engineering) to intelligent systems and process control and process engineering (E&E and mechanical engineering) creating a 'one-stop' capability to address challenging scientific and engineering problems.

The centre boasts a large arrays of modern equipment including; a fourier transfer infared spectrometer, powder x-ray diffractrometer and a temporal analysis of products reactor.

The centre has also published many papers on Catalysis including;

- Hydroisomerisation of n-alkanes over partially reduced MoO3: Promotion by CoAlPO-11 and relations to reaction mechanism and rate-determining step
- On the need to use steady-state or operando techniques to investigate reaction mechanisms: An in situ DRIFTS and SSITKA-based study example
- Solution state coordination polymers featuring wormlike macroscopic structures and cage-polymer interconversions
- Polar self-assembly: Steric effects leading to polar mixed-ligand coordination cages.

QUEENS UNIVERSITY BELFAST

SCHOOL OF CHEMISTRY AND CHEMICAL ENGINEERING (RAE GRADE 4 - CHEMICAL ENGINEERING)

NUMBER 15: INNOVATIVE MOLECULAR MATERIALS (IMM)

IMM is focused on understanding, characterising and controlling the properties of molecular materials, many of which have mesoscale (nm- mm) structure.

The main interests of the group are in the preparation and characterisation of innovative materials, particularly through laser based methods. The primary characterisation method is Raman spectroscopy, which provides detailed structural information on even the most challenging compounds and chemical systems. This involves extensive collaborations both with other academic research groups and commercial/governmental organisations.

A real-life application of the centres research has achieved considerable commercial success. The Fluorescent PET sensor design was used as the platform of a portable diagnostic tool - a blood gas analyzer for hospital critical care units and ambulances. The specific sensors for sodium, potassium and calcium were designed, synthesized and tested in collaboration with scientists at AVL Bioscience Corporation, Roswell, GA. The product was rolled out in 1997 and has been sold by AVL, Roche Diagnostics and OSMETECH in turn. The total sales of the sensor cassette are around $40M US so far.

QUEENS UNIVERSITY BELFAST

SCHOOL OF CHEMISTRY AND CHEMICAL ENGINEERING (RAE GRADE 4 - CHEMICAL ENGINEERING)

NUMBER 16: SYNTHESIS AND BIOLOGICAL ORGANIC CHEMISTRY (SYNBIOC)

SYNBIOC provides a unique environment for innovative training of synthetic chemists in order to facilitate their integration into the ever-evolving world of interdisciplinary research at the Physical and Life Science interface. To achieve excellence in interdisciplinary research of this type, the hands-on and taught training activities maximise acquisition of expertise in the fields of organic synthesis, medicinal chemistry, spectroscopy, enzymology, biology and biotechnology.

The work involves the development of novel chemical methodologies that allow the efficient synthesis of a variety of protein binding substances including purine, nicotinamide, sugar, inositol, nucleotide, and dinucleotide derivatives. To obtain information on these biological processes, we develop new synthetic methodologies to prepare biologically active molecules. Production of new chemical species exhibiting specific enzymatic affinity is the principal focus of this work.

Research is centred on the application of methods of X-ray structure analysis, database searching, theoretical, computational and modelling methods to problems of geometry and stereochemistry, particularly in organic molecules. The School has a Bruker AXS SMART CCD single-crystal X-ray diffractometer, a Siemens P4 four-circle single-crystal diffractometer, a PANalytical X'PERT PRO variable-temperature X-ray powder diffractometer and a wide range of high performance workstations with full molecular modelling packages. The technique of choice is single-crystal analysis and particularly the application of anomalous dispersion methods to the determination of absolute structure.

QUEENS UNIVERSITY BELFAST

SCHOOL OF ELECTRONICS, ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
(RAE GRADE 5 - ELECTRICAL AND ELECTRONIC ENGINEERING)
(RAE GRADE 4 - COMPUTER SCIENCE)

NUMBER 17: ELECTRICAL POWER AND ENERGY SYSTEMS

The main interests of this research group are:

- modelling, operation and control of power plant and power systems,
- development of wind and wave energy systems
- electrical machine design and control.

In particular, expertise has been developed in neural networks, fuzzy logic and local model networks for parallel modelling and on-line control. The group has also developed an interest in artificial intelligence techniques for supervisory control and management information systems, the most recent dealing with plant efficiency. A close relationship with industry both locally and internationally has been formed.

The power engineering research group at Queen's has been engaged in many aspects of this activity. There is considerable emphasis on the application of advanced control technology to large-scale generation and transmission plant, with the objective of improving efficiency, flexibility and supply quality. Power systems work is concerned with economic operation and stability, and with the various issues raised by embedded generation. The work on renewables has concentrated on wave power, while the fundamental study of electrical machines continues, with the emphasis on alternator design and the development, via power electronics, of effective induction generators. The extensive support from the manufacturing and supply industry is detailed below.

There is a thriving wave-power group within the university encompassing aeronautical, civil, mechanical and electrical engineers. Queen's University is one of the few universities that own and operate a pilot wave-power station, which is situated on the west coast of Scotland on the Island of Islay.

QUEENS UNIVERSITY BELFAST

SCHOOL OF ELECTRONICS, ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
(RAE GRADE 5 - ELECTRICAL AND ELECTRONIC ENGINEERING)
(RAE GRADE 4 - COMPUTER SCIENCE)

NUMBER 18: HIGH PERFORMANCE AND DISTRIBUTED COMPUTING

The primary aim of this research group is to bridge the wide gap between theory and practice of high performance and distributed computing.

The cluster is also involved in hand crafting algorithms and software to exploit the architecture of high performance and distributed systems, not only to advance the application domains, but also to provide realistic test bed applications of substance that can inform the development of appropriate abstract models of computation. The ultimate aim is to develop serviceable models which can be used in the disciplined development of robust, efficient parallel applications software: proof-of-concept will be demonstrated using the test bed applications. There are two main areas of research;

Grid Computing
This research programme has two main themes. The first is primarily concerned with the design and implementation of an abstract programming model for middleware and its application in a range of applications.

Specific areas of interest include:

- investigation of the semantics of new models of distributed computation, in particular, orchestration languages which may be used to exploit the computing resources available on the Grid;
- implementation of Grid simulators based on abstract programming models;
- investigation of autonomic adaptively of Grid components to differing environments;
- investigation of the usefulness of Grid computing in the context of iterative numerical computation.

High Performance Computational Science and Engineering
This multidisciplinary area is primarily concerned with developing algorithms and software to exploit high performance architectures in computational science and engineering domains. These high performance computing architectures are not only of intrinsic interest but also as powerful computational components within a heterogeneous Grid. A particular focus is the development of robust, high performance numerical software. Knowledge and experience gained in developing such software is useful in highlighting the strengths and exposing the weakness of abstract programming models.

QUEENS UNIVERSITY BELFAST

SCHOOL OF ELECTRONICS, ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
(RAE GRADE 5 - ELECTRICAL AND ELECTRONIC ENGINEERING)
(RAE GRADE 4 - COMPUTER SCIENCE)

NUMBER 19: INTELLIGENT SYSTEMS AND CONTROL (ISAC)

The main interests of this research group are :

- intelligent systems,
- industrial process monitoring and control,
- environmental monitoring and control
- virtual reality and robotics

Research at Queen's is concerned with both principles and practical applications, the aim being to link theoretical and technological advances with industrial requirements for intelligent systems and advanced control. There is therefore significant experience and expertise in aerospace, robotics and chemical process applications, as well as active collaboration with colleagues in the Power and Energy Systems group.

In recent years, the main research programmes have been as follows: Intelligent Systems, Industrial Process Modelling and Control, Virtual Reality and Robotics. Some research was also carried out on Environmental Monitoring and Control.

Projects on Intelligent Systems have produced progress on new training algorithms for neural networks, local model network based identification methods, and multiple-model approaches to bootstrap filtering and neuro-fuzzy Kalman filtering. These results have supported work on nonlinear model predictive control, intelligent instrumentation, manoeuvring target tracking and nonlinear autopilot design.

QUEENS UNIVERSITY BELFAST

SCHOOL OF ELECTRONICS, ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
(RAE GRADE 5 - ELECTRICAL AND ELECTRONIC ENGINEERING)
(RAE GRADE 4 - COMPUTER SCIENCE)

NUMBER 20: KNOWLEDGE AND DATA ENGINEERING

This group carry out research and/or applications in the areas of distributed databases, data mining, reasoning under uncertainty, scheduling and optimisation, adaptive software and environmental modelling.

The centre carries out original research and/or applications in the areas of distributed databases, data mining, reasoning under uncertainty, scheduling and optimisation, adaptive software and environmental modelling. Collaborative opportunities for work with other research groups the school are actively sought. The staff have developed strong links with other academic disciplines, for example Psychology, Sociology, Medicine and Engineering, and with a wide range of industrial collaborators and users.

QUEENS UNIVERSITY BELFAST

SCHOOL OF ELECTRONICS, ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
(RAE GRADE 5 - ELECTRICAL AND ELECTRONIC ENGINEERING)
(RAE GRADE 4 - COMPUTER SCIENCE)

NUMBER 21: SEMICONDUCTORS AND NANOTECHNOLOGY - THE NI SEMICONDUCTORS RESEARCH CENTRE (NISRC)

The NISRC is a centre of excellence for research and development in silicon technology, thin film technology and novel device structures. The Centre is set up as a versatile research laboratory rather than a dedicated IC production facility. This enables it to respond to an increasingly wide range of industrial needs.

The NISRC has recently entered the world of Nanotechnology forming part of the new £11 million Nanotech NI project in collaboration with Chemistry and Physics within QUB and the Nanotechnology Research Institute based at the University of Ulster Jordanstown. Employing state of the art technology such as E-beam Lithography, Atomic Layer Deposition (ALD), the centre aims to fabricate nanoscale devices and Nano Electro-Mechanical Systems (NEMS).

The Centre has a complete silicon processing suite suitable for the fabrication of 0.8 mm CMOS integrated circuits on 100mm diameter substrates and limited capability on 150mm wafers. For thin film work there is a wide range of PVD systems including dc and rf magnetron sputtering and EB evaporation. The Centre is set up as a versatile research laboratory rather than a dedicated IC production facility. This enables it to respond to an increasingly wide range of industrial needs.

Current research cover such areas include;
- UHV-CVD of Si1-X Gex for thin SOI and silicon HBTs
- Metallic ground planes and thermal vias for SOI applications
- CVD of tungsten and copper
- High density interconnects
- Thin Film Transistors on glass substrates
- mm wave components
- Clinical sensors
- Micro- and Nano-mechanical devices
- Soft magnetic layers
- Device Simulation

QUEENS UNIVERSITY BELFAST

SCHOOL OF MATHEMATICS AND PHYSICS
(RAE GRADE 5 - PHYSICS)
(RAE GRADE 3A - PURE MATHEMATICS)

NUMBER 22: ASTROPHYSICS RESEARCH CENTRE

The Astrophysics Research Centre (ARC) carries out research in a range of areas including stellar, galactic and solar systems. As a research centre ARC have access to large ground-based telescopes and space observatories including the European Southern Observatory, Gemini and the Hubble Space Telescope. There is also a programme on the study of laboratory plasmas and their astrophysical counterparts. The research is currently supported by several substantial PPARC and EPSRC grants.

Research areas include:
- Hot stars
- Nebulae
- Cool stars and the sun
- Super novae
- Astrochemistry
- Astronomical and laboratory plasmas

QUEENS UNIVERSITY BELFAST

SCHOOL OF MATHEMATICS AND PHYSICS
(RAE GRADE 5 - PHYSICS)
(RAE GRADE 3A - PURE MATHEMATICS)

NUMBER 23: ATOMISTIC SIMULATION[112]

The behaviour of materials and fluids depends on the motion of atoms and with the use of large computers the motion of atoms can be simulated. This has many uses including; creating new alloys, or understanding the dynamics catalysis in car exhausts.

The behaviour of materials and fluids depends on the motion of atoms, and we can simulate it with the help of powerful computers. Atomistic simulation is similar to an experimental science, only the experiments are done on completely clean materials under precisely controlled conditions of temperature and external pressure, such as may never be attainable in a laboratory. We study and understand a wide variety of systems in this way, such as oxide-metal interfaces, which are at the front line of corrosion, high-performance alloys, the dynamics of catalysis in car exhausts, and the complicated ways in which water acts as a solvent, to name but four.

Current research in this field is interdisciplinary because it crosses the traditional boundaries between chemistry, physics and materials science. The centre is working with physicists and chemists, theoretical and experimental, in Ireland and around the world, as it tries to understand solids, interfaces, surfaces and solutions from a fundamental point of view. Particular international collaborations at present are with research institutes in Stuttgart (Germany), Besançon (France), Bariloche (Argentina) and Sandia National Laboratories in Livermore (California).

Recent (2006) publications from the Atomic Simulation centre include:

- A phase-field model for computer simulation of lamellar structure formation in gamma
- Classical computation with quantum systems
- Simulation of the surface structure of butylmethylimidazolium ionic liquids
- Density functional theory study of tetrathiafulvalene and thianthrene in acetonitrile: Structure, dynamics, and redox properties
- Simple models of complex aggregation: Vesicle formation by soft repulsive spheres with dipolelike interactions.

112. Originally classified under Advanced Manufacturing, this centre was reclassified on request of Prof. Bowman.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MATHEMATICS AND PHYSICS
(RAE GRADE 5 - PHYSICS)
(RAE GRADE 3A - PURE MATHEMATICS)

NUMBER 24: CENTRE FOR NANOSTRUCTURED MEDIA (CNM)

CNM is investigating the science and development of a series of technologies that are based on nano-structured substrates, which integrate nano-scale ferroelectrics, nano-magnetics, nanotubes and nano-optics and plasmonics to create new media and processes for advanced data-storage and information processing applications.

The CNM team of researchers is at the forefront of this science and technology. The development of new media and their potential exploitation in commercial devices is also relevant to the work carried out by the staff. The main aim of the CNM research is to contribute to the development of media and processes for advanced data storage and information processing applications CNM have clustered their research into two themes and an enabling technology.

Nanoscale functional materials and devices
Nanophotonics and plasmonics
CNM's strategy is simple, two-fold and takes into account the life-cycle of technologies and the desire to perform useful research.

Near-term research
In the near term (5-10 years), as a University based research grouping CNM should not compete with leading international and multi-national companies with huge research portfolios - here CNM will develop partnerships to suit mutual needs.

Long-term research
Looking out towards 10 years and beyond, we have to be at the forefront of research developing new processes, media and associated intellectual property in our areas of research strength, capability and expertise.

CNM's research is housed in a wide range of laboratories. All the labs are supplied by a filtered positive air flow to minimise dirt and particle contamination. The range of laboratories include; metallurgy lab, substrates and optics labs, sputter dep. lab, functional testing lab, bulk ceramics processing lab and a nano-optics lab.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MATHEMATICS AND PHYSICS
(RAE GRADE 5 - PHYSICS)
(RAE GRADE 3A - PURE MATHEMATICS)

NUMBER 25: PLASMA PHYSICS

This centre concentrates on the growing area of plasma physics. A plasma is created when the energy content of a material is increased to allow and sustain ionisation of the constituent atoms or molecules. The energy input can be in many forms: thermal, chemical, photonic, electrical or nuclear.

The three main areas of study are;
- High temperature, laser produced plasmas
- Low temperature, electrically produced plasmas
- Atomic, Molecular and Ion Physics.

The laser-plasma interaction group at QUB is currently the largest experimental university group in this field the UK. Members of the group are at the forefront of research into fast ignitor physics, novel proton beam imaging techniques, X-ray scattering from plasmas, and X-ray lasers.

The Plasma Physics group has an active interest in all of these types of physics experiments. Experimental activity in these areas is carried out by this group at large facilities worldwide. These currently include:
- Central Laser Facility at the Rutherford Appleton Laboratory
- Laboratoire pour l'Utilisation des Lasers Intenses in Palaiseau, France
- PALS system in Prague, Czech Republic.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MATHEMATICS AND PHYSICS
(RAE GRADE 5 - PHYSICS)
(RAE GRADE 3A - PURE MATHEMATICS)

NUMBER 26: PURE MATHEMATICS

In 1999, the School of Mathematics and Physics was placed in the top 10% of UK universities. Major areas of study include Analysis and Algebra with Topology studied to a lesser degree.

Pure Mathematics is one of the four teaching divisions in the School of Mathematics and Physics in Queen's University Belfast and one of the seven research centres in the School. The Pure Mathematics Department with, at present, nine members of staff makes a major contribution to this, its modules in Mathematical Investigations and Computer Algebra having been singled out for special mention by the review panel. The 2005 internal USR review of teaching was likewise favourably impressed: sixteen of the twenty-five summary points were commendations.

Research in Analysis has increased significantly in recent years and has become focussed into a broadly based Functional Analysis group. Apart from six full time academic staff, the group currently includes a post-doctoral researcher and three PhD students. The Algebra group is expanding, albeit not quite as fast as hoped. It currently consists of two full time academics, two researchers holding fellowships and two PhD students. The Topology group is now reduced to one member of academic staff and two PhD students. It is expected that research in this area will cease on the retirement of the academic member of the group.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MATHEMATICS AND PHYSICS
(RAE GRADE 5 - PHYSICS)
(RAE GRADE 3A - PURE MATHEMATICS)

NUMBER 27: STATISTICS

Current research areas of the Centre for Statistical Science and Operational research (CenSSOR) include Survival Analysis, Bayesian networks, Markov Modelling and Stochastic Models.

The Statistics school has published many papers in recent years including;

- Modelling the flow of congestive heart failure patients through a hospital system
- Estimating costs for a group of geriatric patients using the Coxian phase-type distribution
- Intelligent Patient Management using Dynamic Models of Clinical Variables
- A Monte Carlo Simulation Model to Assess Volunteer Response Times in a Public Access Defibrillation Scheme in Northern Ireland
- Managing a Hospital Ward: Identifying Cost-Effective Strategies
- Modelling the Health Care Costs of Geriatric Inpatients

QUEENS UNIVERSITY BELFAST

SCHOOL OF MATHEMATICS AND PHYSICS
(RAE GRADE 5 - PHYSICS)
(RAE GRADE 3A - PURE MATHEMATICS)

NUMBER 28: THEORETICAL AND COMPUTATIONAL PHYSICS

This School specialises in studying theoretical atomic, molecular and optical physics. Specific research areas at the moment include;

- Quantum Optics
- Intense Laser-Matter Interactions
- Atomic Physics for Astrophysics
- Positron interaction with atoms and molecules and positron annihilation.

Research interests include
Recently they have been developing interests in related areas such as atom optics, where the atom has wave-like properties and can be diffracted and reflected by light fields.

Bose-Einstein condensation of dilute atomic vapours and laser-like atomic beams; ion traps - the centre of mass motion of ions in the harmonic potential of an ion trap shows many interesting features, including non-classical states.

Laser cooling - this technique shows that atoms can be cooled to much lower temperatures using lasers than other techniques (its inventors received the 1997 Nobel Prize for Physics).

The calculation of electron-impact excitation cross sections and rates, incorporating important effects such as correlation, configuration interaction and the complicated resonance phenomena which are found to be essential in producing rates of the highest accuracy.

Many-body theory in atoms.

Electron-atom scattering, negative ions, photodetachment.

Interaction of positrons with atoms and molecules: scattering, bound states and annihilation.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MECHANICAL AND AEROSPACE ENGINEERING (RAE GRADE 5* IN 2001 AND 1996)

NUMBER 29: DESIGN AND MANUFACTURING

Computer Aided Engineering/Advanced Control Engineering: This consists of a group focusing on finite element modelling and a group focusing on advanced control engineering.

Current Research is focussing on:
- Nasal surgery simulation incorporating haptic-enabled CAE analysis
- Intelligent process simulation and optimisation system for integrated product design and manufacturing
- Parametric CAD models for robust design
- An augmented reality device incorporating 3D surface projection

QUEENS UNIVERSITY BELFAST

SCHOOL OF MECHANICAL AND AEROSPACE ENGINEERING (RAE GRADE 5* IN 2001 AND 1996)

NUMBER 30: INTEGRATED AEROSPACE TECHNOLOGIES - CENTRE OF EXCELLENCE FOR INTEGRATED AIRCRAFT TECHNOLOGY (CEIAT)

A strategic partnership between the Schools of Aeronautical Engineering and Mechanical & Manufacturing Engineering at Queen's University Belfast, in association with Bombardier Aerospace, the NI Aerospace Consortium and the newly formed Queen's University Virtual Engineering Centre established under the SPUR initiative.

A major focus of the Centre will be the integration of engineering disciplines into an overall systems framework. Such an approach will seek to introduce best cost and performance, at an early stage of design, within the context of Integrated Product and Process Development, Multidisciplinary Optimisation and Technology Transfer. This type of research demands a high degree of specialist knowledge in several areas of Aeronautical Engineering and close links between academia and industry.

There are four main areas of research focus; Aerodynamics, fluid dynamics and acoustics

Within this are the following research projects are ongoing;

- Guidance of supersonic/hypersonic projectiles using pin-based actuators
- Effect of Lipskin Damage on Aircraft Performance and Safety
- Integration of Generator Set Enclosure Structural and Acoustic Design
- Noise Reduction of an Enclosed Diesel Generator Set

Structures and Materials - with research investigating;

- Composites
- Metallic Structures
- Integration and Systems Engineering
- Precision Concept Design Model of Manufacture for Competitive Advantage
- Integration of Manufacturing Process Parameters with Structural Design
- Cost Modelling
- Life-cycle Modelling
- Bio-fluids
- Nasal flows
- Blood flows

QUEENS UNIVERSITY BELFAST

SCHOOL OF MECHANICAL AND AEROSPACE ENGINEERING (RAE GRADE 5* IN 2001 AND 1996)

NUMBER 31: INTERNAL COMBUSTION ENGINES AND GAS TURBINES (ICERG)

Research here focuses on Catalysis and After treatment, Modelling and Computational Fluid Dynamics, Engine and Test Development and Turbo Machinery. This research takes place in three research centres namely: the GM Automotive and Emissions Collaborative Research Centre (AEC), the Centre for Theory and Application of Catalysis (CenTACat) and the Virtual Engineering Centre (VEC)

The Internal Combustion Engines Research Group (ICERG) is a strong and very active research team with considerable experience and an international reputation in the area.

Amongst its clients are many of the major engine and automotive companies throughout the world. The group's reputation has evolved over many years with most of the work directed at the traditional two-stroke engine applications; motorcycles, outboards, chainsaws, generators and light aircraft. However, the introduction of new technologies and the impact of emissions legislation has gradually shifted the emphasis of the research from traditional engine design. The group's efforts are now concentrated on providing design tools for engine development and on strategies for emissions improvement.

Research Areas include;

- Engine-based Catalyst
- Computational Fluid Dynamics
- Engine Modelling and Simulation
- Two-Stroke Engine Design
- Gas Turbine Development

Specialist Facilities at the centres include;

- Dynamometer Engine Testbeds
- Industry Standard Emissions Equipment
- Pressure Trace Capture and Analysis
- Transient Test Rigs for Catalyst Evaluation
- UNIX and NT Computer Network

QUEENS UNIVERSITY BELFAST

SCHOOL OF MECHANICAL AND AEROSPACE ENGINEERING (RAE GRADE 5* IN 2001 AND 1996)

NUMBER 32: POLYMERS - MEDICAL POLYMERS RESEARCH INSTITUTE (MPRI)

Complimenting the work of the PPRC the MPRI brings together researchers from the School of Chemical Engineering, the School of Mechanical Engineering and the School of Pharmacy at Queen's University Belfast to develop new polymeric materials, products and processes for the medical devices and drug delivery industries.

Within the Cluster is the Polymer Processing Research Centre (PPRC) formed in 1996, to focus on advanced extrusion, rotational moulding and thermoforming technologies and the Medical Polymers Research Institute (MPRI), established in 2003 through a joint initiative with the School of Pharmacy, and dedicated to high technology R&D for healthcare industries in respect of medical materials and devices. In recent years the significant investment in processing, analytical and testing facilities has created an outstanding research infrastructure and a platform for undertaking high quality applied and fundamental research, reflecting the needs of the polymer industry in the UK and abroad.

Current research is focussed on:

- Polymethyl methacrylate (PMMA) bone cements
- Bioreabsorable ploymers
- Polymer processing
- Nanofibre reinforced polymer biocomposites
- Modification of textile fibres using nanofillers
- Modelling and control experiments

There is a range of facilities available to the polymer cluster:

- Medical Polymer Research Institute
- Polymer Processing Research Centre
- Electron Microscopy Unit
- Mechanical & Aerospace Engineering

QUEENS UNIVERSITY BELFAST

SCHOOL OF MEDICINE AND DENTISTRY
(RAE GRADE 4 - CLINICAL LABORATORY SCIENCES)
(RAE GRADE 5 - COMMUNITY BASED CLINICAL SUBJECTS)
(RAE GRADE 3A - HOSPITAL BASED CLINICAL SUBJECTS)
(RAE GRADE 3A - CLINICAL DENTISTRY)

NUMBER 33: CLINICAL AND POPULATION SCIENCES

Providing a new impetus to translational research, the Centre for Clinical and Population Sciences has merged the expertise of researchers from Epidemiology & Public Health (rated 5 in the last RAE), Medicine, Reproductive Medicine, Clinical Chemistry, Nephrology, Neuroscience, and Cardiology and Rheumatology and Trauma.

This research group has sub-groups who each specialise in a particular area of research.

Diabetes Research Group
The research of the group is focused on the development of atherosclerosis in a number of projects using basic/molecular and clinical approaches. There are active collaborations with local clinicians (diabetes), and with national and international groups.

Epidemiology Research Group
The primary aim of the group is to originate and undertake high quality research on the distribution and determinants of diseases and their outcomes. Emphasis is placed on both the genetic and environmental components of risk.

Genetic Epidemiology Research Group
This group is focussed on the epidemiology of chronic kidney disease and the genetic risk factors for renal disease. The groups research is funded by grants from Diabetes UK, JDRF, National Kidney Research Fund, DHSS RDO and the NI Kidney Research Fund. The research laboratory is located in the Clinical Genetics department of the Belfast City Hospital.

Musculoskeletal Research Group
The Group works at the interface between basic science and its application to clinical practice. It is engaged in research for the treatment of bone trauma and disease using cell based therapies.

Neuroscience Research Group
Encompasses a broad range of clinical and laboratory-based research programmes aimed at obtaining a better understanding of psychiatric and neurodegenerative disorders and their treatment. These research programmes can be defined under the overlapping themes of clinical psychiatry, psychopharmacology and neurochemistry, neuropsychiatric genetics and molecular biology of neurodegenerative and psychiatric disorders.

Nutrition and Metabolism Research Group
The Nutrition and Metabolism Research Group is interested in the relationship between nutritional factors and the development of complex multifactorial disease. The main work of the group relates to antioxidant vitamins and micronutrients, and the importance of these is studied through the medium of epidemiological studies and clinical intervention trials. Substantial external funding is held from the Wellcome Trust, Food Standards Agency, Food Safety Promotion Board and the NI Research and Development Office. The laboratories of the group provide a wide range of antioxidant related assays and act as coordinating laboratory for a number of ongoing national and international studies.

Reproductive Medicine Research Group
Over the past five years, the primary research interest has been in Andrology; the study of male reproductive function. The twin aims are to understand male reproductive dysfunction at a cellular and molecular level by comparisons of infertile with fertile seminal profiles. Secondly they are establishing novel prognostic tests to predict pregnancy in assisted conception and currently validating an algorithm based on sperm nuclear and mitochondrial DNA.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MEDICINE AND DENTISTRY
(RAE GRADE 4 - CLINICAL LABORATORY SCIENCES)
(RAE GRADE 5 - COMMUNITY BASED CLINICAL SUBJECTS)
(RAE GRADE 3A - HOSPITAL BASED CLINICAL SUBJECTS)
(RAE GRADE 3A - CLINICAL DENTISTRY)

NUMBER 34: ORAL SCIENCES AND HEALTH CARE

The centres for Oral Science and Oral Health research address Operative Dentistry, Endodontics, Periodontics, Oral Medicine, Surgery and Pathology, Dental Public Health, Paediatric and Preventive Dentistry and Orthodontics.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MEDICINE AND DENTISTRY
(RAE GRADE 4 - CLINICAL LABORATORY SCIENCES)
(RAE GRADE 5 - COMMUNITY BASED CLINICAL SUBJECTS)
(RAE GRADE 3A - HOSPITAL BASED CLINICAL SUBJECTS)
(RAE GRADE 3A - CLINICAL DENTISTRY)

NUMBER 35: RESPIRATORY MEDICINE

This group is focusing their future research on preventing adult ill-health through interventions in childhood (neonatal and paediatric research); preventing ill-health caused by environmental degradation (adult and paediatric asthma) and prevention of acute exacerbations of chronic disease (cystic fibrosis, COPD, bronchiectasis). This will be approached via the following research programmes: the long-term consequences of chronic lung disease of prematurity; the role that respiratory epithelial cells and interactions with viruses have in the early onset of allergic sensitisation; the role of epithelial stress and dysregulation of epithelial repair in persistent childhood asthma; the effect of indoor air pollution on respiratory health and non-invasive markers of airway inflammation in adult and paediatric asthmatics; microbial interactions with airway mucus and epithelial cells; transport of drugs through mucus to lung tissue slices ; the influence of polymorphisms with disease severity, lung inflammation and disease progression in cystic fibrosis.

The integration of laboratory studies and clinical trials is a high priority for the group and several members are currently principal investigators in eight clinical trials.

QUEENS UNIVERSITY BELFAST

SCHOOL OF NURSING AND MIDWIFERY

NUMBER 36: THE NURSING AND MIDWIFERY RESEARCH UNIT (NMRU)

This unit was recently established as a focus of all strategic research activity in the School. It is focused around two main themes.

QUEENS UNIVERSITY BELFAST

SCHOOL OF NURSING AND MIDWIFERY

NUMBER 37: MATERNAL AND CHILD HEALTH GROUP

This group addresses the monitoring and surveillance of high risk childhood populations, the investigation of access to effective healthcare and the investigation of health and quality of life.

This group has three main areas of study. Monitoring and surveillance activities include the Neonatal Outcomes and Research Evaluation Project (NICORE) set up in 1994 to monitor the care and outcomes of vulnerable infants in need of neonatal intensive care.

Investigating access to effective health care includes a constellation of work involving systematic reviews of common interventions used in maternal and child health care undertaken by Alderdice et al who was an honorary Cochrane Fellow at the UK Cochrane Centre (2002-05). These systematic reviews form part of the ongoing strategy to identify the effectiveness of interventions contributing to the construction of a reliable evidence base for clinical and policy decisions.

Studies of Health and quality of life into children with cerebral palsy have been undertaken as part of several funded studies. The SPARCLE study (funded by the EU's Framework 5) is investigating the role of environmental factors on quality of life and participation in 8-12 year old children with cerebral palsy in eight regions of Europe.

QUEENS UNIVERSITY BELFAST

SCHOOL OF NURSING AND MIDWIFERY

NUMBER 38: EVALUATION OF COMPLEX HEALTHCARE INTERVENTIONS

This group focus on developing methods for evaluating complex healthcare interventions, conducting intervention studies and exploring lay perceptions of healthcare interventions. This research group has are conducting studies on three different areas:

Developing methods for evaluating complex health care interventions: Porter's examination of how critical realism can benefit research in general and evaluation research in particular, provides the methodological bedrock for the exciting new approaches to evaluation research that the group is developing. Blackwood and O'Halloran have contributed significantly to the development and application of frameworks for the implementation and evaluation of complex health care interventions.

Substantive understanding of particular interventions: This trial overcame many of the methodological limitations of previous studies and has been included in a recent Cochrane review, where it is recognised as helping to tip the balance of the evidence away from the effectiveness of hip protectors in the nursing home setting.

Exploring lay perspectives on health care interventions: Social theory was used to explore why the lay voice is so frequently absent from the design of health care interventions. It was applied to these social theories in empirical research which explores men's lay perspectives on partner notification and sexual health services.

QUEENS UNIVERSITY BELFAST

SCHOOL OF PHARMACY (RAE GRADE 4)

NUMBER 39: MOLECULAR THERAPEUTICS

Specifically biomedical science and experimental therapeutics.

In the field of Biomedical Science there are two main areas of focus:

The Protease Inhibitor Programme focuses on the design, synthesis and biological application of inhibitors of the serine and cysteine proteases of pharmaceutical and biomedical importance, and on pharmacogenetics.

The Applied Genomics Programme investigates the genetics of susceptibility and disease modification of autoimmune diseases with particular emphasis on multiple sclerosis, rheumatoid arthritis and juvenile idiopathic arthritis.

In the field of Experimental Therapeutics there are two main areas of interest:

Research in the Gene Therapy/Radiation Biology Programme is centred on 'Experimental Therapeutics' in relation to cancer, including strategies for enhancing radiotherapy and chemotherapy. The programme is developing novel gene therapy approaches that package genes within delivery systems that are attracted specifically to tumour cells, focusing on inducible nitric oxide synthase as a therapeutic transgene.

The Medicinal Chemistry Programme focuses on biomolecules of therapeutic interest and is currently being developed through the appointment of the new John A. King Chair in Medicinal Chemistry, and a supporting lectureship.. The concept is to link ongoing research on naturally-occurring biomolecules with new synthetic and structure-activity approaches to biomolecular drug discovery provided via the £2 million King donation to the School.

The School's McClay Research Centre for Pharmaceutical Sciences is a £3.5 million facility. The Centre houses new laboratories for the Drug Delivery and Biomaterials Research Group, and for the Biomolecular Science Research Group.

Since 2002, with the continuing expansion of the School, additional new facilities and equipment have been brought on-stream, or are planned, constituting a further investment of around £10 million. This latest expansion is in addition to the McClay Centre development and includes:

- multi-layer extrusion and polymer characterisation facilities, as part of the Medical Polymers Research Institute
- Experimental Therapeutics Research Laboratory
- Instrumental Analysis Laboratory
- Clinical Analysis/Pharmacokinetics Laboratory
- Solid Dosage Suite
- International Partnership for Microbicides Laboratory for Vaginal Drug Delivery
- Medicinal Chemistry Research Laboratory (presently in planning), funded by the King Donation

QUEENS UNIVERSITY BELFAST

SCHOOL OF PHARMACY (RAE GRADE 4)

NUMBER 40: PHARMACEUTICAL SCIENCE AND PRACTICE

This group concentrates on two specific areas; drug delivery and biomaterials and clinical/professional practice.

The Drug Delivery Programme focuses primarily on the design of polymeric systems for application at accessible cutaneous and epithelial absorption barriers, together with design optimisation and performance prediction through a fundamental appraisal of physicochemical and mechanical properties.

The programme has established strong collaborations with major pharmaceutical companies and many research projects are co-developments with industry. Currently, programmes focus, in particular, on intravaginal drug delivery, HIV vaginal vaccines and microbicides, mucoadhesion and rheology of semi-solids, and drug delivery of photosensitisers for photodynamic therapy (PDT).

The clinical/professional practice programme involves national and international collaborations with clinical and professional colleagues in a range of leading hospital institutions, with two dedicated academic practice units having been established in major teaching hospitals to facilitate clinical development of the departmental-based research activities. A new GLP-compliant PD/PK laboratory has been established to provide an analytical capability for clinical pharmacokinetics.

QUEENS UNIVERSITY BELFAST

SCHOOL OF PLANNING ARCHITECTURE AND CIVIL ENGINEERING
(RAE GRADE 5 - CIVIL ENGINEERING)
(RAE GRADE 2 - BUILT ENVIRONMENT)
(RAE GRADE 3B - TOWN AND COUNTRY PLANNING)

NUMBER 41: BUILD ENVIRONMENT

The Centre aims to integrate architecture technology and design with engineering principals and practices in order to provide solutions to a range of problems in the Built Environment, by resorting to both fundamental and applied research at nano-, micro-, macro-scales. Therefore, the Centre undertakes its activities under the following areas:

Each of these is led by a senior academic member with international reputation, who is supported by a group of other research personnel from both within and outside the Centre.

- Advanced Construction Materials and Technologies
- Durability of Structural Materials and Technologies
- Environmentally Sustainable Urban Development
- In Situ Tests for Assessing Structures and Materials
- Intelligent Sensing and Communication Technologies in the Built Environment
- Structural Behaviour and Composites
- Sustainable Materials and Building Technologies

The centre has the following research facilities;

- Facilities for manufacturing test specimens
- Curing and conditioning facilities
- Sample preparation facilities
- Structural testing facilities
- Material testing facilities
- Material analysis facilities
- Computational/Manufacturing/Instrumental support

QUEENS UNIVERSITY BELFAST

SCHOOL OF PLANNING ARCHITECTURE AND CIVIL ENGINEERING
(RAE GRADE 5 - CIVIL ENGINEERING)
(RAE GRADE 2 - BUILT ENVIRONMENT)
(RAE GRADE 3B - TOWN AND COUNTRY PLANNING)

NUMBER 42: ENVIRONMENTAL ENGINEERING

The Environmental Engineering Research Centre (EERC) was established to provide underpinning science and engineering research, as needed, to integrate the sustainability requirements of society and the environment. Current areas of research include Geotechnical Engineering, Water Treatment and Environmental Engineering and Geohydrology and Contaminated Land.

The facilities available to the EERC include;

- EERC Analytical Laboratory
- Environmental Tracers Laboratory
- Stable Isotope Forensics Facility
- Wave Tank

Recent R&D Highlights

Both scientific excellence and relevance to problems affecting today's society of the research undertaken by members of the EERC are clearly recognised by winning prestigious awards such as the Parsons Brinckerhoff's Project of the Year 2004 award in the 'Studies and Special Projects' category for the SEREBAR Groundwater Treatment System, or by being one of the seven consortia to be awarded funding through EPSRC's 4th Think Crime Programme for a research project on Isotope Profiling (or Fingerprinting) of Drugs.

QUEENS UNIVERSITY BELFAST

SCHOOL OF PLANNING ARCHITECTURE AND CIVIL ENGINEERING
(RAE GRADE 5 - CIVIL ENGINEERING)
(RAE GRADE 2 - BUILT ENVIRONMENT)
(RAE GRADE 3B - TOWN AND COUNTRY PLANNING)

NUMBER 43: SPATIAL AND ENVIRONMENTAL PLANNING

This is one of the fastest growing and dynamic areas of research in the UK at the moment. Research programmes are based on the concept of spatial planning and whilst its empirical work is partly grounded in the region, it is built on strong international, interdisciplinary and theoretical references.

The Institute works to a long term research strategy which has helped to deliver considerable investment in staff, studentships and infrastructure in spatial planning. The research reflects the regionally distinctive planning environment but is intimately connected to global debates about the changing nature of space, policy and practice.

The group have three areas of research specialism:

Spatial planning and sustainability
This research cluster on sustainable communities draws on the expertise of staff with an international reputation in flood management, environmental disputes and regulatory compliance. The portfolio of current projects includes major funding for the research councils, the UK Government and the EU.

Spatial planning and rural development
ISEP has a research tradition in rural planning and development spanning nearly 50 years and shares close interdisciplinary links with the newly established School of Agri-food and Land Use and the Gibson Institute, which is a dedicated research centre on rural development in NI.

Spatial planning and contested spaces
The Institute has developed a world leading cluster in the study of planning and contested space. The research focuses on the construction and meaning of identity places, the cultural significance attached to territory and normative response of planning and urban managers to its more wicked effects. The research draws on and contributes to international experiences in the study of divided places and strong links have been built with Universities in the United States, Germany, Israel and the Republic of Ireland.

QUEENS UNIVERSITY BELFAST

SCHOOL OF BIOMEDICAL SCIENCES (RAE GRADE 5 - CANCER STUDIES)

NUMBER 77: BIOIMAGING CORE TECHNOLOGY UNIT

The Bioimaging Initiative at Queens has been funded through SRIF2. It establishes, for the first time, a Core Technology Unit that supports the use and implementation of established and novel bioimaging techniques for the biomedical research community within the university and to outside bodies. The aim is to grow this unit to provide extensive imaging facilities for a range of applications.

The unit is fully equipped with up to date technology including:

The Bioimaging Unit is equipped with the most recent confocal microscopy technology for live and fixed cell imaging. Two confocal microscope laboratories exist within the unit. One will be dedicated to fixed cell analysis. A dedicated confocal microscope will form part of the Category II laboratory specifically designed for live cell analysis with UV capability.

Flow cytometry is a core technique that is used extensively across a variety of biomedical disciplines. The Bioimaging Unit will have a dedicated flow cytometry laboratory with a fully equipped research instrument capable of analysis and advanced cell sorting.
In vivo biophotonic imaging is a proprietary technology from Xenogen that illuminates biological processes taking place in a living mammal. By measuring and analyzing the light emission, researchers can monitor cellular or genetic activity and use the results to track gene expression, the spread of a disease, or the effect of a new drug candidate in vivo.

High Resolution Slide Scanning - The Bio-Imaging Unit has unique digital slide scanning facilities. These allow high resolution digital slides to be recorded for analysis, for presentation, for training and education. Our ScanScope CS machines are a fully-integrated linear-array based slide scanners. They enable the rapid digitization of entire microscope slides at diagnostic resolution

The Bioimaging Unit is equipped with a number of high specification fluorescence microscopes capable of both fixed and live cell imaging. This will provide a pre-confocal analysis suite and also dedicated facilities for fluorescence imaging with image capture and analysis capabilities.

Integrated within the Bioimaging unit is a fully equipped Category II laboratory with cell culture facilities. This allows easy transfer of Cat II materials for analysis by confocal microscopy and flow cytometry.

The Bio-Imaging Unit will be equipped with the latest image analysis software for image storage, comparison, processing, 3-D reconstruction and quantitative analysis from microscopic and cytometric data. A central file server and backup facility for the Bioimaging Unit will allow rapid storage and retrieval of image and cytometric data. Each item of equipment will be networked within the unit to the central file server.

The Bioimaging Unit is also equipped with a stand-alone microinjection unit permitting the efficient delivery of known concentrations of proteins, DNA or small molecules into cells. As part of the Bioimaging Unit this allows advanced direct observation of the effect these agents on cell function. Microinjection for transgenic research will also be a key capability of the unit.

QUEENS UNIVERSITY BELFAST

SCHOOL OF MUSIC AND SONIC ARTS

NUMBER 78: SONIC ARTS RESEARCH CENTRE

The Sonic Arts Research Centre (SARC) is a newly established centre of excellence, dedicated to the research of music technology. This unique interdisciplinary project has united internationally recognised experts in the areas of musical composition, signal processing, internet technology and digital hardware.

The Centre is established in a purpose-built facility, located alongside the engineering departments of Queen's University. The centrepiece of SARC, the Sonic Laboratory, provides a unique space for cutting-edge initiatives in the creation and delivery of music and audio. The Sonic Laboratory's uniqueness is vested in the degree of flexibility it can provide for experiments in 3D sound diffusion and for ground-breaking compositional and performance work within a purpose-built, variable acoustic space. The new building houses five multi-channel studios, two computer labs, meeting rooms, seminar spaces and the world's first Sonic Laboratory

Areas of research carried out at SARC include:

- Accessibility through Sound and Haptics
- Computer Game Audio
- Human-Computer-Interaction: Learning from Music
- Performance Technologies
- Physics-based Sound Design
- Practice-led Research in the Creative Arts
- Signal Processing for Audio
- Recent SARC Projects
- Sound and Locative Media - Context Aware Audio for Mobile Applications
- A Novel Electronic Percussion Instrument - Instrument based on a real-time controlled FPGA implementation of a plate model
- Real-Time Physically Informed Audio Synthesis - Creating an interactive virtual environment with physics-driven audio and visuals
- Audio Alchemy - Signal Processing Methods for the Enhancement of Spatial Audio
- Virtual Room Acoustics - Numerical Simulation and Auralisation of Acoustic Spaces
- Extraction of Physical Model Parameters from Music - Sensing, Modelling and Signal Processing for Physics-Analysis/ Re-Synthesis of Woodwind Tones
- SKILLS - The SKILLS project deals with the acquisition, storing and transfer of human skill by means of multimodal interfaces, Virtual Environments technologies and Interaction Design methodologies.

QUEENS UNIVERSITY BELFAST

THE CENTRE FOR CLIMATE, THE ENVIRONMENT AND CHRONOLOGY

NUMBER 79: THE CENTRE FOR CLIMATE, THE ENVIRONMENT AND CHRONOLOGY

This research group specialise in measuring climate and environmental change and also the discipline of dating (chronology) of ancient artefacts. The main thrust of the research involves using modern dating technologies to investigate the causes of climate and environmental changes in the past.

The centre has access to a large array of modern equipment including;

- Accelerator Mass Spectrometer
- Carbon Dating
- Radiocarbon Calibration
- Dendrochronology
- Stable Isotope Lab
- INQUA Data-handling Methods
- Pollen Catalogue of the British Isles
- Microfossil Data Handling
- psimpoll
- New Laboratory

UNIVERSITY OF ULSTER

LIFE AND HEALTH SCIENCES

NUMBER 80: ENVIRONMENTAL SCIENCES RESEARCH INSTITUTE

The mission of the Environmental Sciences Research Institute (ESRI) is to promote understanding of the Earth systems and to provide knowledge that will lead to more effective management of the environment. As a result of its international reputation for quality, research in Environmental Sciences was recently granted Research Institute status by the University. The Institute has foci of activity in a number of disciplines and prides itself in encouraging an interdisciplinary approach in many of its research programmes. The Institute incorporates the Centre for Coastal and Marine Research, the Centre for Maritime Archaeology, and a number of other research groups.

Themes that embrace the work of the Institute are:

- Ancient and recent dynamic changes in the earth's crust
- How environmental change in coastal zones and in the general landscape and can be detected, predicted and managed
- Environmental science applied to maritime archaeology
- The science behind biogeochemical cycles that govern water quality
- The ecology of interactions that govern the status of surface waters and forests

Underpinning these research themes are a range of technological and analytical innovations, such as remote sensing, geographical information systems and advanced mathematical modelling, that enable problems to be tackled on a number of different fronts.

The Institute has a suite of equipment and facilities to facilitate the research that it carries out, including;

- Side-Scan Sonar system (EG&G)
- Full Spectrum Digital Sub-bottom Seismic Profiler System (EG&G)
- Digital Marine Magnetometer (Fisher)
- 15ft Hovercraft (with GPS mounting)
- Various marine research vessels
- Land-based Magnetometer
- Ground Penetrating Radar
- GeoExplorer GPS system with Focus FM
- Current Meters
- Total Station (EDM) survey system
- Full differential, dual-frequency sub-centimeter GPS system 4800 series
- Settling Tube (Fall Column) and standard sieving equipment in dedicated lab space
- Computer Laboratory (PC and UNIX workstations)
- High Resolution Aeolian Sediment Traps
- High resolution electronic Tide and Wave Guages - Dobie
- Satellite Imagery facilities

ALMAC

ALMAC SCIENCES

NUMBER 81: PHARMACEUTICAL AND BIOTECHNOLOGY RESEARCH AND DEVELOPMENT

Almac Sciences works with organisations large and small across the globe, including the top pharmaceutical companies, Biotechs, Virtuals, and Universities. Services extend from contract R&D, through small scale custom synthesis, to cGMP synthesis up to 10s Kgs and at the levels of containment required for highly potent/cytotoxic compounds. In addition to providing support for synthesis operations, our extensive analytical facilities and expertise are available as a stand-alone service.

The group has recently rebranded all five of its business units under one brand name ‘Almac’. The five business units are:

Almac Clinical Services
Works with many smaller companies including biotech, virtual, CRO’s and also participates in government sponsored studies. Services extend from phase one to four and include child resistant supplies for the US market and release of product by a Qualified Person on first entry into Europe

Almac Clinical Technologies
Specialises in the implementation of interactive trial management solutions. Almac Clinical Technologies serves both pharmaceutical and biotechnology industries, managing multiple facets of clinical trials.

Almac Pharma Services
Almac Pharma Services is an FDA-approved outsourcing partner to the international pharmaceutical and biotechnology sectors.

Almac Diagnostics
With operations in Europe and North America, Almac Diagnostics develops and delivers genomics solutions for the advancement of science and the improvement of patient care

Almac Sciences
Almac have developed services and products that are individually attractive and compelling in combination

CENTRE FOR EXCELLENCE IN CONTROLLED DRUG DELIVERY

NUMBER 82: CENTRE FOR EXCELLENCE IN CONTROLLED DRUG DELIVERY

The Group Technical Centre has accelerated existing product and process development work, enhancing laboratory services and exploring new areas of research to develop innovative and added value dairy products for ultimate production in the United Group`s five manufacturing facilities. The Centre of Excellence has allowed an increased number of commercially viable projects to be completed more rapidly, the result of which is the improved competitiveness and increased profitability for the company.

CENTRE FOR SCIENTIFIC CAMERAS

ANDOR TECHNOLOGIES

NUMBER 83: CENTRE FOR SCIENTIFIC CAMERAS

Andor, a spin-out company from Queen's University, has successfully established itself as one of the key players supplying specialist scientific cameras and associated products used within the spectroscopy market for the measurement of light. Its core products are essentially specialist cameras that measure either very low levels of light (single photons i.e., the smallest level of light that exists) or changes in light occurring on very short time-resolution (~1 billionth of a second). The Centre of Excellence for Scientific Cameras has helped the company strengthen its position in the spectroscopy market and to expand in the imaging market.

Facilities

The largest Andor facility is based in Belfast, which is a new, purpose-built 50,000sq. ft premises. The premises include state of the art optical, electronic and mechanical workshops, a 3000sq. ft clean room, vacuum and electronic processing facilities. Andor has operated a quality management system since 1998 which currently complies with the requirements of BS EN ISO9001:2000 and has other accreditations including Investors in People and ISO14001 environmental compliance.

In summarising the capability of QUB, it can be seen from the above table that real capability at an international level exists with regards to the following:

- Electrical and Electronic Engineering
- Mechanical, Aeronautical and Manufacturing Engineering
- Physics
- Community based clinical subjects
- Civil Engineering

A.4
UNIVERSITY OF ULSTER (UU)

The following table lists and details the faculties and research institutes for UU that are applicable to the sector capability assessments addressed in the main body of the report, and where available their most recent Research Assessment Exercise (RAE) scores (those from 2001) are again listed.

In total there are 17 research institutes consisting of in excess of one hundred research groups at UU, however in the frame of this activity we have identified seven institutes and some 28 groups to be applicable.

UNIVERSITY OF ULSTER
KNOWLEDGE TRANSFER (INSTITUTIONS WITH A CLEAR KNOWLEDGE TRANSFER REMIT)
DEPARTMENT OF LIFE AND HEALTH SCIENCES BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)
NUMBER 45: OFFICE OF INNOVATION

The Office of Innovation is a key aspect of the University to Business agenda where UU see themselves as a key stakeholder in regional economic development and thereby servicing the requirements of all companies in NI. The offerings range from contract and collaborative research to consultancy and technology/knowledge transfer services. To achieve this, UU has a Business Liaison Office on all four campuses and these provide a focus for enterprise innovation, networking, research, training and development projects etc.
The Office of Innovation, therefore, acts as a gateway to all of the academic staff, research and facilities within the university. It also enables a worldwide network.

Situated in the £14 million Centre for Molecular Biosciences (funded through SPUR) and including the major INI Centre of Excellence in Functional Genomics (£4.4 million)

Nine research groups, led by senior scientists with international reputations and extensive experience of managing research in their own fields. These groups are described below.

Unilever and University of Ulster: Dr Stephen McClean, Biomedical Sciences Research Institute, explained: ‘Unilever has been interested in studying the response of the human skin to various stimuli, and in particular the profile of molecules the skin produces. Unilever obtained the samples in their labs and then approached the Institute to carry out mass spectrometric analysis’.

NUMBER 44: CANCER AND AGEING

A particular strength is in the quality of facilities and high specification analytical instrumentation. Cancer (therapeutics), Alzheimer's disease and Werner syndrome (premature ageing).

The main focus of the Cancer and Ageing research Group (CARG) has been to investigate factors affecting the mutability, growth and developmental controls of human cells and of a variety of animal models. Much of this work is conducted in close collaboration with members of the NI Centre for Food & Health (NICHE), especially in cases where dietary factors are implicated; and also with the Biomedical Genomics Research Group.

The Group uses a range of techniques, from human dietary studies to molecular analysis of individual genes from individual cells to transgenic models. Researchers from this Group have pioneered techniques in analysis of DNA repair and replication at the single-cell level; in the creation of human monosomic cells; in the discovery of novel cell cycle controls; and of molecular aspects of nutritional factors affecting carcinogenesis. The laboratories are extensively equipped for proteomic and genomic analysis and for molecular imaging of cultured cells.

The group have a strong emphasis on collaborations. Current collaborations exist with the NICHE and many of the other Biomedical research groups at the University of Ulster. CARG is also collaborating with research groups in Aberdeen, Belfast, Berlin, Bologna, Brighton, Bristol, Cambridge, Cardiff, Chapel Hill, Dublin, Fort Collins, Gatersleben, Heidelberg, Helsinki, Huddinge, Leiden, Leipzig, Moscow, Roskilde, Padua, Paris, Szeged, Toulouse, Tübingen, Ulm, Uppsala, Vienna, and Zurich.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 45: DIABETES

Since 1989, the Group has built an extensive range of external networks, being the founder of the European Association for the Study of Diabetes (EASD) Islet Study Group and playing a pivotal role in the establishment of the EU-funded Islet Research European and Latin-American Networks. The Group has also played a key role in diabetes research both nationally and internationally through senior positions in the British Diabetic Association/ Diabetes UK, the EASD and establishing rich collaborations with numerous Centres of Excellence worldwide. The Group's activities are expanding and the recent formation of a province-wide HPSS funded RRG in Diabetes and Endocrinology will further strengthen local clinical collaborations.

With a primary aim to conduct cutting-edge diabetes research of therapeutic importance, the focus has been on understanding pancreatic beta cells, antidiabetic and antiobesity efficacy of structurally modified brain-gut peptides; discovery, targets and action of new antidiabetic drugs. They have isolated new insulin-releasing agents from amphibian skin secretions and documented antidiabetic properties of medicinal plants.

There are four main areas of research focus:

Insulin secretion and gene therapy
Bioengineering and proteomics of candidate insulin-secreting surrogate cells suitable for unravelling the mechanisms of pancreatic beta cell function and dysfunction and paving the way for the future gene therapy of diabetes.

Antidiabetic actions of structurally modified peptides
Investigating the impact of structural modification of biologically active brain-gut peptides on the regulation of feeding, pancreatic beta cell function and anti-hyperglycaemic activity.

Discovery, targets and action of antidiabetic drugs
Characterization of novel antidiabetic agents, isolation of new compounds from natural sources, elucidation of their sites and modes of action and potential therapeutic role in correcting insulin secretion and action in diabetes.

Mechanisms of pancreatic beta-cell dysfunction and insulin glycation
Involvement of glucose, lipid and drug toxicity and glycation of insulin and other pancreatic beta cell proteins in insulin secretory dysfunction, insulin resistance and pathogenesis of diabetes.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 46: HUMAN NUTRITION AND DIETETICS

This Group is centred on NICHE, the NI Centre for Food and Health. This was set up as a TDP centre of excellence in 1996 to provide greater understanding of diet-related health issues, particularly in the areas of heart disease, stroke, cancer and obesity, for the benefit of both the consumer and the food industry. An important aspect of the work is the development and validation of biomarkers for chronic disease to facilitate dietary intervention studies in healthy, or 'at risk', subjects. The available infrastructure includes a facility for dietary intervention trials currently unique in the UK – a residential suite with accommodation for up to 12 volunteers, and a kitchen for preparation of duplicate meals, and for the analysis of the effects of such trials; mass spectrometric analysis; an exercise suite with BodPod, ergometer, treadmill, ergospirometer; and bone densitometer; a food sensory lab, and a gastrointestinal laboratory for faecal analysis, and access to Category II laboratory for blood sampling and analysis.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 47: VISION SCIENCE

This group conducts basic/developmental research, incorporating experimentation in biochemistry, molecular biology, optics, rheology, psychophysical studies, clinical investigations, mathematical modelling and clinical and research-based ethics, which it then applies to clinical problems through established links with clinical centres and industry. International collaborations exist between groups in The Republic of Ireland, Bulgaria, Poland, Australia, Austria, Germany, France, India and the USA.

Ongoing Research Topics include:

The short wavelength sensitive system
This pathway of the visual system is served by the short-wavelength (blue) cones and its own particular ganglion cell type in the retina and displays functional characteristics which are very different from the other visual pathways.

Ocular Ageing
Change with age to the lens and cornea of the eye is a major topic of interest to the group. This includes changes to the refractive index, curvature and underlying protein biochemistry of these structures.

Imaging through cataracts
The complicated relationship between forward and back-scattered light is poorly understood and the visual imagery seen by a cataract sufferer cannot be ascertained from slit-lamp assessment.

Optics of the eye and accommodation
The optical properties of the lens are being investigated using ray tracing and fibre optic sensing to understand the contribution of the shape and tissue properties to accommodation and to its changes with age.

Modelling dynamic changes in the optical elements of the eye
The lens and cornea are being studied using eye models and modelling analysis tools. The work involves collaboration with The Wroclaw University of Technology (Prof Kasprzak) and with the Department of Computing and Information Engineering at The University of Ulster (Prof Scotney). The work is funded by Essilor International.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 48: BIOIMAGING

This group has expertise in the applications of electron, light and scanning probe microscopes; 3D measurement and modelling of tissues; in vivo microscopy of blood formation; and nanotoxicology. The bioimaging assets available to the group are extensive including the most up-to-date microscopic equipment available worldwide.

In addition, the recently opened FEI Centre of Excellence for Electron Microscopy within the Group possesses the world's only examples of certain specialised microscopy equipment for imaging frozen and living cells and tissues. The centre opened following a £1.3 million investment by the Department for Employment and Learning and the Office of Science and Innovation through the UK Science Research Investment Fund (SRIF 2006-2008) and the purchase of equipment from FEI Company, a world leader in providing advanced characterisation and analysis Tools for NanotechTM. The FEI centre has been working in conjunction with Unilever on various projects.

The instrumentation in the FEI Centre for Advanced Imaging include:

Nova Nanolab cryo-dualbeam system with FEGSEM. This system is housed within its own laboratory and is served by two computers for rapid storage and retrieval of results;

Tecnai 12 Spirit TEM – latest model from FEI Company capable of tomographic imaging structures within a section six times thicker than those used by other instruments. Full software suite for image processing and analysis of x, y, and z-dimensional data plus reconstruction;

ESEM – operates at both ambient pressure (100% humidity) and ultra high vacuum. Peltier stage which can operate between 20°C and +150°C. Dual computer control and additional software licence for remote analysis; Ultramicrotomy: two RMC ultramicrotomes, one for resin section and one for cryo-ultramictrotomy.

Data storage: all instruments report back to a 2.5 terabyte DVD jukebox. Individuals can call up their own files only from the University network.

The BRG has dedicated cell, tissue and organism culture laboratories with full phase and fluorescence facilities for digital recording of results. There are also central glassware washing and sterilisation facilities.

Confocal Laboratory: multiphoton microscope, three video rate confocal microscopes, BioRad MRC 600 confocal microscope, deconvolution and three dimensional reconstruction software installed on all machines.

Confocal Atomic Force Microscopy (AFM): combined AFM confocal set-up for simultaneous imaging of AFM tip sample interaction and inverted recording of changes in ion movement or other dynamic events.

Fluorescence Imaging and DNA damage: four fluorescence microscopes dedicated to measurement of DNA damage and repair, one with motorised stage and filters for fast channel changing.

Histology Laboratory: automated tissue processing, automated slide staining and coverslipping, motorised cryostat, rotary microtomes (wax), rotary microtomes (resin). Photomicrography: facilities for fluorescence, phase contrast, darkground and brightfield microscopy on both inverted and compound microscope stands as well as stereo zoom. Three dimensional reconstruction software and deconvolution. PALM laser capture micro-dissection microscope equipped with motorised programmable stage and sample holder for slides and multiwell plates. Eppendorf capture facility for up to six different sample types. Intelligent software for calculation of area, volume, etc.

Stereology: two fully equipped stereology laboratories with a range of microscope/computer configurations for the measurement of 1st and 2nd-order stereological estimators.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 49: BIOMEDICAL GENOMICS

Group members have extensive expertise relating to key molecular biology and nucleic acid and proteomic based techniques, data integration and pathway modelling. Since these are strongly interrelated, and many complex biological and biomedical questions demand an integration of these approaches, the group work across all the research groups within the Biomedical Sciences Research Institute.

The group cover all major aspects of transcriptional control including:

- the investigation of basic mechanisms of gene regulation;
- the investigation of the structural basis for mechanisms of transcriptional control;
- the design of nucleic acid based composits to therapeutically modulate aberrant gene expression patterns;
- the analysis of the interplay of disease and a major class of transcriptional regulators (the 'superfamily' of nuclear hormone receptors with a specific focus on the vitamin D receptor; and
- the analysis of the correlation between genetic variability (SNPs), gene expression, promoter methylation status and specific diseases.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 50: MICROBIOLOGY AND BIOTECHNOLOGY

The group encompasses two general lines of approach. One involves a common interest in providing a deeper understanding of the distribution, function and control of bacteria, protozoa and viruses of importance to biomedical science. Research along these lines has recognised the importance of the environment not only as a reservoir of both established and emerging microbial pathogens but also as a source of micro-organisms producing novel bioactive molecules. The other is based on exploiting biological materials other than micro-organisms as a source of molecules with biological activity, and hence therapeutic potential.

Research within the Microbial Biotechnology Research Group (MBRG) is focused upon the use of genomic and proteomic tools to understand more fully the medical and/or industrial relevance of specific micro-organisms.

Together with researchers at Belfast City Hosptial and the Centre for Disease Control (Atlanta, GA, USA), rapid molecular based tools are being developed within the MBRG to study the emerging protozoan pathogen Cryptosporidium parvum.

Interest in bacteria capable of growth at high temperatures, in excess of 70oC, has led the MBRG, together with colleagues at the Georgia Institute of Technology (USA) to work on sequencing the genome of the aerobic, obligately thermophilic Gram positive bacterium Geobacillus thermoleovorans.

A third research priority within the group is the study of opportunistic pathogens Pseudomonas aeruginosa and Burkholderia cepacia and their involvement in biofilm formation in people with Cystic Fibrosis.

Finally, the MBRG has a strong interest in the biosynthesis and biotransformation of organophosphonate compounds with biocidal activity.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 51: STEM CELL & EPIGENETICS

This group, recently formed to exploit the developing theme of stem cell research, is equipped with high specification molecular biology and microscopy facilities and equipment. There are also designated stem cell laboratories for culture, differentiation and visualisation of stem cells. Work in the group centres on the stem cells in the blood and gonads.

There are four main research areas that this group focuses on:

Epigenetics
The group have been studying how cells undergo reprogramming, especially how they remove blocks on transcription of certain genes and when they add new blocks. They are studying how and when this process occurs and what proteins are involved in controlling it.

Fertility
Infertility affects up to one in ten couples of childbearing age in Western society and many people now avail of assisted reproduction techniques. They are investigating the potential role of one gene, which is strongly expressed in the testis in causing infertility in a subclass of infertile male patients characterised by a lack of sperm production.

Haematopoietic Stem Cells
One of the main areas of interest is studying the signalling events, which control the self-renewal of haemopoietic stem cells and developing chemically defined media for the ex vivo expansion of HSCs from UCB. In parallel to the ex vivo expansion, the group are establishing techniques for ex vivo differentiation of T lymphocytes from the UCB stem cells in the absence of a thymic microenvironment

Leukaemias
Another area of research is the development of model systems to study leukaemia. Leukaemias are a group of diseases resulting in the abnormal production of any type of white blood cell. The group are therefore developing model systems to differentiate mouse embryonic stem cells to specifically form either myeloid or lymphoid white blood cells. These models can then be used to study the processes involved in leukaemogenesis.

UNIVERSITY OF ULSTER

BIOMEDICAL SCIENCE RESEARCH INSTITUTE (RAE GRADE 5*)

NUMBER 52: SYSTEM BIOLOGY

Scientists study and model pathways and networks with an interplay among experiment, theory, and information and communication technology (ICT). Systems biology employs a wide range of ICT methodologies and technologies to process and model biological information including data, information and knowledge modelling and management; statistical analysis; data and text mining; mathematical and computational modelling and simulation of biological processes and systems; and networked computer infrastructures such as grid computing and Web services.

The group applies recent advances in computational biology to a wide range of biomedical problems. This area is of very great relevance to current and emerging industry as it endeavours to cope with massive amounts of data generated from fast-throughput analysers, e.g. for DNA sequencing or clinical trials.

UNIVERSITY OF ULSTER

HEALTH AND REHABILITATION SCIENCES RESEARCH INSTITUTE (RAE GRADE 4)

NUMBER 53:

Unique on the island of Ireland, this group brings together researchers in a range of allied health professions (Physiotherapy, Occupational Therapy, Podiatry, Radiography, Speech & Language Therapy). World-wide, research in this group is not well developed however the UU group gained Grade 4 in the 2001 RAE – the best score for any such discipline. The expertise of the group is ideally suited to working with an ageing population, e.g. significant strength in dealing with patients with stroke or other immobilities. They collaborate actively with colleagues in computer science developing leading-edge approaches to, e.g. sensors to monitor and care for elderly or infirm patients living independently, and a range of virtual environments to give feedback to recovering stroke patients so that their recovery may be accelerated.

UNIVERSITY OF ULSTER

NURSING RESEARCH INSTITUTE (RAE GRADE 4)

NUMBER 54:

While most of the research in this institute is focussed on health and social care issues locally, nationally or globally, it also is a major focus for nurse training in research skills. This is extremely important for the pharmaceuticals industry for the design and conduct of clinical trials - more than 10% of all the UK's PhD-student nurses being registered at UU.

UNIVERSITY OF ULSTER

FACULTY OF ENGINEERING

The University of Ulster has three main research institutes within the faculty of engineering. The University has an outstanding track record in the commercialisation of research outputs and is pivotal to national and international outreach networks. The latest phase in UU support for research and knowledge/technology transfer has been the establishment of Research Institutes in disciplines across the University. These disciplines are housed within the three main engineering institutes; 1.Built Environment, 2.Computer Science and 3.Nanotechnology and Advanced Materials.

German software giant SAP is working in collaboration with the new campus engineering centre at the University of Ulster. SAP will employ up to 40 PhD and postdoctoral researchers in development of future grid computing products.

UNIVERSITY OF ULSTER

COMPUTER SCIENCE

Research carried out in the Computer Science Research Institute is built upon strengths in Software Engineering (SE), Information Engineering (IE), Artificial Intelligence (AI), Intelligent Systems (IS) and Internet Technology (IT). The Institute has staff with an international reputation in Data Mining, Requirements Engineering, Intelligent and Embedded Systems, Reasoning Under Uncertainty, Machine Learning, Intelligent Agents and Web Mining. Within the Computer Science there are three research centres and within each research centre there are further research groups and sub groups. The three research groups are NIKEL, NICeB and CSPT, and they are described in turn below.
(RAE Grade 4)

UNIVERSITY OF ULSTER

NI KNOWLEDGE ENGINEERING LABORATORY (NIKEL)
NIKEL HAS TWO MAIN OBJECTIVES; TO CONTINUE TO PRODUCE HIGH QUALITY RESEARCH IN AI AND RELATED TECHNOLOGIES. ALSO TO HELP COMPANIES IN NI AND BEYOND GAIN COMPETITIVE ADVANTAGE THROUGH THE APPLICATION OF ADVANCED SOFTWARE TECHNOLOGY. NIKEL HAS BEEN INVOLVED IN RESEARCH IN; BUSINESS PROCESS RE-ENGINEERING, DECISION SUPPORT, KNOWLEDGE BASED SYSTEMS AND KNOWLEDGE DISCOVERY/DATA MINING.

NUMBER 55: ARTIFICIAL INTELLIGENCE RECOGNISED RESEARCH GROUP

This research group is part of the NIKEL research centre. The challenges taken up by the AI Group are concerned with two key themes: Reasoning Under Uncertainty (RUU) and Machine Learning (ML) (in its broadest sense), and deal with a number of specific subjects, e.g. Classification, Causal Modelling and Decision Making. Past research projects include; access to distributed databases for statistical information and analysis, intelligent content management system and foundations and applications of non-invasive networks. The AI groups research is divided among four sub-groups;

Intelligent Software Agents Research Group - conducts research on a number of topics including intelligent interface agents, agent-based KDD on the Internet, and planning & plan recognition.

Natural Language Processing Research Group - aims to support and promote excellence in research in the broad area of language related computing with members drawn from the Faculty of Informatics and the Faculty of Social and Health Sciences and Education.

Uncertain Reasoning Research Group - dealing with uncertain and imprecise information has been one of the major issues in almost all intelligent systems. These systems include Decision Making Systems, Diagnostic Systems, Intelligent Agent Systems, Planning Systems, Machine Learning and Data Mining, Pattern Recognition, Case-based Reasoning, Image Processing, Robotics, and Financial Engineering.

Intelligent MultiMedia (IntelliMedia) focusses on the computer processing and understanding of signal and symbol input from at least speech, text and visual images in terms of semantic representations. The Intelligent MultiMedia research group focusses on four sub themes, all important for the development of IntelliMedia systems: spoken dialogue systems, computer graphics & vision, distributed communications systems, and multimedia.

UNIVERSITY OF ULSTER

NI KNOWLEDGE ENGINEERING LABORATORY (NIKEL)

NUMBER 56: INFORMATION ENGINEERING RESEARCH GROUP

The Information Engineering Research Group is also a part of the NIKEL research centre. It covers the development of methodologies and systems for Data Mining and Knowledge Discovery in Databases, the integration of heterogeneous distributed data sources, Knowledge Discovery from imprecise and uncertain information, automated case knowledge discovery, intelligent diagnostic and prognostic systems, clinical data mining and decision support systems. Some of the proposed projects for the research group include; reconfigurable real-time embedded systems, a P2P mesh network framework for streaming media to mobile devices and spell mining for patient data streams.

The Information Engineering Research Group is divided into three Sub Groups;

Statistical and Distributed Databases Research Group
The explosion of developments in computer technology and electronic networks has created a huge international source of information that may be searched for knowledge on a huge variety of topics. Users of statistical information such as Eurostat (the EU statistical agency) have much to gain from using the Internet to access and utilise data from different locations. The work of this research group aims to increase the efficiency of data utilisation.

Data Mining Group
With more and more companies realising the value of the data that they store, data mining is rapidly being used to achieve competitive advantage. Theoretical work by the Group is mainly exploited through applications developed in the NI Knowledge Engineering Laboratory (NIKEL) and some interdisciplinary applied research groups in University of Ulster. (BioInformatics, NIBEC Hearing Group, and Medical Informatics Recognised Research Group)

Computer Vision and Image Processing Research Group
This research group concentrates on cutting edge technology in various fields including proposed work on; laser surgery, intelligence surveillance systems, semantic web based multimedia retrieval and multi-scale feature detection in 3D digital images.

UNIVERSITY OF ULSTER

NI KNOWLEDGE ENGINEERING LABORATORY (NIKEL)

NUMBER 57: MEDICAL INFORMATICS RECOGNISED RESEARCH GROUP

This research group is part of the NIKEL research centre and also the NI Bio-Engineering Centre (NIBEC) in an interdisciplinary structure between the two research centres. In addition, other research areas in the Faculty contribute to this novel and exciting area, which includes such topics as telemedicine and hearing technology.
This research group has carried out a wide range of research projects:

- Component-ware for Autonomic, Situation-aware Communications And Dynamically Adaptable Services
- Helping People with Mild Dementia Navigate Their Day
- Cell phone video streaming in Alzheimer's disease
- Mobile Phone-based Video Streaming system in providing home-support for patients with early Alzheimer's disease
- Exploitation of emerging ICT Technologies for Ageing in Place
- A Feasibility Study Identifying Cost Effective Strategy for Realisation of Life-time Homes in Existing Stock
- Evaluation of AI/IT systems designed for health care
- Real Time Acquisition and Processing of Biomedical Signals
- Knowledge Based Systems for Industrial & Medical Applications.

UNIVERSITY OF ULSTER

NI KNOWLEDGE ENGINEERING LABORATORY (NIKEL)

NUMBER 58: INTELLIGENT SYSTEMS ENGINEERING LABORATORY (ISEL)

ISEL embraces the topic of intelligent systems in the widest sense; the activities of the group encompass research into a range of intelligent and hybrid technologies, and include work on neural networks, fuzzy systems, genetic/evolutionary algorithms, hybrid intelligent systems, reasoning, multiple valued logic and model predictive control. The research is being applied to topics as diverse as intelligent embedded systems, hybrid intelligent machine vision systems, re-configurable computing, hardware-software partitioning, design automation, and self-repair of complex embedded systems.

Current research projects include:

- DETI Broadband Flagship Derry City has been designated by the Department for Enterprise, Trade and Investment as the location for the NI Flagship Project - the demonstration of Wireless Broadband Technology.
- INTERWAVE Interconnections by Electromagnetic Wave Propagation in Silicon-based Artificial Spiking Neural Networks
- Sense Maker: A Multi-sensory, Task-specific Adaptable Perception System.
- DIESEL Remote-access Experimental Laboratory
- Distant Internet-Based Embedded Systems Experimental Laboratory
- Perfecseal Project
- An Investigation into Innovation and Knowledge Development of Medical Adhesive Components.

UNIVERSITY OF ULSTER

NI CENTRE FOR E-BUSINESS (NICEB)

NUMBER 59

NICeB brings together the University's research expertise in business and information technology to offer a dynamic new facility providing advice on technical requirements and customised research studies in e-business. Research so far has concentrated on new internet technologies and electronic commerce tools developed within the Centre and by commercial partners such as BT, Sun Microsystems and IBM. Through its relationship with NIKEL, the Research Centre will have a large and growing population of client businesses with which to test new and existing services, products and programmes. The centre has also been informing policy makers in the local economy with significant results from academic research and surveys of leading edge international best practice.

NICeB provides a forum which brings together the outputs from leading edge research with the centre including:

- Web-Enabled Call Centres
- Knowledge Acquisition via the Internet
- WAP Technologies and Services
- Intelligent Agents
- Spatial data Mining
- EDI
- e-procurement
- e-banking
- e-marketing

In terms of other types of research, the Centre could become a testing or proving ground for: new internet technologies and electronic commerce tools developed within the Centre and by commercial partners such as BT, Sun Microsystems and IBM.

Creating a conduit for business advice, research-based consultancy and training which draws on disparate activities throughout the University by presenting a single stop solution to business managers in the north of Ireland Informing policy makers in the local economy with significant results from academic research and surveys of leading edge international best practice.

Producing a body of research on uptake and use of ecommerce that can then be disseminated and inform the formulation of new e-commerce programmes and initiatives and monitoring the uptake of ecommerce in Northern Ireland.

UNIVERSITY OF ULSTER

CENTRE FOR SOFTWARE PROCESS TECHNOLOGIES (CSPT)

CSPT's activities cover a wide range of areas affecting the quality and effectiveness of both software development processes and products, from process measurement, through business process co-evolution, to object oriented software complexity metrics. The CSPT's technical focus is concentrated in the fields of software process and product engineering and quality. It is in these areas that they seek to investigate high quality software process and product metrics, and to define, develop and use supporting tools. Current research activity falls broadly into 4 categories: (i) Software Process Improvement Frameworks, (ii) Software Engineering Project Management, (iii) Effective Software Engineering practices, (iv) Management and Engineering Metrics.

NUMBER 60: SOFTWARE ENGINEERING RECOGNISED RESEARCH GROUP

This research group works within the CSPT research centre. The Software Engineering Research Group's work covers all aspects of software development, the organisational context in which it is used, software tools, and the detailed development of algorithms for specific domains (including numerical analysis and image processing). The group focuses its research in three key areas;

Parallel Numerical Algorithms Research Group
This group is mainly concerned with the development of algorithms for (i) the computation of partial eigensolutions of extremely large matrices, (ii) the computation of solutions of large, sparse, linear systems of equations, and (iii) the construction of library quality implementations of the algorithms that are portable and efficient across a wide range of massively parallel scalable platforms.

Requirements Engineering Research Group
Established in 1992, major themes running through several projects are (i) Development of the BASE Methodology (ii) Use of Soft Systems Methodology (iii) Evolutionary system change, and (iv) Use of formal modelling

Systems Software Engineering Group
Main research themes are (i) Process and methods for the development of systems (ii) Reuse and reengineering for legacy systems (iii) Requirements capture and management (iv) Architectural design, and (v) Component-based systems engineering

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CENTRE FOR SOFTWARE PROCESS TECHNOLOGIES (CSPT)

NUMBER 61: INTERNET TECHNOLOGY RESEARCH GROUP

This is an emergent research area. Areas of expertise include ATM Switch Fabric Analysis, SDH Multiplexer Design, Neural Network Management Protocols and Intelligent Mobile Agents. Current research is focused on a variety of areas include; RFID enabled location based gaming, Integrated biometric sensor and GPS tracking, exploitation of emerging ICT technologies for ageing, web based remote management systems and also various HEIF8 projects. Research projects undertaken by this group include:

- Centre for Software Process Technologies
- Child Safety through Continuous RFID Enabled Location Awareness
- An Analysis of Real-time Protocols for Chaotic Encryption in IPv6
- Optimization of High-Speed Network Management Functions through the Application of Real-Time Neural Network Algorithms
- Integration of a shopping cart solution with back-end accounting systems.
- Video Streaming Solution for outsourced Recruitment Company

UNIVERSITY OF ULSTER

CENTRE FOR SOFTWARE PROCESS TECHNOLOGIES (CSPT)

NUMBER 62: MATHEMATICS, STATISTICS AND OPERATIONAL RESEARCH RESEARCH GROUP

This expertise includes: Statistical Modelling for Manpower Planning, Application of Probability Theory to the study of the behaviour of Random Polynomials, Queueing Theory, and Consensus Modelling. A number of research projects undertaken by this research group include:

- MULTI-CRITERIA Hierarchical Modelling
- DENI Statistical Study on Bullying in Schools in Northern Ireland
- Local Initiatives Project to Combat Social Exclusion
- Random Polynomials: crossings of levels, and turning points
- A Feasibility Study Identifying Cost Effective Strategy for Realisation of Life-time Homes in Existing Stock
- Addressing Cross Community Participation Rates and Geodemographic Disparity in Further and Higher Education

UNIVERSITY OF ULSTER

BUILD ENVIRONMENT (RAE GRADE 5)

In 2001 the built environment unit received the green light for a major boost in funding and has resulted in new high-tech labs and an increase in academic staff being appointed. The recently formed Built Environment Research Institute now has 22 academic staff, 8 associated academic staff, and 25-30 full time contract researchers. 65 FTE PhD students are enrolled to undertake research across a wide spectrum of areas that range from fire engineering research to property and planning. This provides an excellent environment for undertaking nationally and internationally important research. Build Environment consists of five major research groupings, but only 3 are applicable in the context of this assignment and they are described below.

NUMBER 63: THE FIRE SAFETY ENGINEERING RESEARCH AND TECHNOLOGY CENTRE (FIRESERT)

This research centre combines a multi-disciplined team of scientists and engineers in a unique laboratory facility. A wide range of scientific, engineering and technical skills are focussed on. Applied, fundamental and user need driven research in the fields of fire safety science and engineering is carried out. Facilities for research and related activities at FireSERT include a 600 square metre burn hall, a range of calorimeters including a ten-megawatt facility for full-scale research. FireSERT main areas of focus are:

Fire dynamics

Research is centered on understanding the initiation, growth and development of fire in enclosures and the behaviour of materials, components and constructional assemblies.

Structural fire engineering

The principal thrust is the experimental evaluation of the structural behaviour in fire of a variety of materials and structural assemblies. The focus is on the principal building materials i.e. steel, concrete and brickwork.

Fire modelling

The Modelling of Fire group strategy is focused on the employment of computational fluid dynamics (CFD) as its tool for basic fire research, including fires, fire related and industrial deflagrations.

Human behaviour in fire

The focus of the group to date has been in relation to the evacuation capabilities of building occupants (including persons with physical and mental capabilities); occupant profiling (including response to fire stimuli and evacuation behaviours in a range of occupancies including retail premises, hotels, leisure centres, theatres and pubs) and the development of risk assessment models.

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BUILT ENVIRONMENT (RAE GRADE 5)

NUMBER 64: CENTRE FOR SUSTAINABLE TECHNOLOGIES (CST)

Sustainable Technologies are engineering systems, built environments and infrastructure that are designed to be in harmony with the environment. The Centre for Sustainable Technologies at the University of Ulster undertakes multidisciplinary research to create, develop, improve, demonstrate and evaluate emerging, existing and alternative sustainable renewable energy, building design, construction materials and environmental modification technologies. Some of the fields of research include; Advanced Glazing Systems, Solar Energy Systems for rural locations, Rational use of energy in buildings.

Research areas include:

- Advanced Glazing Systems
- Solar Energy Systems for Rural Applications
- Sensible Heat Storeage
- Total life-cycle energy chain and environmental impact assessment
- Design for Eco-sustainability in the Built Environment
- Corrosion management in reinforced concrete
- Computational Fluid Dynamics and Ray Tracing

The Centre has access to the following facilities;

- A planner solar simulator
- An illuminated calorimeter
- External Solar Test Rig
- A small scale experimental timber drying kiln
- Window weather test apparatus
- River Channel Facility
- Thermal calibration equipment
- A network of Sun UNIX workstations
- Infrared thermal imaging camera
- Vacuum chambers

UNIVERSITY OF ULSTER

BUILT ENVIRONMENT (RAE GRADE 5)

NUMBER 65: NI CENTRE FOR ENERGY RESEARCH AND TECHNOLOGY (NICERT)

NICERT is active in European R&D in the areas of technical, economic and environmental assessment of power generation systems, and in the evaluation of refrigerant-lubricant interactions and compressor performance for the refrigeration, air-conditioning and heat pump industries. Research with NI industry is also conducted in the field of refrigeration and in the use of biomass and appropriate wastes for energy conversion. The Centre is currently concentrating on the following areas:

- Waste Utilisation Technologies
- Fossil Fuel Power Generation
- CHP Studies
- Greenhouse Gas Emission Reduction Studies
- Biomass Utilisation Technologies
- Heat Pumps
- Energy Efficiency

UNIVERSITY OF ULSTER

NANOTECHNOLOGY AND ADVANCED MATERIALS INSTITUTE
(INCLUDING; NANOTECHNOLOGY, BIOENGINEERING AND STRUCTURAL MATERIALS RESEARCH)
(RAE SCORE 4 – METALLURGY AND MATERIALS)
NANOTECHNOLOGY AND INTEGRATED BIOENGINEERING CENTRE (NIBEC)
NIBEC is a consolidation of various research groups, with a combined focus on Biomedical Sensors, Tissue Engineering, Environmental Materials and Nanomaterials. Its research groups are described below.

NUMBER 66: BIOMATERIALS AND TISSUE ENGINEERING GROUP

This group looks to develop new and improved biomaterials that form key components of next generation medical devices and therapies. Specifically the group focuses on the development and exploitation of micro- and nano-technology to provide surface engineered systems for important applications in regenerative medicine and tissue engineering.

Key Projects
Physical coating technologies such as sputter deposition, and surface modification methods such as dielectric barrier discharge, offer an extensive range of options for the functionalisation of biomaterial surfaces. In this regard, the group has extensive facilities to manipulate and control the properties of the bio-interface and to identify and study the subsequent cellular response in vitro.

Nano-featured surfaces with controlled pit/pore density, size, shape, depth, distribution and chemical activity are being developed for use in bioactive cell culture and bioreactor matrices (2-D and 3-D). Such surfaces can also be used for nano-sensor and micro-electrode (below diffusion layer thickness) applications.

Nanometer scale structure-forming systems in biology are inherently self-organising, and exhibit highly selective molecular recognition properties. Hence, exploration of the biomolecular mechanisms involved in control of the size, distribution, and assembly of interesting and functionally applicable inorganic nanostructures is being carried out that offers direct applications in tissue engineering, sensors and coatings.

Advanced polymer systems are used extensively in medical devices and their associated packaging. In this regard, studies are in progress to assess catheter shelf life, radiation degradation of polymers, and properties of high temperature polymer nano-composites.

Extensive R&D effort is being directed at the following key areas:

- Deposition and manipulation of high performance bioactive coatings for the enhancement tissue/implant interactions;
- Modification of biopolymer surfaces by atmospheric pressure plasma processes;
- Determination of the role of nano-scale properties in the delivery of targeted cell/protein surface interactions;
- Control and medication of cell-surface interactions in a dynamic bioreactor environment.

UNIVERSITY OF ULSTER

NANOTECHNOLOGY AND ADVANCED MATERIALS INSTITUTE
(INCLUDING; NANOTECHNOLOGY, BIOENGINEERING AND STRUCTURAL MATERIALS RESEARCH)
(RAE SCORE 4 – METALLURGY AND MATERIALS)
NANOTECHNOLOGY AND INTEGRATED BIOENGINEERING CENTRE (NIBEC)

NUMBER 67: ELECTRODES AND SENSORS GROUP

This group has extensive experience and expertise in the design, fabrication and characterisation of a wide range of sensors and related devices (bio-sensing, electrophysiological monitoring, pacing, defibrillation and wound healing). The group has major strengths in the areas of AC impedance/dielectric spectroscopy, cyclic voltammetry and potentiometry and in their use in the characterisation of materials, interfaces and devices.

Key Projects for the Group

Impedance and dielectric measurements can be used to study and characterise the electrical properties of materials and their interfaces. Such data can in turn be used to furnish information on the homogeneity, thickness and integrity of layers, the roughness and quality of interfaces and on reactions, such as corrosion, taking place at interfaces. At NIBEC suitable measurement cells have been designed and constructed and AC impedance devices adapted and used successfully to study the integrity and surface topography of deposited coating layers and the electrical properties of human tissue in vivo. Electrical Impedance Spectroscopy (EIS) is now the accepted technique for both determining corrosion rates and identifying corrosion reaction mechanisms due to its ability to detect interfacial relaxations covering a wide range of frequencies and thus distinguish the different corrosion processes taking place.

Collaborations

Currently, collaborations are ongoing with Dublin City University and the Royal Victoria Hospital Belfast on an All Ireland Point-of-Care Sensors project. Previous European projects have included MICROCARD and MICROTRANS. The group has close links with the Biomedical Microsensors & Microsystems group, CNRS LPM, Lyon, France.

Industrial Partners;

The group is/has been involved in the successful design and development of a wide range of novel Sensing and Stimulation Bio-medical electrodes for leading companies/organisations. Much of this work has been patented and successfully transferred to industry. Astronaut-monitoring systems have been designed for several space agencies including the Anglo-Soviet JUNO space mission, the German-Soviet MIR programme and a NASA mission. One patented design is for a disposable ECG electrode presently marketed world-wide by over 10 of the top biomedical device companies. As a consequence, the group is widely recognised as world leaders in the fields of Biomedical Electrode Technology and Bio-Impedance Spectroscopy. The group has acted as consultant to several leading companies including Welch Allyn, UnoMedical, Aspect Medical, Hewlett Packard, Elan, and Laboratoires Fournier.

UNIVERSITY OF ULSTER

NANOTECHNOLOGY AND ADVANCED MATERIALS INSTITUTE
(INCLUDING; NANOTECHNOLOGY, BIOENGINEERING AND STRUCTURAL MATERIALS RESEARCH)
(RAE SCORE 4 – METALLURGY AND MATERIALS)
NANOTECHNOLOGY AND INTEGRATED BIOENGINEERING CENTRE (NIBEC)

NUMBER 68: PHOTOCATALYSIS RESEARCH GROUP

The photocatalysis group research group works on the development of semiconductor materials, which will convert light energy into electrochemical energy for the oxidation of chemicals such as environmental pollutants. This group has established internationally recognised research programmes.

Key Projects

The group has participated in FP4, FP5 and FP6 EC projects involving photocatalysis. Currently the group is a lead partner in an FP6 INCO-Dev project, aiming to develop enhanced solar disinfection technology to reduce the incidence of waterborne disease in developing countries where access to clean drinking water is a major problem. Previously, the group has demonstrated that photocatalysis is effective for killing chorine resistant pathogens in water. Other current projects investigate the use of photocatalytic coatings for the ‘self-sterilisation’ and ‘self-decontamination’ of implantable medical devices and surgical instruments. The group is also taking a lead in the development of novel photocatalytic materials such as $TiO2$ nanotubes. These structures have great potential for photocatalytic applications due to their enormous surface area and may find application in other fields such as dye sensitised solar cells, sensors, and bioactive coatings.

IP protection and commercialisation of the research generated is important. Currently the group has two Proof-of-Concept projects funded by Invest Northern Ireland. The first is aimed at the commercialisation of a point-of-use photocatalytic water purification device and the second aimed at commercialisation of photocatalytic coatings for medical device sterilisation in order to prevent patient to patient transmission of disease.

Collaboration

The group collaborates with universities and research institutes both nationally and internationally including; Joseph Fourier University, Grenoble, (France), Ben Gurion University (Israel), Groningen University (Netherlands), University of Southampton (UK), Royal College of Surgeons in Ireland (Ireland), Dublin Institute of Technology (Ireland), Edinburgh University (UK), University of Havana (Cuba). We are a lead partner in the EU FP6 INCO-Dev project SODISWATER collaborating with eight other partners throughout Europe and Africa for the development of solar water disinfection technology.

UNIVERSITY OF ULSTER

NANOTECHNOLOGY AND ADVANCED MATERIALS INSTITUTE
(INCLUDING; NANOTECHNOLOGY, BIOENGINEERING AND STRUCTURAL MATERIALS RESEARCH)
(RAE SCORE 4 – METALLURGY AND MATERIALS)
NANOTECHNOLOGY AND INTEGRATED BIOENGINEERING CENTRE (NIBEC)

NUMBER 69: PLASMA AND NANOFABRICATION GROUP

Plasma processing is central to the research on functional materials and using this as the model, UU can map out a route to controlled ultra-thin deposition and conditioning.
The material characteristics of the films, such as structure and composition, have then to be correlated with their ultimate functional properties, which usually entails the development and use of nanoscale microscopical techniques appropriate to films at the dimensions envisaged.

Key Projects
Plasmas - Including (i) RF electrical spectroscopy for monitoring and control, (ii) substrate ionic and neutral bombardment species energy and flux characterisation, (iii) plasma species characterisation and modelling, (iv) correlation of plasma and substrate bombardment characteristics with resultant materials properties, (v) techniques for plasma in-situ materials monitoring leading ultimately to real-time processing sensors

Plasma System Design - For processing of large-scale and small-scale three dimensional substrates and ultra-thin (10nm) non-planar materials deposition.

Microplasmas - Novel microdischarge devices and operating regimes for application in medical device diagnostics and sensors

Biomaterials - Diamond-like amorphous carbon (hydrogen free) by filtered vacuum cathodic arc and unbalanced magnetron sputtering. Hydrogenated amorphous carbon (a-C:H) and polymeric films by RF planar and RF coaxial PECVD. Surface modification and nanoscale coating of implantable medical devices (e.g. cardiovascular stents) for enhanced biocompatibility.

Industrial Partners of the group include; Seagate; Intel; Oxford Institute; Boston Scientific

UNIVERSITY OF ULSTER

NANOTECHNOLOGY AND ADVANCED MATERIALS INSTITUTE (RAE SCORE 4 – METALLURGY AND MATERIALS)

NUMBER 70: THE ENGINEERING COMPOSITES RESEARCH CENTRE (ECRC)

The ECRE centre provides a forum for advanced thinking in the field of composite technology and devises, undertakes and co-ordinates research projects in this rapidly expanding area. Industries focused on include aerospace, automotive, transportation, construction, civil engineering and medical applications. The centre has close collaboration with REX composites and CTMI, both located in France. Areas of expertise include; design of 3D tailored complex technical textiles, materials characterisations, the manufacture of test composites and modelling of mechanical properties of composite components.

UNIVERSITY OF ULSTER

NANOTECHNOLOGY AND ADVANCED MATERIALS INSTITUTE (RAE SCORE 4 – METALLURGY AND MATERIALS)

NUMBER 71: THE ADVANCED METAL FORMING RESEARCH GROUP (AMFOR)

The AMFoR group was established to address the problems associated with the increasing levels of technology used in the metal forming process by applying science to the art of metal forming. The main objective of the research is to replace the old skilled based system with a knowledge based system. The group currently works closely with Bombardier, Short Brothers plc, ESI Group UK and Airbus UK. Recently the team has started to investigate the hydroforming and roll bending process. All the research is firmly rooted within an industrial context where a key element is the practical application of the work through technology transfer.

A.5
JOINT QUB AND UU RESEARCH

The following table details the joint research initiatives undertaken by QUB and UU.

QUEENS UNIVERSITY BELFAST/UNIVERSITY OF ULSTER
NANOTECHNOLOGY CENTRES
NUMBER 72: NANOTEC NI

Nanotec NI is a dual-sited research centre combining nanotechnology facilities in both Queen's University and University of Ulster. The centre aims to conduct industrially relevant research, development and service work in nanotechnology. Major Nanotech NI Research Themes;

Nanoelectronics and sensors
Nano- & microelectronic devices, high density interconnects, lab-on-a-chip fluidics, photonic materials and nano-optics, bio-sensors, molecular logic devices, molecular nanosensors.

Nanomaterials and coatings
Magnetic storage media, nanostructured media technology, electroceramics and ferroelectrics, diamond-like carbon, electro-chemical characterisation and coating, photocatalysis, dense plasma processing.

Nanoscale surface and interface science and simulation
Scanning probe microscopies, electron & ion microscopies, surface analytical techniques, atomistic simulation, plasma systems modelling.

Molecular self-assembly
Nanoscale chemistry, nanoparticles, supramolecular chemistry.

Nanoscale biotechnology
Tissue engineering, nanostructured biosurfaces, drug delivery systems, molecular microscopy, immobilisation strategies.

A.6
OTHER BODIES

The following table lists and details the research capability of the Physics Department of the Armagh Observatory. Only those two research groups have any potential link with the context of this assignment and as such are briefly outlined for completeness.

ARMAGH OBSERVATORY
PHYSICS (RAE GRADE 4)
NUMBER 73: CLIMATE AND METEOROLOGY

Research into a gaining a greater understanding about how the sun affects the earths' climate.

ARMAGH OBSERVATORY
PHYSICS (RAE GRADE 4)
NUMBER 74: SOLAR PHYSICS

This is a broad ranging field of study covering the following topics; electron density, nano-flaring, solar energy formation, solar quakes, solar jets and the future of the sun.

AFBI

AGRI-FOOD AND BIOSCIENCES INSTITUTE

NUMBER 75: AGRI-FOOD AND BIOSCIENCES INSTITUTE

The Agri-Food & Biosciences Institute (AfBI) was created on 1st April 2006 as an amalgamation of the Department of Agriculture and Rural Development (DARD) Science Service and the Agricultural Research Institute of NI (ARINI). AfBI is a DARD Non-Departmental Public Body (NDPB). AfBI carries out high technology research and development, statutory, analytical, and diagnostic testing functions for DARD and other Government departments, public bodies and commercial companies.

AfBI's DARD-funded research is conducted through programmes in:

- Crop & Grass Production
- Livestock Production
- Animal Health & Welfare
- Food Quality & Processing
- Food Safety
- Fisheries & their Environment
- Environmental Management
- Economics & Rural Development
- Forestry

AfBI possesses excellent facilities in terms of modern scientific laboratories and equipment.

The following are some examples of the facilities AfBI has to offer:

High pressure processing
AfBI has a commercial high pressure food vessel which complements other laboratory scale equipment. This enables AfBI to work with other research centres and the food industry in research and development of pressure-treated foods

Sensory evaluation
Appearance, odour, flavour and texture are extremely important for the enjoyment of foods. The AfBI Sensory Evaluation Unit is used for research, industry and training.

RV Corystes vessel
AfBI's ocean-going marine research vessel provides a multi-functional platform for research and monitoring in marine fisheries, oceanography and sea-bed mapping.

CAFRE

NUMBER 76: COLLEGE OF AGRICULTURE, FOOD AND RURAL ENTERPRISE

The College of Food, Agriculture and Rural Enterprise (CAFRE) is an integral part of the NI Department of Agriculture and Rural Developments Service Delivery Group. The College supports technology transfer and innovation. CAFRE also provides a range of training programmes aimed at farmers, farm family members and those who work in the land based Industries. These training opportunities allow participants to learn and develop new technical and practical skills. CAFRE Offers Industry Training in each of the following areas;

- Environmental Conservation
- Agriculture
- Information Technology
- Equine
- Challenges
- Food
- Business Management
- Health and Safety

Information on the three colleges in CAFRE:

Enniskillen Campus – Agricultural College
Enniskillen Campus has a reputation for turning out highly motivated and professionally trained men and women destined for successful careers in industries associated with the land. The Campus uses comprehensive up-to-date teaching and learning facilities.

Greenmount Campus – Agricultural and Horticultural College
Greenmount offers a range of full time, part time and short courses to people entering and those already working in the NI Agri-food industry. Explore further to find how Greenmount can meet your needs

Loughry Campus - Food Science College
The Loughry campus is centrally located in the heart of Northern Ireland, between Cookstown and Dungannon. The campus buildings are set in parkland bordered by mature woodlands and the Killymoon River, providing a perfect setting for a student campus.

A.7 SUMMARY

It can be seen from the above that there is a real breadth and depth to the research capability of the HE sector in NI. This brings both positive and negative aspects to an assignment such as this. However, as while definite capability exists across almost all elements of each of the sectors under analysis, this fact makes it more difficult to identify and prioritise areas for further development.

APPENDIX B
COMPANY LISTS

B

A.6
OTHER BODIES

ADVANCED MANUFACTURING

COMPANY NAME	COMPANY DESCRIPTION
Bedeck	Manufacture of made-up textile articles, except apparel
A J Power	Manufacture of electric motors, generators and transformers
Academy Lithoplates	Manufacture of photographic chemical material
Adamsez	Manufacture of other rubber products
Adria	Manufacture of knitted and crocheted hoisery
Alphagraphic Inks	Manufacture of paint, varnishes and similar coatings, printing, ink and mastics
Arbarr Electronics	Manufacture of electronic valves and tubes and other electronic components
Armagh Observatory	Research and experimental development on natural sciences and engineering
Arntz Belting Company	Manufacture of other rubber products
Ashdale Engineering	Manufacture of tools
Ashland Chemicals And Hygiene	Manufacture of soap and detergrnts, cleaning and polishing preparations
B O C Gases Ireland	Manufacture of industrial gases
Baker Hughes	Manufacture of tools
Bass Ireland	Manufacture of beer
Bespro Chemicals	Manufacture of soap and detergrnts, cleaning and polishing preparations
Brian & Lynne Hunniford	Manufacture of soap and detergrnts, cleaning and polishing preparations
Brook Design Hardware	Manufacture of non-domestic cooling and ventilation equipment
Calcast	Manufacture of parts and accessories for motor vehicles and their engines
Canyon (Europe)	Manufacture of other general purpose machinery not elsewhere classified
Carton Die (NI)	Manufacture of dyes and pigments
Cde Ireland	Manufacturing of machinery for mining, quarrying and construction
Cheiftain Engineering	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers & semi-trailers
Chieftain Trailers	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers & semi-trailers
Clinty Chemicals	Manufacture of other inorganic basic chemicals
Coca-Cola Bottlers (Ulster)	Production of mineral waters and soft drinks
Colloide Engineering Systems	General mechanical engineering
Colorite Europe	Manufacture of plastics in primary forms
Connect Engineering Attachments	Manufacturing of machinery for mining, quarrying and construction
Copeland	Manufacture of pumps and compressors
Crossland Tankers	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers & semi-trailers
Crystal Coatings	Manufacture of paint, varnishes and similar coatings, printing, ink and mastics
Delta Pressroom Products	Manufacture of paint, varnishes and similar coatings, printing, ink and mastics
Derek McAleese	Manufacture of plastics in primary forms

COMPANY NAME	COMPANY DESCRIPTION
Dernaseer Engineering	Manufacturing of machinery for mining, quarrying and construction
Digestors Silos & Tanks	Manufacture of GPR and plastics products
Dupont (UK)	Manufacture of man-made fibres
Eden Printing Inks	Manufacture of paint, varnishes and similar coatings, printing, ink and mastics
Edina Manufacturing	Manufacture of engines and turbines except aircraft vehicle and cycle engines
Elite Car Products	Manufacture of soap and detergents, cleaning and polishing preparations
Elizabeth Smith	Manufacture of soap and detergents, cleaning and polishing preparations
Endosim	Manufacture of medical and surgical equipment and orthapaedic appliances
Extec Screens And Crushers (NI)	Manufacturing of machinery for mining, quarrying and construction
F G Wilson (Engineering)	Manufacture of electric motors, generators and transformers
Fast Engineering	Manufacture of builders' carpentry and joinery of metal
Finlay Bme	Manufacture of special machinery not elsewhere classified
Finlay Hydrascreens (Omagh)	Manufacture of other general purpose machinery not elsewhere classified
Fintec Crushing & Screening	Other/undefined as no SIC Code
Fisher Engineering	Manufacture of metallic structures and parts of structures
Fortress Doors	Manufacture of builders' carpentry and joinery of metal
Giltspur Scientific	Manufacture of medical and surgical equipment and orthapaedic appliances
Glen Electric	Manufacture of electric domestic appliances
Gray And Adams (Ireland)	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers & semi-trailers
Groundsman Industries	Manufacture of agricultural and forestry machinery
Harland & Wolff Heavy Industries	Building and repairing of ships
Harvard Manufacturing	Manufacture of photographic chemical material
Hill Engineering	Manufacturing of machinery for mining, quarrying and construction
Huco Lightronic NI	Manufacture of electric motors, generators and transformers
Interface Europe	Manufacture of carpets and rugs
Invista Textiles (UK)	Manufacture of man-made fibres
Iq Medical Systems	Other/undefined as no SIC Code
Jordan, Alan L/conemaster	Other/undefined as no SIC Code
Keystone Lintels	Manufacture of metallic structures and parts of structures
Kilco Chemicals	Manufacture of other organic basic chemicals
Kitchenmaster (NI)	Manufacture of soap and detergents, cleaning and polishing preparations
Kla Plastics NI	Manufacture of plastics in primary forms
KMC Engineering(NI)	Manufacture of other general purpose machinery not elsewhere classified
M J M Marine	Building and repairing of ships
Magma Heat	Plumbing

COMPANY NAME	COMPANY DESCRIPTION
Mc Closkey International	Manufacturing of lifting and handling equipment
Mc Elmeel Mobility Services	Manufacture of parts and accessories for motor vehicles and their engines
McKibbin Engineering	Manufacture of electricity distribution and control apparatus
McMullen Architectural Systems	Manufacture of builders' carpentry and joinery of metal
Michelin Tyre Plc	Manufacture of rubber tyres and tubes
Montupet (UK)	Manufacture of parts and accessories for motor vehicles and their engines
Mr D Moore/Mrs G Moore	Manufacture of perfumes and toilet preparations
Mr Thomas Devlin	Manufacture of soap and detergrnts, cleaning and polishing preparations
Mr W Mathers & Mr S Beck	Manufacture of perfumes and toilet preparations
Muldoon Transport Systems	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers & semi-trailers
Mulmuf (NI)	Manufacture of parts and accessories for motor vehicles and their engines
Munster Simms Engineering	Manufacture of pumps and compressors
N C Engineering (Hamiltonsbawn)	Manufacture of agricultural and forestry machinery
Nacco Materials Handling	Manufacturing of lifting and handling equipment
Nectar International	Manufacture of perfumes and toilet preparations
Northern Engineering	Manufacture of agricultural and forestry machinery
NI Railways Company	Transport via railways
Nu-mac Waste Systems	Manufacture of builders' carpentry and joinery of metal
P F Copeland	Manufacture of metallic structures and parts of structures
Peadar Hughes/generals Cabins & Engineering	General mechanical engineering
Pollock Lifts	Manufacturing of lifting and handling equipment
Powerscreen International	Manufacturing of machinery for mining, quarrying and construction
Powershield Doors	Manufacture of builders' carpentry and joinery of metal
Pro-fit Trailers	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers & semi-trailers
Protech Geothermal	Other/undefined as no SIC Code
Pvc Surgery	Manufacture of plastics in primary forms
Qualitrol - Hathway Instruments Division	Manufacture of other electrical equipment not elsewhere classified
Quantum Wireless	Other/undefined as no SIC Code
Quinn Glass	Manufacture of hollow glass
Quinn Manufacturing	Manufacture of concrete products for construction products
Redrock Engineering	Manufacture of agricultural and forestry machinery
Regency Carpet Manufacturing	Manufacture of carpets and rugs
Rfd	Other/undefined as no SIC Code
Roll Formed Fabrications	General mechanical engineering
Roy Tsang	Manufacture of perfumes and toilet preparations

COMPANY NAME	COMPANY DESCRIPTION
Ryobi Aluminium Casting (UK)	Casting of other non-ferrous metals
S D C Trailers	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers & semi-trailers
S J Wylie Engineering	Manufacture of agricultural and forestry machinery
Sb Chemicals	Manufacture of soap and detergents, cleaning and polishing preparations
Schlumberger Oilfield UK Plc	Manufacturing of machinery for mining, quarrying and construction
Schrader Electronics	General mechanical engineering
Seagoe Technologies	Manufacture of electric domestic appliances
Sean Nugent Engineering	Manufacture of agricultural and forestry machinery
Sensor Technology & Devices	Research and experimental development on natural sciences and engineering
Short Brothers Plc	Manufacture of aircraft and spacecraft
Spec-drum Engineering	General mechanical engineering
Springfarm Architectural Mouldings	Manufacture of knitted and crocheted hoisery
Eps	Manufacture of plastics in primary forms
Survitec Group	Manufacture of other rubber products
Telestack	Manufacturing of lifting and handling equipment
Tennants Textile Colours	Manufacture of dyes and pigments
Tesab Engineering	Manufacture of non-electric domestic appliances
Thales Air Defence	Manufacture of weapons and ammunition
The Old Bushmills Distillery	Manufacture of distilled potable alcohol drinks
Tr Shipping Services	Manufacture of metallic structures and parts of structures
Trimite	Manufacture of paint, varnishes and similar coatings, printing, ink and mastics
Tyrone Fabrications	Manufacture of tools
Ulster Carpet Mills (Holdings)	Manufacture of carpets and rugs
Ulster Industrial Explosives	Manufacture of other chemical products
Ultra Spreader International	Manufacture of other rubber products
Visteon UK	Manufacture of parts and accessories for motor vehicles and their engines
Vita Cortex (NI)	Manufacture of plastics in primary forms
W J Collins Distribution	Manufacture of soap and detergrnts, cleaning and polishing preparations
Walk Thru	Manufacture of prepared unrecorded media
Walter Watson	Manufacture of metallic structures and parts of structures
Warmflow Engineering Co	Manufacture of central heating radiators and boilers
Wilhelmina McCartney & William	Manufacture of plastics in primary forms
William Clements (Chemicals)	Manufacture of soap and detergents, cleaning and polishing preparations
Wonder Wash	Manufacture of soap and detergents, cleaning and polishing preparations
Wrightbus	Manufacture of motor vehicles

ADVANCED MATERIALS

COMPANY NAME	COMPANY DESCRIPTION
Almac Sciences / Chemical Synthesis Services	Nanostructured materials
Amtec Medical	Multi-functional materials
Andor Technologies	Nanostructured materials
Avalon Instruments/Perkin-Elmer	Polymers; nanostructured materials
AVX-Kyocera	Ceramics
BCO technologies	Polymers
Biosyn Diagnostics	Biomaterials; nanostructured materials
Bombardier-Shorts-Aerospace	Composites; polymers; nanostructured materials
Boxmore Plastics	Polymers; nanostructured materials
BP Diagnostics	Biomaterials; nanostructured materials
Brett Martin	Polymers
Clarehill Plastics	Polymers
Coates-Barbour, Lisburn	Nanostructured materials; coatings
Colorite Europe	Polymers
Creative Composites ;	Composites
Delta Packaging	Nanostructured materials
Denroy Plastics	Polymers
DuPont (NI)	Polymers; coatings
FG Wilson Engineering	Magnetic materials; metals
Fortress Diagnostics	Biomaterials; nanostructured materials
Fusion Antibodies	Nanostructured materials
Gazer Technologies	Electronic material; biomaterials;
Gendel	Biomaterials
Heartsine Technology	Electronic material; biomaterials;
Huhtamaki	Polymers
Icemos Technology	Electronic material; nanostructured materials
Kent Plastics	Coatings
Macrete Ireland	Composites
Meridian Medical Technologies	Biomaterials; multi-functional materials;
Micro-Flexitronics	Multi-functional materials; electronic material
Montupet	Multi-functional materials;; metals
Perfecseal Polymers	Nanostructured materials; coatings
Randox Laboratories	Magnetic materials; biomaterials

COMPANY NAME	COMPANY DESCRIPTION
Schrader Electronics	Multi-functional materials; electronic materials
Seagate Technology Recording Head & Media Divisions	Electronic material; magnetic materials; coatings
Seagoe Advances Ceramics	Ceramics
Sean Quinn Group (Plastics, Glass, Cement)	Composites
Sensor Technology + Devices	Biomaterials; nanostructured materials; coatings
Springvale EPS	Polymers
TFX Medical	Biomaterials; coatings
Thermomax	Mult-ifunctional materials; nanostructured materials; coatings
TSM	Multi-functional materials;
William Clark & Sons (Textile Manufacturers)	Multi-functional materials; polymers; coatings
Wilsanco Plastics	Polymers
Xenosense	Biomaterials; coatings
Xiomateria	Biomaterials

SUSTAINABLE PRODUCTION AND CONSUMPTION

COMPANY NAME	COMPANY DESCRIPTION
Abna	Manufacture of prepared animal feeds
Aes (NI)	Production of electricity
Airtricity Energy Supply (NI)	Production of electricity
Allied Bakeries Ireland	Manufacture of bread, manufacture of fresh pastry goods and cakes
Anglo Beef Processors	Production and preserving of meat
Anglo Beef Processors	Production and preserving of meat
Antrim Construction Company Armaghdown	General construction of building and engineering works
Creameries	Operation of dairy and cheese making
Associated Processors	Preparation and spinning of other textile fibres
Avondale Foods (Craigavon)	Processing and preserving of fruit and vegetables
Ballyrashane Co-op Agricultural	Operation of dairy and cheese-making
Bite Snack Foods	Manufacture of bread, manufacture of fresh pastry goods and cakes
British Bakeries	Manufacture of bread, manufacture of fresh pastry goods and cakes
Bsg Civil Engineering	General construction of building and engineering works
Clearway Disposals	Recycling of metal, waste and scrap
Crossgar Poultry	Production and preserving of poultry meat
Dale Farm	Operation of dairy and cheese-making
David Patton & Sons (NI)	General construction of building and engineering works
Davison Quality Foods	Processing and preserving of fruit and vegetables
Department Of Agriculture & Rural Development	Wrecking of buildings , earth moving
Devenish Nutrition	Manufacture of prepared animal feeds
Eurostock Foods Newry	Production of meat and poultry products
Evron Foods	Manufacture of bread, manufacture of fresh pastry goods and cakes
Felix O Hare & Co	General construction of building and engineering works
Forker Garden Products	Manufacture of fertilisers and nitrogen compounds
Foyle Meats	Production and preserving of meat
Fraser Homes	General construction of building and engineering works
G E Mc Larnon And Sons	Manufacture of prepared animal feeds
Gilbert-ash NI	General construction of building and engineering works
Glanbia Cheese	Operation of dairy and cheese-making
Graham Martin	General construction of building and engineering works
Grampian Country Pork	Production of meat and poultry products
Greenway (Ireland)	Recycling of metal, waste and scrap

COMPANY NAME	COMPANY DESCRIPTION
H&J Martin	General construction of building and engineering works
Henry Brothers (Magherafelt)	General construction of building and engineering works
Heron Bros	General construction of building and engineering works
Howden Power	General construction of building and engineering works
Hubert Brown Kerr	Manufacture of bread, manufacture of fresh pastry goods and cakes
James A S Finlay	Processing and preserving of fruit and vegetables
John Graham (Dromore)	General construction of building and engineering works
John Mackle (Moy)	Manufacture of prepared pet foods
John Mc Ardle	Manufacture of fertilisers and nitrogen compounds
John Thompson And Sons	Manufacture of prepared animal feeds
Joseph & Andrew Thompson	Manufacture of pesticides and other agro-chemical products
Kemira Growhow NI	Manufacture of fertilisers and nitrogen compounds
Kerry Foods	Production of meat and poultry products
Linden Foods	Production and preserving of meat
Macneice Fruit	Processing and preserving of fruit and vegetables
Mcaleer & Rushe	General construction of building and engineering works
Mccolgan Bros	Production of meat and poultry products
Mcerlain's Bakery (Magherafelt)	Manufacture of bread, manufacture of fresh pastry goods and cakes
Mclaughlin & Harvey	General construction of building and engineering works
Mcnicholas Construction (Holdings)	General construction of building and engineering works
Mivan Group Holdings	General construction of building and engineering works
Mourne Compost	Manufacture of fertilisers and nitrogen compounds
Mourne Country Meats	Production of meat and poultry products
Moy Park	Production and preserving of poultry meat
Mr Paul Damien Mccann	Manufacture of fertilisers and nitrogen compounds
NIE Powerteam	Distribution and trade in electricity
NI Electricity	Transmission of electricity
Northstone NI	General construction of building and engineering works
Northstone NI	Construction of motorways, roads, railways, airfields and sports facilities
O'kane Poultry	Production and preserving of poultry meat
Omagh Meats	Production and preserving of meat
Phoenix Natural Gas	Distribution and trade of gaseous fuels
Premier Power	Production of electricity
Pritchitt Foods	Operation of dairy and cheese-making
Pritchitts	Manufacture of rusks and biscuits, manufacture of preserved pastry goods and cakes

COMPANY NAME	COMPANY DESCRIPTION
Reen Compost	Manufacture of fertilisers and nitrogen compounds
Science Innovation Centre	Science & Innovation
Strathroy Dairy	Operation of dairy and cheese making
T S Foods	Production of meat and poultry products
Taggart Homes	General construction of building and engineering works
TAL	General construction of building and engineering works
Tayto (NI)	Processing and preserving of potatoes
The Innovation Centre	Innovation
Tmc Dairies (NI)	Operation of dairy and cheese-making
United Dairy Farmers	Operation of dairy and cheese-making
United Feeds	Manufacture of prepared animal feeds
Viridian Energy Supply	Transmission of electricity
W D Irwin & Sons	Manufacture of bread, manufacture of fresh pastry goods and cakes
W D Meats	Production and preserving of meat
Westland Horticulture	Manufacture of fertilisers and nitrogen compounds
Whitemountain (Surfacing)	Construction of motorways, roads, railways, airfields and sports facilities

LIFE SCIENCES

COMPANY NAME	COMPANY DESCRIPTION
Almac – Almac Diagnostics	Genomic expression services
Almac – Almac Sciences	Chemistry services
Almac – Clinical Services	Manufacture of supply chain logistics
Almac – Pharma Services	Pharmaceutical and biotechnology outsourcing services
Amtec Medical	DVT detection
Armstrong Medical	Respiratory disposal products
Avalon Instruments	Range of raman analysers
Bio Kinetic Europe	Clinical trials
BioColour	Bench tools
Biopanda Diagnostics	Immunology reagents
BioSearch NI	Microbiological analysis
Bluescope Medical Technologies	Cardio-pulmonary monitoring
Clonnallon Laboratories	Sterile dressings and theatre packs
Diabetica	Biopharmaceutical therapies
Field Boxmore Belfast	Packaging
Forress Diagnostics	Diagnostics
Galen	Medication manufacture
Gambro/Ivex Pharmaceuticals	Intravenous and other sterile solutions
Gendel	Medical devices for the treatment of solid cancer tumors
Haemoband Surgical	Haeomoband multi-ligator
HealthTek	Range of devices to monitor patient conditions
HeartScape Technologies	PRIME ECG systems
Heartsine	Innovative Defribulators
i-Path Diagnostics	Digital education, quality assurance and virtual slide archiving in pathology
Kiel Pharmaceutical	Solid, semi-solid and liquid dosage forms
MDS Pharma Services	Clinical research and clinical trials
Medevol Clinical Services	Clinical trials
Morris Consulting	Easiread non-invasive blood pressure measurement
Nicobrand	Active pharma ingredient for the smoking cessation industry
Norbrook Laboratories	Veterinary and medical products, chemical synthesis
Orthodocs	Pressure care cushions and bed rail protection systems
Randox Laboratories	Manufacture of diagnostic kits
Regal Processors	Functional Proteins

COMPANY NAME	COMPANY DESCRIPTION
Sepha	Deblistering and leak testing equipment
Shiraz Medical	Disposable stethoscope covers
ST&D	Medical electrodes and sensors
TG Eakin	Manufacture of ostomy and wound drainahe/skin protection products
Tru-Corp	Training components for medical simulation manikins
Tyco Healthcare Manufacturing	Manufacture of medical devices
Victoria Pharmacies	Pharmaceutical development
Warner Chilcott	Pharmaceutical development and manufacturing
XenoSense	Test kits

ELECTRONICS AND PHOTONICS

COMPANY NAME	COMPANY DESCRIPTION
Acksen	Manufacturing instruments and appliances for measuring, checking, testing, navigating, and other purposes
Adt Europe	Manufacture of television and radio receivers, sound or video recording or reproducing appararus and associated goods.
Andor Technolgy Plc	Manufacturing instruments and appliances for measuring, checking, testing, navigating, and other purposes except industrial process control equipment.
Audio Processing Technology	Manufacture of television and radio receivers, sound or video recording or reproducing appararus and associated goods.
AVX	Manufacture of electronic valves and tubes and other electronic components.
Celeritek UK	Manufacture of electronic valves and tubes and other electronic components
Contacq	Additional companies with incomplete/non-influencial data
Controlled Electronic Management Systems	Manufacture of computers and other information processing equipment
Crossbows Optical	Manufacture of builders' ware of plastics
Daewoo Electronics UK	Manufacture of television and radio receivers, sound or video recording or reproducing appararus and associated goods
Digital Theater Systems (NI)	Other (from additional requested information)
E&I Engineering	Manufacture of industrial process and control equipment
Elite Electronic Systems	Manufacture of electronic valves and tubes and other electronic components
Fibre Optic Installation Services	Manufacturing instruments and appliances for measuring, checking, testing, navigating and other purposes except industrial process control equipment
Flextronics (UK) Design Services	Wholesale of computers, computer peripheral equipment and software
Fsl Electronics	Manufacture of other electrical equipment
Fujitsu Telecommunications Europe	Manufacture of radio, television and communication equipment and apparatus
Gilfresh Produce	Manufacturing instruments and appliances for measuring, checking, testing, navigating, and other purposes except industrial process control equipment
Glentronics	Manufacture of radio, television and communication equipment and apparatus
Hivolt Capacitors	Manufacture of electronic valves and tubes and other electronic components
Humax Electronics Co	Additional companies with incomplete/non-influencial data
Infineer	Manufacturing instruments and appliances for measuring, checking, testing, navigating, and other purposes except industrial process control equipment
Innovation Technologies (Ireland)	Research and experimental development on natural sciences and engineering
Inspecvision	Manufacture of computers and other information processing equipment
Integrated Process Control	Manufacture of industrial process and control equipment

COMPANY NAME	COMPANY DESCRIPTION
JMG Systems	Manufacture of electricity distribution and control apparatus
Marturion	Research and experimental development on natural sciences and engineering
MCA Systems	Manufacture of industrial process and control equipment
Mindready Solutions (NI)	Manufacturing instruments and appliances for measuring, checking, testing, navigating, and other purposes except industrial process control equipment
Nortel Networks UK	Manufacture of radio, television and communication equipment and apparatus
Power Action	Manufacture of electronic valves and tubes and other electronic components
R F Integration	Manufacture of electronic valves and tubes and other electronic components
Radiocontact	Manufacture of television and radio receivers, sound or video recording or reproducing appararus and associated goods
Star Instruments	Manufacturing instruments and appliances for measuring, checking, testing, navigating, and other purposes except industrial process control equipment.
Taran Systems	Manufacturing instruments and appliances for measuring, checking, testing, navigating, and other purposes except industrial process control equipment.
United Optical Laboratories	Manufacture of optical instruments and photographic equipment

ICT

COMPANY NAME	COMPANY DESCRIPTION
8over8	Other software consultancy and supply
Aepona	Other software consultancy and supply
Aerona Software Systems	Other software consultancy and supply
Alta Systems (NI)	Other software consultancy and supply
Amacis	Other software consultancy and supply
Amt-sybex (NI)	Other software consultancy and supply
Andronics	Other software consultancy and supply
Asidua	Other software consultancy and supply
Atlas Communications NI	Telecommunications
Audiences NI	Other software consultancy and supply
Avec Solutions	Other software consultancy and supply
Axis Three	Other software consultancy and supply
Beatties Distribution Services	Courier activities other than national post activities
Biznet Solutions	Other software consultancy and supply
Black Box Network Services (UK)	Telecommunications
Bluechip Technologies	Other software consultancy and supply
Breezemount Transport	Courier activities other than national post activities
Brookson Management Services	Other software consultancy and supply
BT	Telecommunications
Bytel	Telecommunications
CanDo Interactive	Other software consultancy and supply
Cara (Northern Ireland)	Hardware consultancy
Carol Mary Mccloy & William Mccloy	National post activities
Ceva	Other software consultancy and supply
City Air Express (NI)	Courier activities other than national post activities
Civil & Structural Computer Services	Other software consultancy and supply
Clarity Telecom	Telecommunications
Clinisys Oncology	Other software consultancy and supply
Consilium Technologies	Other software consultancy and supply
Core Systems	Other software consultancy and supply
Cover.net	Other software consultancy and supply
CSC Computer Sciences Activity	Other software consultancy and supply
Datatactics	Other software consultancy and supply

COMPANY NAME	COMPANY DESCRIPTION
DHL International (UK)	Courier activities other than national post activities
DX Network Services	Courier activities other than national post activities
Ecom Software	Telecommunications
Eg. Information Consulting	Other software consultancy and supply
Energis Communications	Telecommunications
EZ-DSP T/a Bittware - UK	Other software consultancy and supply
Fern Computer Services	Other software consultancy and supply
Finisco	Other software consultancy and supply
Fionn Technologies	Other software consultancy and supply
Fujitsu Services	Other software consultancy and supply
Gazer Technologies Research	Other software consultancy and supply
Goodrich Control Systems	Other software consultancy and supply
Huntleigh Healthcare	Courier activities other than national post activities
ICS Computing	Other software consultancy and supply
Intelliden	
Interval Software Services	Other software consultancy and supply
Invision Software	Other software consultancy and supply
Ion Technologies	Other software consultancy and supply
IT Alliance NI	Other software consultancy and supply
J G Gough	National post activities
J Thompson Solutions	Other computer-related activities
Kainos Software	Other software consultancy and supply
Kingston Communications (Hull)	Telecommunications
Lagan Technologies	Other software consultancy and supply
Lakeland Computer Consultancy Services	
Latens Systems	Other software consultancy and supply
Level Seven	Other software consultancy and supply
Mail Screening & Security	National post activities
Mairead Donnelly	National post activities
Mallon Technology	Other software consultancy and supply
Mclernon Computers (NI)	Other software consultancy and supply
Mediacom (Ireland)	
Memsis	Telecommunications
Meridio	Other software consultancy and supply
Merlin Interactive	Other software consultancy and supply
Micro Computer Solutions	Manufacture of computers & other info processing equipment

COMPANY NAME	COMPANY DESCRIPTION
Mobile Cohesion	Other software consultancy and supply
Mobility Data Systems	Telecommunications
Modcoms	Other computer related activities
Momedisys	Other software consultancy and supply
Newell & Budge Security	Other computer-related activities
Nisoft (UK)	Other software consultancy and supply
Nitec Solutions	Other software consultancy and supply
Northbrook Technology	Other software consultancy and supply
Northgate Information Solutions UK	Other software consultancy and supply
NTL Group	Telecommunications
Openwave Systems (NI)	Other software consultancy and supply
Opt 2 Vote	Other software consultancy and supply
Opus Solutions	Other software consultancy and supply
Parity Training	Other software consultancy and supply
Paul Lennon	National post activities
Paul Molloy	Other software consultancy and supply
Post Office	
Raytheon Systems	Other software consultancy and supply
Real Time Systems	Other software consultancy and supply
Relay Business Software	Other software consultancy and supply
Responsian	Other software consultancy and supply
RJH Haulage	Courier activities other than national post activities
Robert Ian Duncan	National post activities
Royal Mail Holdings	
Sanderson	Other software consultancy and suppl
Sanmina-sci	Manufacture of computers & other info processing equipment
SAP Research	
Serpico Software	Other software consultancy and supply
Siemens Business Services	Other software consultancy and supply
Singularity	Other software consultancy and supply
Steria	Hardware consultancy
Stirk, Lamont & Associates	Other software consultancy and supply
Stream International (NI)	Other computer related activities
Streamon.net	Other software consultancy and supply
Sureskills	Other computer related activities
Swan Labs	Other software consultancy and supply

COMPANY NAME	COMPANY DESCRIPTION
Synstar	Other software consultancy and supply
Sysco Software (NI)	Other software consultancy and supply
TI Solutions	Other software consultancy and supply
Telephone Services	Telecommunications
Terence Quigley	Courier activities other than national post activities
Texthelp Systems	Other software consultancy and supply
The Internet Business	Telecommunications
Tibus	Telecommunications
Tomcat Systems	Other software consultancy and supply
Tri Mobile Communications	Telecommunications
Tri-tec Support (NI)	Maintenance and repair of office, accounting and computing machinery
Unite Solutions	Telecommunications
UTV Internet	Telecommunications
Vision Information Consulting	Other software consultancy and supply
VME Retail Systems	Other software consultancy and supply
Wellington Computer Systems	Other software consultancy and supply
Wombat Financial Software	Hardware consultancy

APPENDIX C
GLOBAL SECTOR ROADMAPS

C

C.1 INTRODUCTION

Based on their current maturity a number of technology trends appear poised to have significant global effects in the next few decades. The key technology sectors which have been identified for this report are; i) Biosciences and Healthcare; ii) Advanced Materials; iii) Design Engineering and Advanced Manufacturing; iv) Electronics and Photonics; v) Emerging Energy Technologies; vi) Information Technology; vii) Sustainable Production and Consumption. It is important to be aware that these sectors are not isolated and there is a significant amount of intersection and cross-fertilisation between each.

In the 20th century, significant progress was achieved in 'pure' subjects such as chemistry and physics. In the 21st century cross-disciplinary advances are more likely to be achieved and the technology sectors identified above will probably dominate. The Bioscience and Healthcare sector[i ii], appears to have a good understanding and controlling of the genetic coding of living things which may result in revolutionary control of biological organisms and their deficiencies. Advances in Biomedical Engineering, Therapeutics, and Drug Development hold additional promises for a wide range of applications and improvements. The US National Nanotechnology Initiative 2000[iii] projected that 'the emerging fields of nanoscience and nanoengineering are leading to unprecedented understanding and control over the fundamental building blocks of all physical things. These developments are likely to change the way almost everything from vaccines to computers to automobile tires to objects not yet imagined are designed and made'. Materials Research and Engineering will probably continue to yield materials with improved properties aided by advances in Computational Science. Examples of such materials will be applied to both commonplace (such as building construction) and specialised materials (such as reconnaissance and surveillance, or aircraft and space systems). In general, materials of the 21st century will likely be smarter, multi-functional and compatible with a broad range of environments.

Advances in all these technology sectors are combining to enable devices and systems with potential global effects on health and safety; the economy, social and political systems; and business & commerce.

This technological revolution, together with the ongoing process of globalisation, enabled by information technology and continued improvements in transportation[iv] on the one hand opens up possibilities for increased life span, economic prosperity, and quality of life and on the other hand introduces further complexities such as privacy, employment and ethical issues.

C.2
DESIGN ENGINEERING AND ADVANCED MANUFACTURING

TABLE C.1: SOME PRESENT AND FUTURE COMMERCIAL APPLICATIONS OF DESIGN ENGINEERING AND ADVANCED MANUFACTURING[v]

AVAILABLE NOW	1-5 YEARS AWAY	5-15 YEARS AWAY
Sunscreens	Lab on chip technologies	Targeted drug delivery and virus detection
Computer hard disks	Smart nano-coatings for packaging and	Anti-corrosion coatings
Semi-conductor lasers for telecommunications	Tracking devices	Improved medical implants and artificially
Harder, stronger, lighter materials	Improved photovoltaic devices for renewable	Created organs
Self-cleaning windows	Energy sources	Molecular methods for disease diagnosis
Sensors for airbags	High-density data storage	Non-invasive molecular imaging in medicine
		Improved sensors e.g. for pollutants

Engineering and manufacturing know-how continues to advance as devices have continued to decrease in size and increase in complexity. Size reduction occurred in 'traditional' fields such as microelectronics but also in new fields such as Micro-Electro-Mechanical Systems (MEMS). These advances have the potential to change the way we engineer our environment, construct and control systems, and interact in society.

The Semi-conductor Industry

SEMATECH (SEmiconductor MAnufacturing TECHnology consortium) is calling for the further reduction in device node size in their latest International Technology Roadmap for Semi-conductors (ITRS). The roadmap calls for a 35 nm gate length by 2015 with a total number of functions in high-volume production microprocessors of around 4.3 billion. For low-volume, high-performance processors, the number of functions may approach 20 billion. Corresponding memory chips (DRAMs) are targeted to hold around 64 gigabytes. This roadmap, based on Moore's law[vi], will continue the exponential trend in processing power, fuelled by and in turn fuelling advances in information technology.

Figure 11.1 show how economic pressures forcing up wafer size, reducing node size and are increasing the cost of fab's[vii] - ultimately driving Advanced Manufacturing.

Potential alternatives to the standard semi-conductor technology are already being investigated - i) defect-tolerant computer architectures such as those prototyped on a small scale by Hewlett-Packard[viii], ii) quantum computing based on devices that take advantage of various quantum effects. An example of which is the spin polarisation of electrons, to determine the state of individual switches, and iii) molecular electronic devices which could operate as logic switches through chemical means, using synthesised organic compounds. All of these technologies are in their infancy and it is likely that the next 15 years will remain under the control of the traditional digital electronic computers based on semiconductor technology.

Micro Electro Mechanical Systems

MEMS is a 'top-down' fabrication technology which enables other application areas that are is especially useful for integrating mechanical and electrical systems together on the same chip. MEMS techniques have been used to make some functional commercial devices such as sensors, single-chip measurement devices and human transport vehicles.

Some of the first applications of MEMS instruments were as basic sensors for acceleration (such as those used in airbags), pressure, etc. Small, microscale, special-purpose optical and chemical sensors have been used for some time in sophisticated laboratory equipment, along with microprocessors for signal processing and computation. As these sensors become more sophisticated and more integrated with computational capability (with the aid of systems-on-a-chip), their utility should grow tremendously, especially in the biomedical arena.

Devices Based on Size Reduction

Simple electro-optical and chemical sensor components have already been successfully integrated onto logic and memory chip designs in research and development labs. The 1999 ITRS predicts the introduction of chemical sensor components with logic in commercial designs by 2002, with electro-optical component integration by 2004, and biological systems integration by 2006. Thus there is clearly time for relatively complex integrated

FIGURE C.1: HOW FABRICATION COSTS ARE REDUCING DRIVING ADVANCED MANUFACTURING

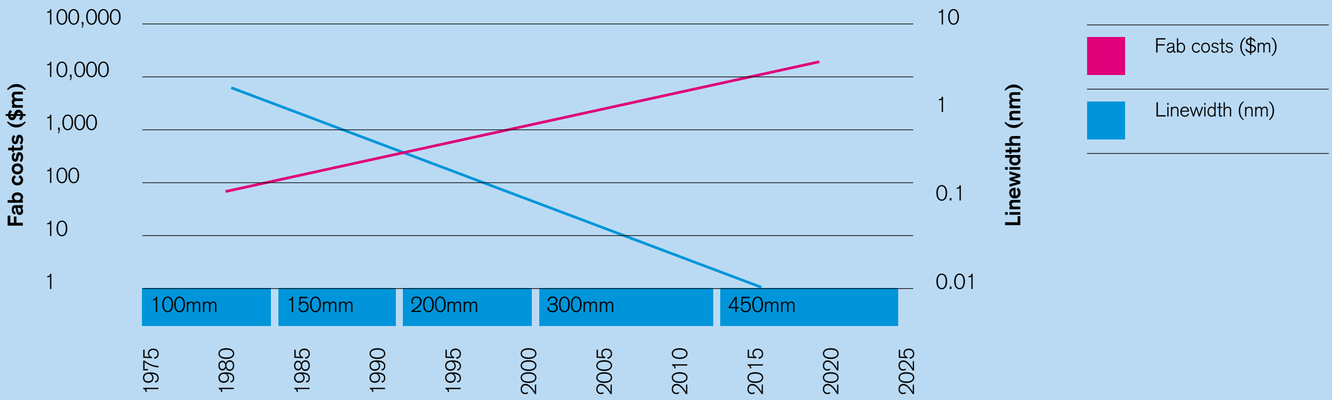
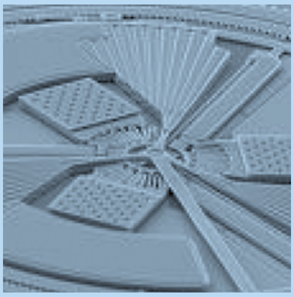


FIGURE C.2: HUMAN TRANSPORT VEHICLE WHICH RELIES HEAVILY ON MEMS GYROSCOPES[ix]

FIGURE C.3: SOME EXAMPLES OF MEMS DEVICES (A RATCHET AND A THERMAL ACTUATOR)[x xi]



systems and applications to develop within the next decade. These advances could enable many applications where increased integrated functionality can become widespread as a result of lower costs and micro-packaging.

Other possible applications include inexpensive networked 'nanosatellites'[xii]. These 'nanosatellites' are targeting order-of-magnitude reductions in both size and mass by reducing major system components using integrated microsystems. If successful, this could economise space missions and approaches (e.g. communication, remote sensing, global positioning and scientific study) while enabling new missions (e.g. military tactical space support and logistics, distributed sparse aperture radar, and new scientific studies).

Nanoscience Investment

International competition for dominance or even capability in cutting-edge nanotechnology may still remain strong, but current investments and direction show that the US and Europe may retain leadership in most of this field. Progress in nanotechnology will depend heavily on R&D investments.

TABLE C.2: GOVERNMENT SUPPORT FOR NANOTECHNOLOGY (£ MILLIONS)

COUNTRY	PAST SPENDING	PLANNED SPENDING	NOTES
Canada		50 (2002-2007)	No national strategy
China	0.16 pa	100 pa	Collaboration with Germany, France and S. Korea
Denmark	84 (1988-1997)	5 pa	3 Nanocentres created in 2003
France		536 over next four years	Priority to fundamental research
Germany	173 in 2003	201 in 2005	Nanotechnology strategy announced ion 2003
India		3.4 pa	Collaboration with US, Japan and Germany
Italy	31 pa		Nanotechnology cluster created in 2002
Switzerland	64 (2000-2003)		
Japan	500 in 2003	200,000 by 2010	Focus on nanoelectronics and nanomaterials
USA	423 in 2003	2,027 pa	National Nano initiative announced in 2000. Creation of 6 new Nanocentres
S. Korea		80 pa	
UK	30	45 pa	Nanotechnology strategy announced in 2003

Consumer Drivers
Semi-customisation is another growing area of Advanced Manufacturing. The driver for this is an increased market focus. An example of this is Bentley car manufacturing, which has lower volumes and increased margins. This is further extending the specialisation of companies and increasing use of the global supply chain.

Price and Speed to Market Drivers
Computational science is an enabler-enhancing manufacturing process allowing the production of complex geometries and reducing time to market. Materials design uses computing power (sometimes together with massive parallel experimentation) to screen many different materials possibilities to optimise properties for specific applications (e.g. nanocomposite and optical materials). Additional changes to processing such as lifecycle analysis, green, lean, and six sigma are also impacting Advanced Manufacturing.

Rapid prototyping is the capability to combine computer-assisted design and manufacturing with rapid fabrication methods that allow inexpensive part production (as compared to the cost of a conventional production line). Rapid prototyping enables a company to test several different inexpensive prototypes before committing infrastructure investments to an approach. Combined with manufacturing system improvements to allow flexibility of approach and machinery, rapid prototyping can lead to an agile manufacturing capability. In addition, the advantage of virtual capability is the ability to design and then outsource product manufacturing, thus offloading capital investment and risk. This capability is synergistic with the information technology revolution in that it is a further factor in globalising manufacturing capability and enabling organisations with less capital to have a significant technological effect. The prototypes were originally made of plastic or ceramic materials and were not functional models, but now the capability exists to make a functional part, for example out of titanium[xiii].

Finally, another exciting trend is biomimetics, which is the design of systems, materials, and their functionality to mimic nature. Current examples include layering of materials to achieve the hardness of an abalone shell or trying to understand why spider silk is stronger than steel.

C.3
ADVANCED MATERIALS

Advanced Materials are often created from pure R&D centres such as universities without any defined industrial issue. Herein lies the main trend for these Advanced Materials – how to apply them to as yet unknown problems. Often these materials can exist for decades before they can be commercially exploited.

Composite materials

Composites are combinations of metals, ceramics, polymers, biological and other materials that allow multi-functional behaviour. One common practice is reinforcing polymers with ceramic fibres to increase strength while retaining light weight and avoiding the brittleness of the monolithic ceramic (similar to re-enforcing concentrate with steel).

Self-assembly materials

Self-assembly materials (similar to molecular manufacturing) refers to the use in materials processing or fabrication of the tendency of some materials to organise themselves into ordered arrays (e.g. colloidal suspensions). This provides a means to achieve structured materials 'from the bottom up' as opposed to using traditional manufacturing or fabrication methods such as lithography, which is limited by current measurement and instrumentation capabilities. Already, organic polymers have been tagged with dye molecules to form arrays with lattice spacing in the visible optical wavelength range and that can be changed through chemical means. This provides a material that fluoresces and changes colour to indicate the presence of chemical species.

Bottom-up molecular manufacturing (assembled atom by atom) differs from microtechnology and MEMS in that the latter employ top-down approaches using bulk materials using macroscopic fabrication techniques. To realise molecular manufacturing, a number of technical accomplishments are necessary - suitable molecular building blocks must be found with the ability to assemble complex structures based on a particular design and systems design. It is important to note that molecular manufacturing remains a very immature technology.

Biomaterials

Biomaterials can be designed to mimic the self-assembly processes of natural tissue matrices and create high-order structures potentially useful for tissue engineering. A recent approach involves using synthetic molecules (A) that are designed to assemble into nanometer-scale rods which induce mineral growth (B). The newly-formed mineral is structurally similar to that of natural human bone tissue and the material may be implanted into a bone defect site to potentially enhance bone regeneration (C). Note that the size scales range from nanometer-scale design of individual molecules to micron-scale self-assembly and ultimately to centimetre-scale tissue regeneration.

Smart materials

Smart reactive materials combining sensors and actuators, perhaps together

FIGURE C.4: MESOSCOPIC COMPUTER SIMULATIONS OF SELF-ASSEMBLED STRUCTURES FORMED BY DIBLOCK COPOLYMERS[xiv]

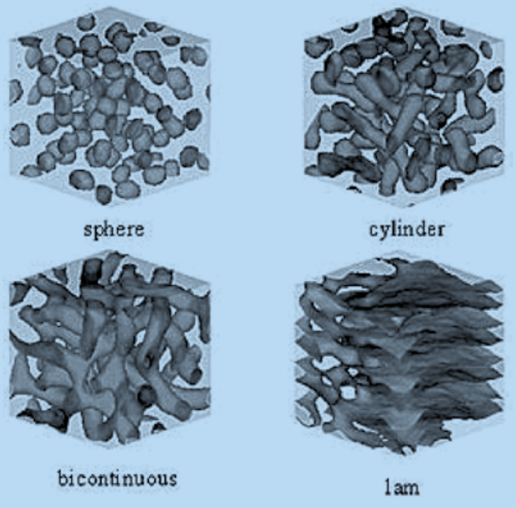
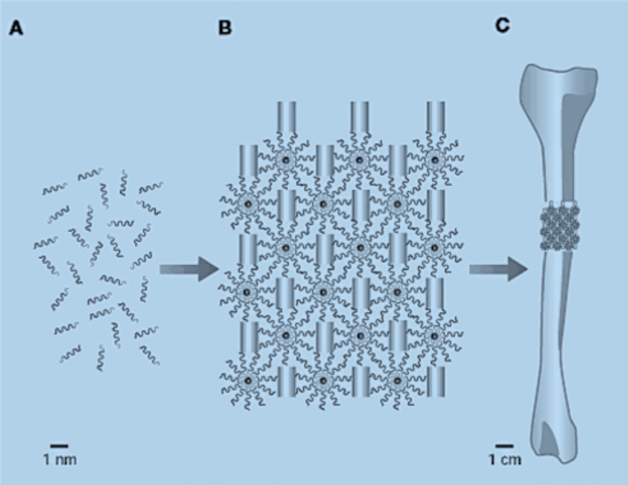


FIGURE C.5: SELF-ASSEMBLY BIOMATERIALS[xv]



with computers, to enable response to environmental conditions. Another example is a drug delivery system using a hydrogel with hydrophilic exterior and hydrophobic interior. Well-publicised systems are fabricated from radar-absorbing materials (e.g. the stealth bomber) that incorporate avionic links and the ability to modify shape in response to airflow. The development of composite materials and the ability to tailor materials at the atomic level will likely provide opportunities to make materials more compatible with the environments in which they will be used. Examples may include prosthetic devices that serve as templates for the growth of natural tissue and structural materials that strengthen/ stiffen during service.

Sensing and Actuating Materials
Several different types of materials exhibit sensing and actuation capabilities, including ferroelectrics (exhibiting strain in response to a electric field), shape-memory alloys (exhibiting phase transition-driven shape change in response to temperature change), magnetostrictive materials (exhibiting strain in response to a magnetic field) and magnetorestive materials (exhibiting a change in resistivity with an applied magnetic field). These effects also work in reverse, so that these materials, separately or together, can be used to combine sensing and actuation in response to environmental conditions. They are currently in widespread use in applications from ink-jet printers to magnetic disk drives to anti-coagulant devices.

Smart Materials
An important class of smart materials is composites based upon lead zirconate titanate (PZT) and related ferroelectric materials that allow increased sensitivity, multiple frequency response, and variable frequency. An example is the 'Moonie'[xvii] a PZT transducer placed inside a half-moon-shaped cavity, which provides substantial amplification of the response. Applications include sensors and actuators that can change their frequency either to match a signal or to encode a signal. Ferroelectrics are already in use as non-volatile memory elements for smart cards and as active elements in smart skis that change shape in response to stress.

Smart polymers (e.g. ionic gels that deform in response to electric fields) have already been used to make 'artificial muscles'. Currently available materials have limited mechanical power, but this is an active research area with potential applications to robots for space exploration, hazardous duty of various types, and surveillance. Hydrogels that swell and shrink in response to changes in pH or temperature are another possibility; these hydrogels could be used to deliver encapsulated drugs in response to changes in body chemistry (e.g. insulin delivery based upon glucose concentration).

The continued development of small, low-profile biometric sensors, coupled with research on voice, handwriting, and fingerprint recognition, could provide effective personal security systems. These could be used for identification by police/military and also in business, personal, and leisure applications. Combined with today's information technologies, such uses could help resolve nagging security and privacy concerns while enabling other applications such as improved handgun safety (through owner identification locks) and vehicle theft control.

Other potential applications of smart materials: clothes that respond to weather, interface with information systems, monitor vital signs, deliver medicines, and automatically protect wounds; airfoils that respond to airflow; buildings that adjust to the weather; bridges and roads that sense and repair cracks; kitchens that cook with wireless instructions; virtual reality telephones and entertainment centres; and personal medical diagnostics (perhaps interfaced directly with medical care centres).

The level of development and integration of these technologies into everyday life will probably depend more on consumer attitudes than on technical developments.

Developments in robotics may provide new and more sensitive capabilities for detecting and destroying explosives and contraband materials and for operating in hazardous environments. Increases in materials performance, both for power sources and for sensing and actuation, as well as integration of these functions with computing power, could enable these applications.

Superconductors
High-temperature superconductors discovered in 1986 can currently operate at liquid nitrogen (rather than liquid helium) temperatures or ultimately at room temperature. Prototype devices such as electrical transmission cables, transformers, storage devices, motors, and fault current limiters have now been built and demonstrated[xviii]. Niche application on electric utility systems should begin within a decade (e.g. replacement of underground cables in cities and replacement of older substation transformers) driven by the need to be more fuel efficient and reduce carbon emissions. Hard materials such as nanocrystalline coatings and diamonds are being developed for applications such as non scratch surfaces, computer disk drives and drill bits for oil exploration. High-temperature materials such as ductile intermetallics and ceramic matrix composites are being developed for aerospace applications and for high-efficiency energy and petrochemical conversion systems.

Nanoscale Materials
Another important class of materials is nanotubes (the open cylindrical sisters of fullerenes). Possible applications are field-emission displays, nanoscale wires for batteries, storage of Li or H2, and thermal management (heat pipes or insulation--the latter taking advantage of the anisotropy of

FIGURE C.6: A DEMONSTRATION OF THE SHAPE-MEMORY EFFECT. THE SUPER-IMPOSED IMAGES ARE OF A ROLLED SHEET, BENT 38° AT ROOM TEMPERATURE AND RECOVERED TO 8° BY HEATING TO 350 °C[xvi]

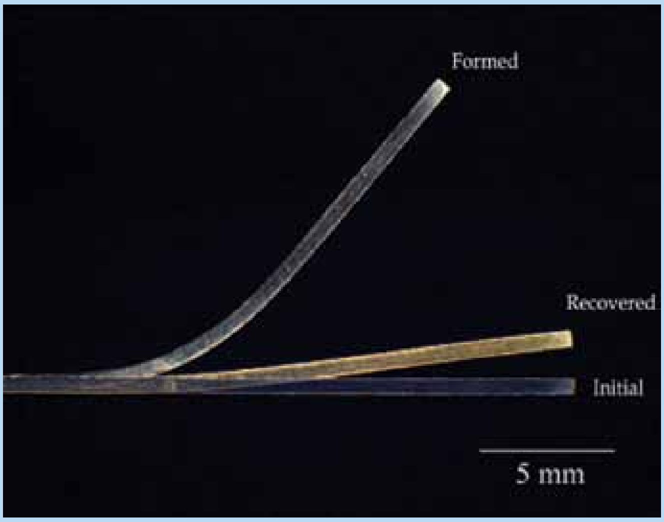
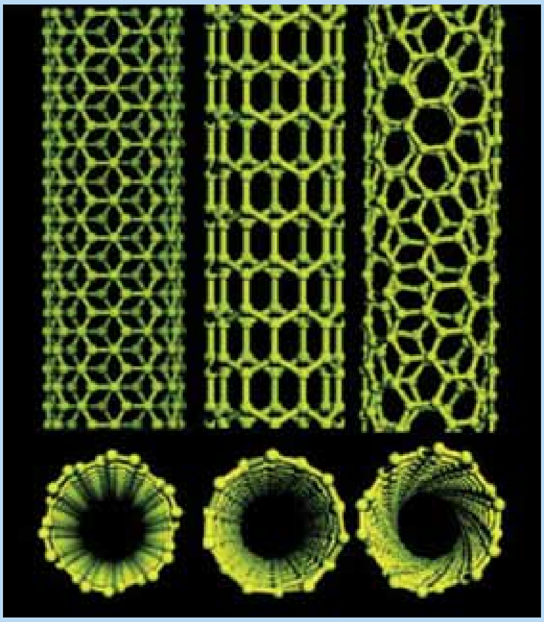


FIGURE C.7: THE STRUCTURE OF CARBON NANOTUBES[xx]



thermal conductivity along and perpendicular to the tube axis). Another possibility is to use nanotubes (or fibres built from them) as reinforcement for composite materials[xix]. Presumably because of the nature of the bonding, it is predicted that nanotube-based material could be 50 to 100 times stronger than steel at one-sixth of the weight if current technical barriers can be overcome.

Nanoscale structures with desirable mechanical and other properties may also be obtained through processing. Examples include strengthening of alloys with nanoscale grain structure, increased ductility of metals with multi-phase nanoscale microstructure, and increased flame retardancy of plastic nanocomposites.

TABLE C.2 ADVANCED MATERIALS SUB-FIELDS – LEADERSHIP ACTIVITY IN VOLUME OF PUBLICATIONS, PATENTS AND COMPANY START-UPS[113]

ADVANCED MATERIALS SUB-FIELD	GLOBAL STATUS
Metals	Dominated by the US, Japan, UK (static) with two non-traditional countries emerging – China and Korea. UK remains static and appears to be losing ground.
Catalysts	Dominated by the US. However, strong growth emerging from Italy, Holland, Germany and France. Emerging centres in China, India and Korea.
Ceramics	Dominated by the US and Japan with Germany being the only European country with significant activity.
Magnetics	Dominated by the US and Japan. UK share is decreasing whilst Holland and Germany are showing leadership positions.
Composites	Global surge in activity with equal shares between US, Japan and Europe. Within Europe, UK has the lead, with followed by Germany and France. Europe could now move to the front line of composites manufacturing and modelling.
Optical Photonic	US has the lead with Italy showing the lead in Europe. Japan remains static and there are emerging nations with China and Korea.
Superconducting	US has the lead with significant challenge from Japan.
Polymers	US has the lead globally and is driven forward by the chemical industry there.
Nanostructured Materials	Slight lead from US, driven by venture capitalist funds. However UK is showing significant strength in Europe with high growth.
Computational Science	US has the lead globally. However strong emerging contenders are Japan and the UK in Europe.

113. Materials R&D/National Research Council/USA

C.4 SUSTAINABLE PRODUCTION AND CONSUMPTION

Sustainable production and consumption requires us to achieve more with less. Current patterns of consumption and production in developed countries could not be replicated world-wide: some calculations suggest that three planets worth of resources would be needed to achieve UK levels of consumption across the globe. The largest and fastest growing pressures on the global environment come from areas such as household energy and water consumption, food consumption, transport and tourism[xxi].

These UN and the Royal Society has stated that trends in effort include[xxii]:

- Vigorous research on sustainable energy sources and on energy efficiency in all its forms, and vigorous promotion of those technologies for energy efficiency that already exist;
- Development and diffusion of environmental technologies;
- Research on ways of defining and determining environmental costs, and on incorporating them into pricing and taxation policies;
- Improvement of energy and land efficiency of food production;
- Management, protection and regeneration of natural systems;
- Minimisation, recycling of materials and of components, and re-use of waste streams; and development of new and replacement materials.

There are increasing numbers of successful cases where products made with less transformation of materials and energy and less environmental impact have at the same time made firms more profitable. The same is true of waste streams. For example, Minnesota Mining & Manufacturing mounted a pollution prevention program that has to date eliminated more than half a million tons of pollutants, with savings of $750 million. Such cases must be understood and multiplied. At the same time, societies need to examine their values and consider how goals can be met with the least damaging consumption. Scientists can help to understand the causes and dynamics of consumptive behaviour. They can also develop indicators that track environmental impacts and link them to consumption activities, build understanding of how environmental and social systems respond to stress, and analyse the effectiveness of different strategies for making and implementing policy choices in the presence of uncertainty.

Regulation

Under the Energy Efficiency Commitment (EEC), electricity and gas suppliers are required to achieve targets for the promotion of improvements in domestic energy efficiency. The EEC contributes to the Climate Change Programme by cutting greenhouse gas emissions.

Organic Foods

Organic foods are produced according to certain production standards e.g. grown without the use of conventional pesticides, artificial fertilisers, human waste, or sewage sludge, and that they were processed without ionising radiation or food additives. For animals, it means they were reared without the routine use of antibiotics and without the use of growth hormones. Organic produce must not be genetically modified. Increasingly, organic food production is legally regulated. The US, the EU, Japan and many other countries require producers to obtain organic certification in order to market food as organic.

Historically, organic farms have been relatively small family-run farms – which is why organic food was once only available in small stores or farmers' markets. Now, organic foods are becoming much more widely available – organic food sales within the US have enjoyed 17 to 20 percent growth[xxiii] for the past few years while sales of conventional food have grown at only about 2 to 3 percent a year. This large growth is predicted to continue, and many companies are jumping into the market.

There is evidence that organic farms are more sustainable and environmentally sound, among other benefits. Many refute this belief and state that while organically grown food certainly has its place in today's free market, the world population could not be fed with pesticide-free agriculture[xxiv]. While organic food accounts for 1–2% of total food sales worldwide, the organic food market is growing rapidly, in both developed and developing nations.

Sustainable Tourism

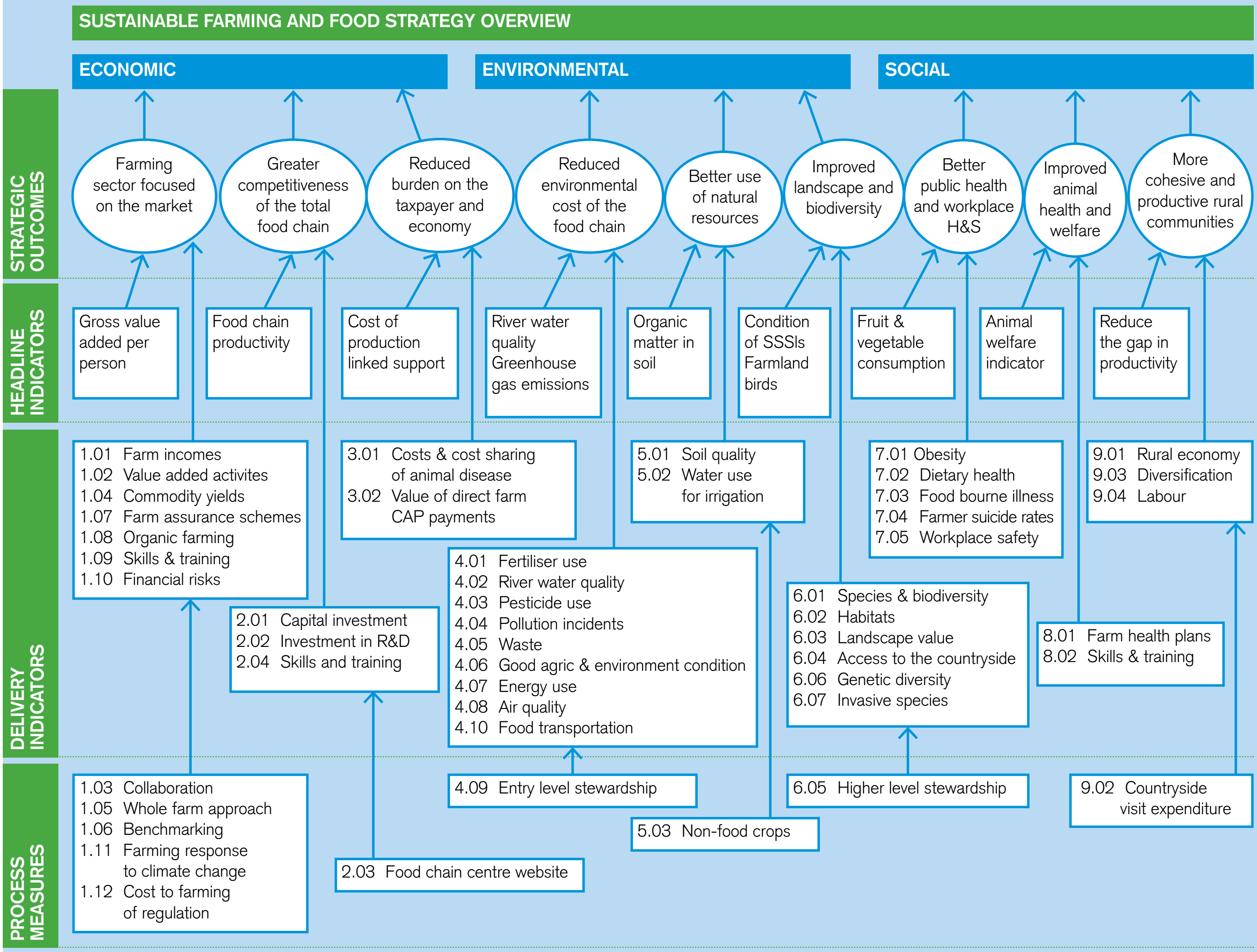
Sustainable tourism refers to an industry that attempts to make a low impact on the environment and local culture, while helping to generate income, employment, and conserving the natural environment. High quality landscapes that are rich in biodiversity, together with clean and friendly urban areas form the essential environment for a successful industry. It is beneficial in the sense that it helps generate greater community support for tourism, it will allow businesses to achieve significant cost savings and it will create new and essential marketing opportunities. Currently, eco-tourism in some areas is growing at 10% per annum.[xxvi]

Recycling

Taking action on waste is another noticeable trend, since we are consuming natural resources at an unsustainable rate and contributing unnecessarily to climate change. Recycling and recovery figures show that the two largest components of the recycled fraction were paper of non-packaging origin and glass packaging. The former made up 34% of recycled waste, while glass packaging added another 26.8%. Eight other categories made up the remaining 39.2%.

In addition to the types of materials being recycled by far the area with the most important recycling route was roadside recycling. More than half of all waste recycled was recycled by this method. A further 29.4% was recycled at Civic Amenity sites and only a

FIGURE C.8: DEFRA FRAMEWORK FOR ACHIEVING SUSTAINABLE PRODUCTION[xxv]

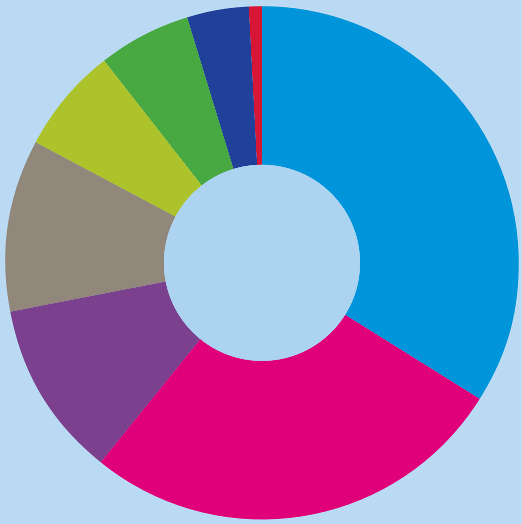


tenth deposited at bring sites. The remaining 4.2% of recycled waste represented material that was donated to jumble sales or charity shops.

Trends can be illustrated through surveys such as the Forrester[xxvii] report of Americans which asked about their decisions to purchase beverages. It showed almost two thirds (64%) thought it was somewhat to very important that containers may be recyclable (top three boxes on a seven point scale). Many of the over 65 age category (45%) agreed that it was very important and rated this as a seven. Additionally, almost half of all respondents said that they are recycling more aluminium beverage cans than they did five years ago (49%) and almost a third (32%) said they were recycling the same number.

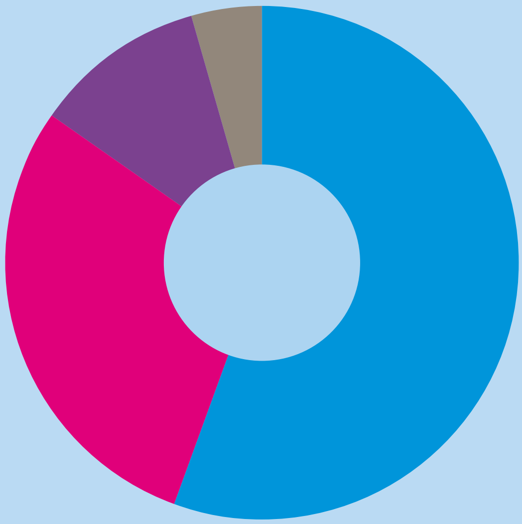
The Construction Industry
Research on composite materials, waste management, and recycling has reached the stage where it is now feasible to construct buildings using materials fabricated from significant amounts of indigenous waste or recycled material content. These approaches are finding an increasing number of cost-effective applications, especially in developing

FIGURE C.9 THE MAIN TYPES OF MATERIALS BEING RECYCLED



- 34% Non-packaging paper
- 26.8% Glass packaging
- 11.3% Metals
- 10.8% Cardboard and paper packaging
- 6.6% Plastics
- 5.7% Miscellaneous combustibles
- 4% Textiles
- 0.7% Miscellaneous non-combustibles

FIGURE C.10 THE MAIN AREAS WHERE MATERIALS ARE BEING RECYCLED



- 55.5% Kerbside recycling
- 29.4% Civic amenity sites recycled
- 10.8% Bring recycling sites
- 4.2% Jumble sales/charity shops

countries. A roofing material used in India is made of natural fibre and agri-industrial waste. Prefabricated composite materials for home construction have also been developed in the US, and a firm in the Netherlands is developing a potentially ubiquitous, inexpensive housing approach targeted for developing countries that uses spray-forming over an inflatable air shell.

C.5 BIOSCIENCE AND HEALTHCARE

There are major threats to health in the future from rising rates of obesity, alcohol consumption and high levels of smoking. These, combined with growing numbers of older people, could put significant burdens on services unless current trends are reversed. There are opportunities to provide better and more effective healthcare through the advancement of bioscience and healthcare.

Individual Healthcare

The next five to 10 years will likely see the integration of computational capabilities with biological, chemical, and optical components in systems-on-a-chip. At the same time, advances in biotechnology will drive drug discovery and genomics. Advances in biomaterials will likely produce biologically compatible packaging, capable of isolating substances from the body in a time-controlled fashion for drug delivery. Continued development of microscale and nanoscale systems may continue to be introduced into the body to perform basic diagnostic functions in a minimally-invasive way, providing new abilities to remedy health problems.

Sustainability

A sustainable health care system will need to focus on primary and secondary prevention across the whole life course. Given the rate of change and uncertainty about the future, health care providers will need to be able to constantly adapt their services to this rapidly changing environment. Some commentators have predicted that the next 20 years, medicine will see as much change as the last 200 years.

Biotechnology

Biotechnology will continue to improve and apply its ability to profile and manipulate the genetic basis of both plants and animal organisms, opening wide opportunities for understanding existing organisms and engineering organisms with new properties. DNA analysis machines and chip-based systems will likely accelerate the proliferation of genetic analysis capabilities, improve drug search, and enable biological sensors. The genomes of plants (ranging from important food crops such as rice and corn to production plants such as pulp trees) and animals (ranging from bacteria such as E. coli, through insects and mammals) will likely continue to be decoded and profiled. To the extent that genes dictate function and behaviour, such extensive genetic profiling could provide an ability to better diagnose human health problems, design drugs tailored for individual problems and system reactions, better predict disease predispositions, and track disease movement and development across global populations, ethnic groups, and other genetic pools. The trend in the development of gene therapies will likely continue, although it is unlikely they will be mature within a decade.

Biotechnology will likely investigate new approaches which might block a pathogen's ability to enter or travel in the body, leverage pathogen vulnerabilities, develop new delivery mechanisms, or modulate or augment the immune response to recognising new pathogens. These therapies may counter the current trend of increasing resistance to existing antibiotics such as drug resistant MRSA, reshaping the war on infections.

Genetic and Protein Profiling

Genetic profiling could also have a significant effect on insurance, security, policing, and law. DNA identification may complement existing biometric technologies (e.g. retina and fingerprint identification) for granting access to secure systems (e.g. computers, secured areas, airports or weapons), identifying criminals through DNA left at crime scenes, and authenticating items such as fine art. Genetic identification will likely become more commonplace tools in kidnapping, paternity, and fraud cases. Biosensors (some genetically engineered) may also aid in detecting biological warfare threats, improving food and water quality testing, continuous health monitoring, and medical laboratory analyses. Such capabilities could fundamentally change the way health services are rendered by greatly improving disease diagnosis, understanding predispositions, and improving monitoring capabilities.

Proteomics (the study of protein function and genes) is the next big technological push after genomic decoding. Progress may likely rely on advances in bioinformatics, genetic code combination and sequencing (akin to hierarchical programming in computer languages), and other related information technologies.

Cloning and Genetically Modified Organisms

Cloning i.e. artificially producing genetically identical organisms will likely be significant for engineered crops, livestock, and research animals. Cloning may become the dominant mechanism for rapidly bringing engineered traits to market, for continued maintenance of these traits, and for producing identical organisms for research and production. Research will possibly continue on human cloning in unregulated parts of the world with possible success in the near future, but ethical and health concerns will likely limit wide-scale cloning of humans in regulated parts of the world.

Genetically Modified Organisms will progress with greater efforts to engineer certain properties into life. Traditional techniques for genetic manipulation (such as cross-pollination, selective breeding, and irradiation) will probably continue to be extended by direct insertion, deletion, and modification of genes through laboratory techniques. Targets include food crops, production plants, insects, and animals. Desirable properties could be genetically imparted to genetically engineered foods, potentially producing: improved taste; ultra-lean meats with reduced 'bad' fats, salts, and chemicals; disease resistance; and artificially-introduced nutrients (so-called 'nutraceuticals').

FIGURE C.11: SHOWING THE FUTURE HEALTH TRENDS[xxviii]

MAJOR DRIVERS	5 YEARS 2010	10 YEARS 2015	15 YEARS 2020	20 YEARS 2025
Patient Expectations	Consumerism Holistic health & wellbeing	Meeting needs of older people		
Medical Advances	Minimally-invasive surgery	Pharmacogenomics	Major Pharmaceutical Innovation Stem Cell Technology Widespread Genetic Screening	
Information & Support Technology	Complete EPR & use of IT networks Home Monitoring	Robotics Intelligent Devices Protocol driven/expert systems		
Demography & Society	Inequalities Smaller households, single parents, living alone	Population growth in 45-75 age group	Population growth in >75 age group	
Epidemiology	Chronic disease increasing Focus on managing risk factors	Greater differentiation of diagnosis		
Labour Force	Portfolio careers Lifelong learning	Labour force aging and participation rates reducing	Increasing informal elderly care demands An end to retirement?	

Time when we predict that a major change may be seen in this dimension.

Genetically modified organisms (GMOs) can potentially be engineered to improve their physical robustness, extend field and shelf life (e.g., the Flavr-SavrTM tomato), tolerate herbicides, grow faster, or grow in previously unproductive environments.

Beyond systemic disease resistance, in vivo pesticide production has already been demonstrated (e.g. in corn) and could have a significant effect on pesticide production, application, regulation, and control with targeted release. Likewise, organisms could be engineered to produce or deliver drugs for human disease control. Cow mammary glands might be engineered to produce pharmaceuticals, therapeutic organic compounds or enhanced foodstuffs; other organisms could be engineered to produce or deliver therapeutics. If ethically accepted, such improved production and delivery mechanisms could extend the global production and availability of these therapeutics while providing easy oral delivery. Genetic engineering of micro-organisms has long been accepted and used. For example, E. coli has been used for mass production of insulin.

In addition to food production, plants may be engineered to improve growth, change their constitution, or artificially produce new products. Trees, for example, will likely be engineered to optimise their growth and tailor their structure for particular applications such as lumber, wood pulp for paper, fruiting, or carbon sequestering (to reduce global warming) while reducing waste by-products. Plants might be engineered to produce bio-polymers (plastics) for applications with

FIGURE C.12: SHOWS THE GROWTH IN THE PRODUCTION OF GM CROPS[xxix]

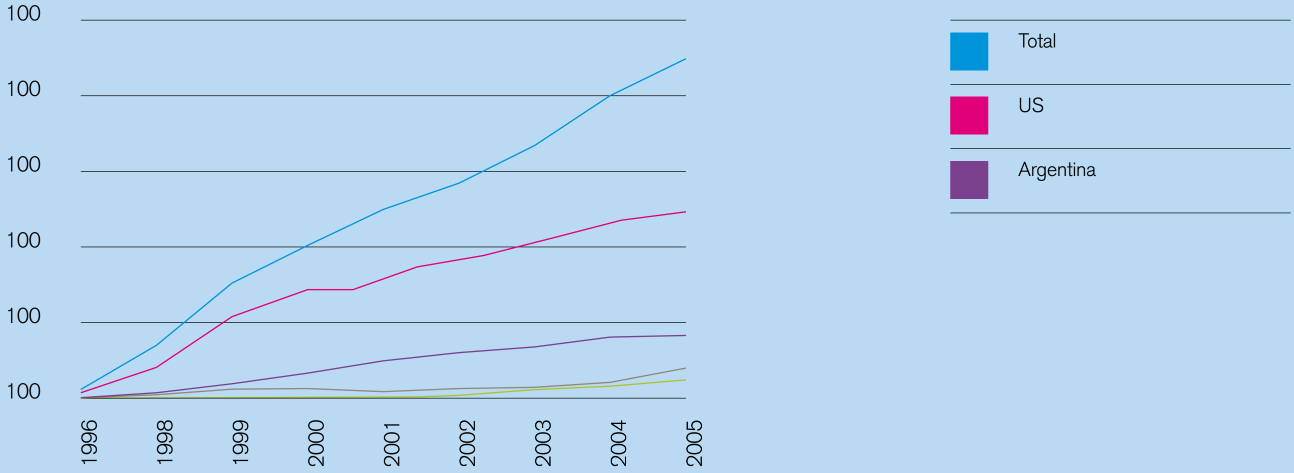
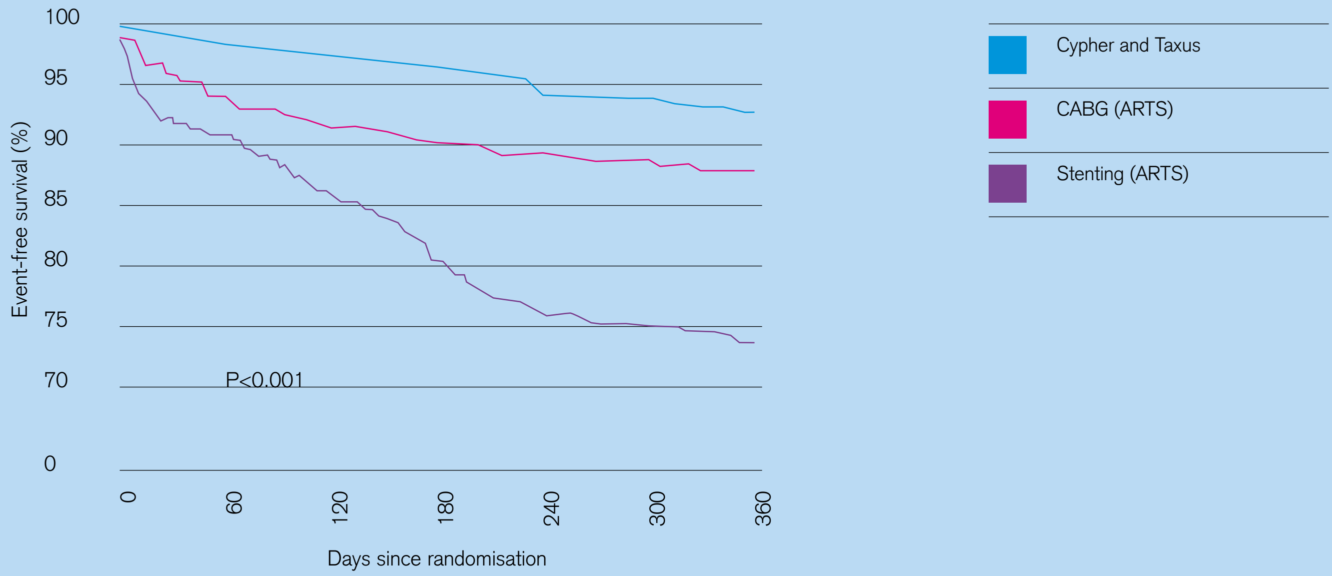


FIGURE C.13: THE EFFECT OF ENGINEERING STENTS ON SURVIVAL RATES[xxxii]



lower pollution and without using oil reserves. Bio-fuel plants could be tailored to minimise polluting components while producing additives needed by the consuming equipment. Research on modifying human genes has already begun and will likely continue in a search for solutions to genetically based diseases. Although slowed by recent ethical issues, gene therapy research will likely continue its search for useful mechanisms to address genetic deficiencies or for modulating physical processes such as beneficial protein production or control mechanisms for cancer. Advances in genetic profiling may improve our understanding and selection of therapy techniques and provide breakthroughs with significant health benefits.

GMOs are also having a large effect on the scientific community as an enabling technology. Not only do 'knock-out' animals (animals with selected DNA sequences removed from their genome) give scientists another tool to study the effect of the removed sequence on the animal, they also enable subsequent analysis of the interaction of those functions or components with the animal's entire system. Although knock-outs are not always complete, they provide another important tool to confirm or refute hypotheses regarding complex organisms.

Drug Development
Drug development will likely be aided by various technology trends and enablers such as computer simulations and molecular imaging technologies to design molecules with desired functional properties. Simulations of drug interactions with target biological systems could become increasing useful in understanding drug efficacy and safety. For example, Dennis Noble's complex virtual heart simulation[xxx], has already contributed to US Food and Drug Administration approval of a cardiac drug. For simpler systems such as the heart, this approach may become a dominant to clinical drug trials by 2015 as R&D costs for drug development are currently extremely high and may even be unsustainable with averages of approximately $600 million per drug brought to market.

Tissue Engineering, Stem Cells and Transplantation
The field of tissue engineering, which is barely a decade old[xxxi], has already led to engineered commercial skin products for wound treatment. Growth of cartilage for repair and replacement is at the stage of clinical testing, and treatment of heart disease via growth of functional tissue in the next decade is a realistic goal.

Research and applications of stem cell therapies will likely continue and expand, using these unspecialised human cells to augment or replace brain or body functions, organs (e.g. heart, kidney, liver, pancreas), and structures. The use of adult human stem cells or stem cell culturing may ultimately produce large-scale cell supplies with reduced ethical concerns of using foetal cells.

Xenotransplantations (transplantation of body parts from one species to a different species) could be improved, aided by attempts to genetically modify donor tissue and organ antibodies, complements, and regulatory proteins to reduce or eliminate rejection. Baboons or pigs, for example, may be genetically modified and cloned to produce organs for human transplant.

Beyond structures and organs, neural and sensor prosthetics could begin to become significant. Retinas and cochlear implants, bypasses of spinal and other nerve damage, and other artificial communications and stimulations may improve and become more commonplace and affordable, eliminating many occurrences of blindness and deafness. This could eliminate or reduce the effect of serious handicaps and change society's response from accommodation to remediation.

The Use of Advanced Materials
Multi-functional materials are being developed that provide both structure and function or that have different properties on different sides, enabling new applications and capabilities. For example, polymers with a hydrophilic shell around a hydrophobic core can be used for timed release of hydrophobic drug molecules, as carriers for gene therapy or immobilised enzymes, or as artificial tissues.

Other materials are being developed for various biomedical applications. Hydrogels with controlled swelling behaviour are being developed for drug delivery or as templates to attach growth materials for tissue engineering. Ceramics such as bioactive calcia-phosphate-silica glasses (gel-glasses), hydroxyapetite, and calcium phosphates can serve as templates for bone growth and regeneration. Bioactive polymers (e.g. polypeptides) can be applied as meshes, sponges, foams, or hydrogels to stimulate tissue growth. Coatings and surface treatments are being developed to increase biocompatibility of implanted materials.

Techniques and Approaches
Recent techniques such as functional brain imaging are revolutionising our endeavours to understand human intelligence. Although artificial systems with intelligence are unlikely in the near future, some simple systems that can robustly perform useful functions such as vacuuming a house, detecting mines, or conducting autonomous search may be possible.

New surgical tools and techniques and new materials and designs for vesicle and tissue support will likely continue to reduce surgical invasiveness and offer new solutions to medical problems. Techniques such as angioplasty may continue to eliminate whole classes of surgeries; others such as laser perforations of heart tissue could promote regeneration and healing. Advances in laser surgery could refine techniques and improve human capability (e.g.

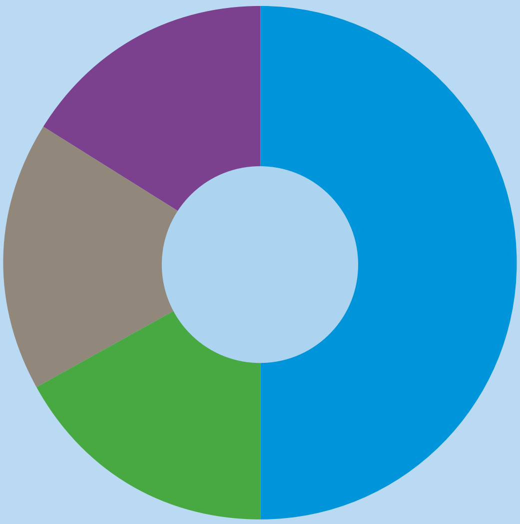
eye surgery to replace glasses), especially as costs are reduced and experience spreads. Less invasive medical procedures require a shorter recovery time[xxxiii]. Development of 'minimally' and/or less invasive approaches to surgical procedures (hip replacement, thoracic surgery, open-heart surgery) and diagnosis supports length of stay reduction and the shift of care from inpatient to outpatient setting. In some cases these less complex medical procedures reduce demand for more complex surgery e.g. the use of angioplasty in heart disease. Carotid stenting will replace traditional endartorectomies. Research suggests that angioplasty, previously an inpatient procedure, may be performed safely on an outpatient basis. Natural orifice surgery will also facilitate the move towards day surgery. Incisionless surgery and totally endoscopic surgery will increase. Use of the Maylard incision has been shown to reduce length of stay for radical hysterectomy. Overall, day case rates and applicability will increase.

The volume and range of medical and pharmaceutical treatments which can replace surgical intervention is increasing. Within cardiovascular care, for example, the widespread use of statin drugs together with the use of angioplasty and drug-eluting stents may eventually replace a substantial portion of open heart surgery. Advances in treatments such as chemotherapy drugs, intravenous antibiotics or some of the new long-acting drugs for long-term conditions mean that this can be done at home or in more local, community settings.

New imaging technologies such as virtual colonoscopy and CT heart scans, have the potential to dramatically increase the number of people screened and the volume of abnormalities identified and treated.

OECD statistics reveal that the majority of Biotechnology firms are engaged in health related activities. Figure C14 provides a breakdown.[xxxiv]

FIGURE C.14 PERCENTAGE OF FIRMS INVOLVED IN BIOTECHNOLOGY APPLICATIONS



50%	Health
19%	Agri-food
15%	Industrial/environment
16%	Other

C.6
INFORMATION AND COMMUNICATION TECHNOLOGIES

The European Commission Information Society and Media believe that all sectors of Europe's economy depend on ICT[xxxv]. ICT is an essential part of national infrastructure and private sector potential. It can create business opportunities, especially for companies located far from urban centres, and improve links among firms, suppliers, and clients. When used well, ICT can also make management and operations more efficient. The Internet can be especially valuable for firms in developing countries because it provides opportunities to connect to markets and participate in trade, domestic and foreign. A recent survey of 56 developed and developing countries found a significant link between Internet access and trade growth - with the greatest benefits accruing to developing countries with the weakest trade links. As with other factors of production, such as capital and labour, ICT use differs based on businesses size, ownership, and export orientation. In developing countries Website and computer (though not necessarily e-mail) use are more common among service firms than firms engaged in manufacturing, agroindustry, and construction. Website and e-mail use are especially high in the telecommunications, information technology, real estate, and hotel and restaurant industries, and among exporters and foreign-owned firms. Among regions, firms in Central and Eastern Europe use such technology the most, reflecting its correlation with national income. Table C.13: Shows the that this sector is expected to continue to grow in both the US and EU.

TABLE C.13: THE ICT SECTOR AND ITS IMPACT WITHIN EUROPE AND THE USA

		EU	US
Size of the economy	1995-1999	5.2%	7.2%
	2000-2003	5.6%	7.2%
Growth (real terms)	2000-2003	5.3%	4.6%
Market revenue growth (nominal terms)	2004	3.8%	3.9%
	2005 (estimate)		
	Total ICT sector	3.6%	3.9%
	Communications	3.1%	2.8%
	ICT	4.1%	4.6%
ICT research and development	% all research expenditure	25%	35%
	% GDP	0.31%	0.63%
Take-up of ICT by businesses	% of enterprises integrating systems with suppliers	10.2%	15%
	% of enterprises integrating systems with customers	9.3%	17%
Investment in ICT	As % of GDP	2.4%	4.2%
Labour productivity	1995-1999 Total	1.8%	2.3%
	1995-1999 ICT	0.9%	1.7%
	1995-1999 Non ICT	0.9%	0.6%
	2000-2004 Total	1.1%	2.8%
	2000-2004 ICT	5.5%	0.9%
	2000-2004 Non ICT	5.5%	1.9%
Innovation by businesses	ICT enabled product/services	17%	
	Non ICT enabled product/services	29%	
	ICT enabled processes	33%	
	Non ICT enabled processes	12%	

TABLE C.14: SHOWS THE INCREASE IN TELEPHONY AND INTERNET USERS OVER THE PAST 25 YEARS[xxxvi]

Population, GDP, and telephone and internet access in developing countries, 1980-2005

INDICATOR	1980	1990	2000	2005
Population (billions)	3.6	4.4	5.1	5.4
	81	83	94	84
GDP (US$ trillions)	3.1	4.2	5.9	7.5
	18	18	19	21
Total telephones (per 1,000 people)	14	27	129	393
	17	22	38	61
Fixed telephones (per 1,000 people)	14	27	83	135
	17	23	43	57
Mobile telephones (per 1,000 people)	N/A	0.09	46	258
		4	32	63
Internet users (per 1,000 people)	N/A	N/A	15	67
			20	41

Eight key findings sketch the global trends in ICT[xxxvii]:

1. Growth has been dramatic, particularly with cellular mobile telephone subscribers exceeding the number of main telephone lines and with Internet users exceeding the number of personal computers;
2. The largest increases in ICT diffusion are in the most populous countries;
3. Some of the fastest rates of growth and most sizeable increases in diffusion are in developing economies;
4. The best penetration rates are still in advanced economies with relatively small populations;
5. The less developed economies still have the poorest ICT penetration rates;
6. Despite the dramatic increases in diffusion of ICT in the most populous countries, it is also in these very same countries where most of the work still needs to be done;
7. The largest markets for ICT applications and content are now a mixture of developed and developing economies;
8. The 'divide' in ICT access has narrowed but low income, particularly severely indebted economies in sub-Saharan Africa, still lag considerably.

Processing Power

Processing power of the microcomputers is improving quicker than that of the supercomputers. Traditionally supercomputers were used for complex or high volume functions, the current trend is to move away and use multiple cheap high performance microcomputers. An example of this is the stripped Linux farms used by Google.

Wireless Capabilities

The growth of wireless connectivity continues with no end in sight. In the US, mobile phone usage now exceeds landline usage and Notebooks outnumber desktops. Most laptops also come with wireless as a standard feature. As a result, more and more small businesses are finding ways to integrate wireless technology into their daily operations.
It is the need and desire of people to access the Internet from anywhere in the world that is driving many of the new changes that are occurring in the largest consumer market ever the wireless mobile device market. There are three main routes to wirelessly access the Internet. Voice is still the main use of mobile devices and the GSM and CDMA networks around the world now connect over 2.3 billion wireless subscribers. The cellular standards are evolving to add high speed data connections, and cellular remains the way we connect from remote locations many miles away from a base station[xxxviii].

'The benefits of mobility in business are well known,' says Nikos Koutsoukos, director of small business product line management at small-business networking giant, 3Com. 'Smaller businesses need to be more flexible both physically and in it terms of business, and going wireless allows them to do so.' Firms are finding a number of ways to incorporate wireless products into their everyday tasks. Transportation companies and businesses with small fleets of cars or trucks, for example, can track vehicle movement using GPS-enabled

FIGURE C.15: IMPROVEMENTS IN THE PERFORMANCE OF MICROPROCESSORS

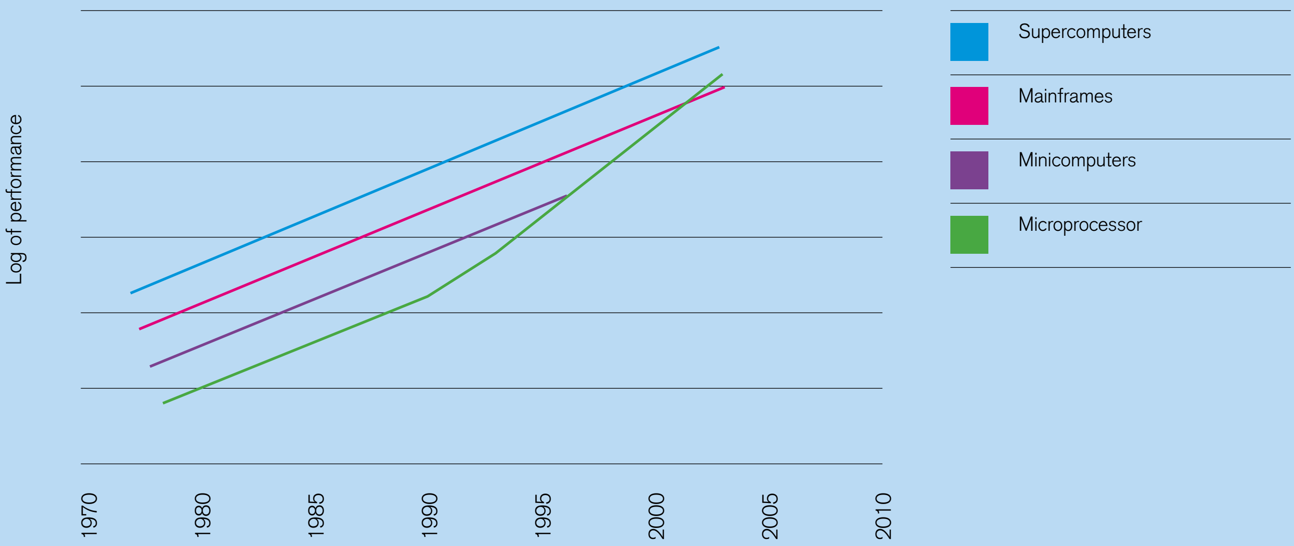
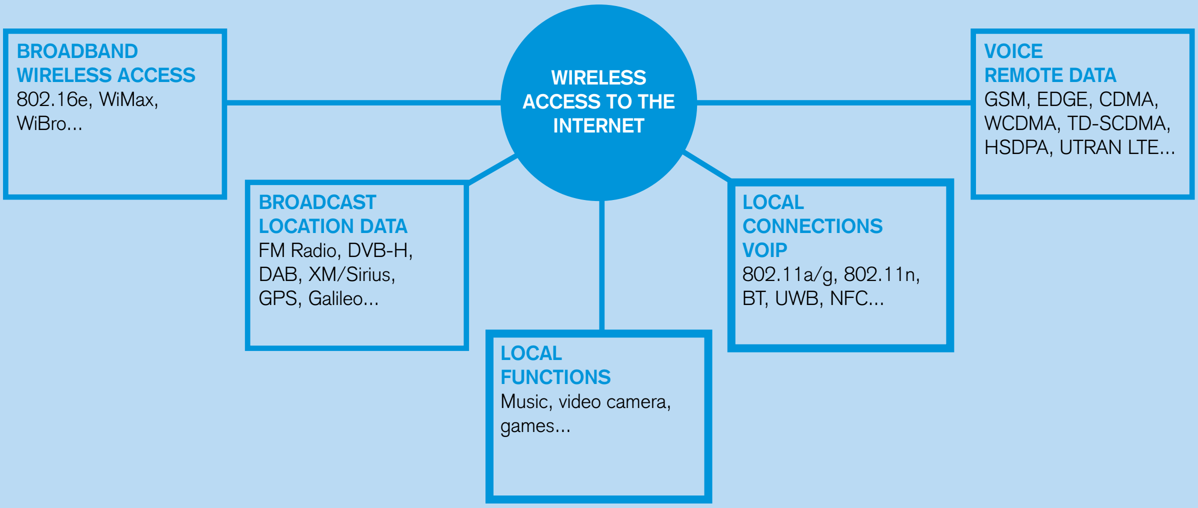


FIGURE C.16: WIRELESS ACCESS TO THE INTERNET EVERYWHERE AND ENTERTAINING FUNCTIONS WILL LEAD TO HIGHLY USABLE AND FUN MOBILE DEVICES



cell phones. Other wireless applications include letting sales people access the company database from anywhere, controlling inventory and letting field technicians update customer accounts or service call systems while out on the road. Such functionality not only saves time and money, but it also improves an organisation's productivity since salespeople no longer need to connect to the network in the morning, download their data and then return to the office to upload their activity reports. That translates into more face time with customers.

Even with increased vendor choices and lower costs, some small businesses aren't rushing to implement wireless. Why? Many remain nervous about wireless security. There are just too many stories of unauthorised access to business networks due to lax wireless security practices.

Tremendous changes are occurring in the area of wireless communications, so much so that the mobile phone of yesterday is rapidly turning into a sophisticated mobile device capable of more applications than PCs were capable of only a few years ago. For example, the data rates provided by the initial High Speed Downlink Packet Access (HSDPA) extension to 3G networks enable a user to wirelessly access the Internet at speeds up to 1.8 MBits/second. Further enhancements in HSDPA modulation schemes will soon increase this speed to greater than 10MBits/second. So downloading your latest e-mails with a 5 MB Powerpoint attachment outside of the office is no longer a frustrating and time-consuming exercise.

Bluetooth Technology

For local connections Bluetooth is rapidly becoming a common feature in mobile devices with almost 30 percent attachment rate expected in 2006. This attachment rate is expected to grow to more than 50 percent over the next three years. Today we are seeing other radios being combined with Bluetooth, such as WiFi, FM radio and Near Field Communications (NFC). Soon we will see combination Bluetooth and Ultra-wideband (UWB) devices to further enhance the wireless distribution of multimedia content.

Open Source Code

Public and private sector around the world are catching onto the 'open source' code fever[xxx], purchasing software or freeware that lets them view and modify source code as opposed to proprietary software such as that made by companies such as Microsoft. But whether the global trend will continue may depend upon new and old factors that could hinder the increased spread of the open-source movement.

Barriers to growth include continued flaws in the ever-improving open-source technologies which are being used more for computer servers than applications - and opposition by Microsoft, the world's dominant software player and thus the one with the most at stake if governments turn to open-source products. The leading open-source product is Linux, and the recent LinuxWorld in California conference focused heavily on product improvements.

In addition, large software makers have been busy obtaining patents on the ideas underlying open-source software, making a more difficult path ahead. And lawsuits are on the rise, even among those firms that espouse open-source thinking.

Even with the competitive hurdles facing open-source software, the US technology industry recognises the deep significance of its introduction into the global market and is hedging bets on the industry's evolution. Companies such as IBM, Intel and Oracle, are finding ways to accommodate open source in their products and services.

Ten emerging software trends according to Manageability.org[xxxi] are:

1. Firefox Browser market share will continue to grow;
2. Eclipse market share will continue to grow;
3. AMD will continue to increase its performance dominance over Intel;
4. Javascript will regain dominance in the space of Rich Internet Applications (RIA);
5. Java developers will continue to abandon EJB as the standard way of building Java based server applications
6. Semantic XHTML will continue to gain mind share as the best way to encode semantic information;
7. Service-orientated architecture will continue to gain popularity;
8. Large costly multi-CPU servers will be abandoned in favour of lots of cheap low cost single CPU servers;
9. IT deflation will be the continuing trend;
10. Scripting languages will become dominant in addressing the needs of situated software.

FIGURE C.17: NUMBER OF WIRELESS HOTSPOTS IN 2005[xxxix]

TOP 10 COUNTRIES		TOP 10 CITIES		TOP 10 LOCATIONS	
US	41,007	Seoul	2,056	Hotel/Resort	31,887
UK	14,933	London	1,943	Restaurant	25,480
Germany	12,509	Tokyo	1,843	Cafe	15,802
South Korea	9,415	Taipei	1,786	Store/Shopping Mall	14,834
Japan	6,258	Paris	1,204	Other	7,850
France	5,334	Berlin	823	Pub	5,348
Taiwan	2,899	San Francisco	805	Office Building	2,386
Italy	2,549	Daegu	787	Gas Station	1,735
Netherlands	2,517	Singapore	671	Airport	1,580
Australia	2,180	New York	669	Library	1,400

FIGURE C.18: TYPICAL SEMI-CONDUCTOR BLOCKS FOR CELLULAR RADIO IN A MOBILE PHONE

T/R SWITCH pHEMT	**FILTERS** $LiTaO_3$	**RF TRANSCEIVER** RF CMOS	**DIGITAL BASEBAND** Advanced CMOS	**APPLICATIONS PROCESSOR** Advanced CMOS
	POWER AMPLIFIER GaAs HBT	**DC/DC CONVERTER & PMU** HV CMOS	**ANALOG BASEBAND** CMOS	**MEMORY** Advanced CMOS HBT

FIGURE C.19: ICT REVENUE BY SECTOR 2005

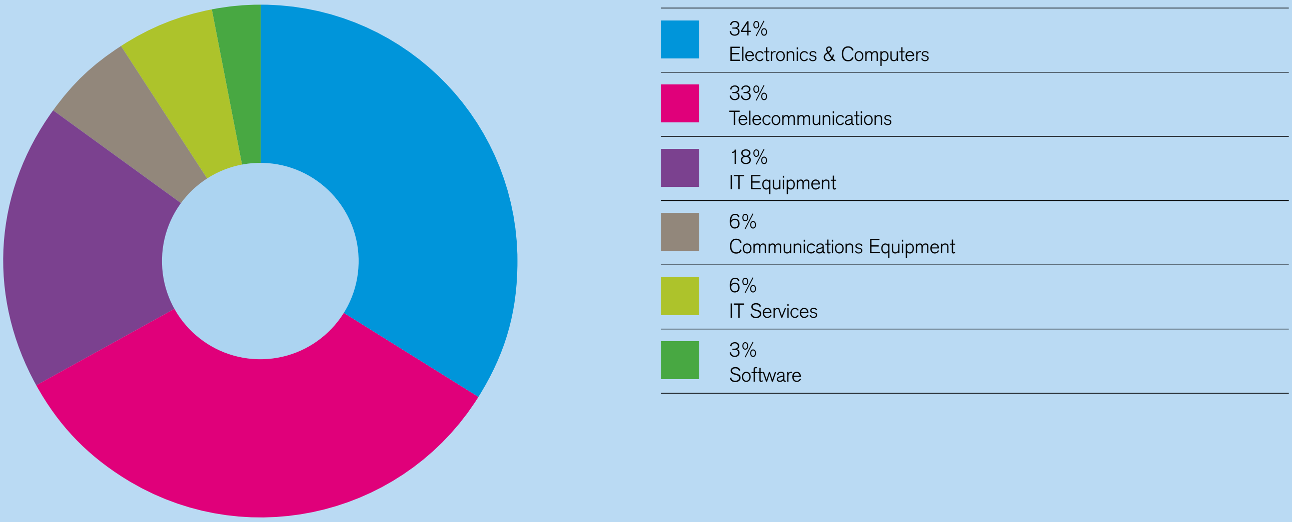
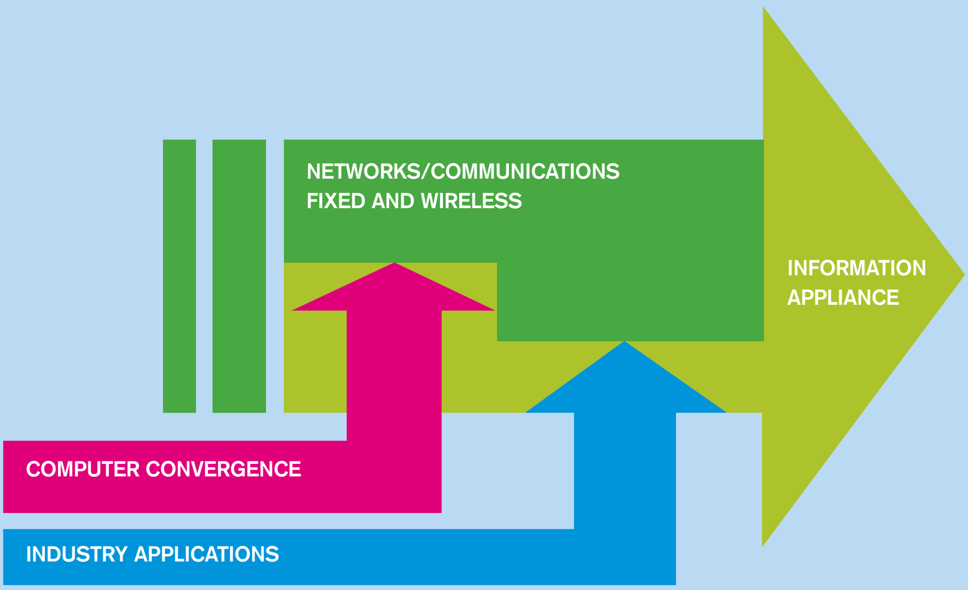


FIGURE C.20: AN OVERARCHING TREND IN THE ICT SECTOR IS THE CONVERGENCE OF HARDWARE AND SOFTWARE



C.7
ELECTRONICS AND PHOTONICS

The electronics and photonics industries have always been considered important drivers of technology. These industries are now significantly more mature than other advanced industries with the main drivers often being reduction of both size and cost.

Consumer electronics is comprised of the following products:

- Televisions and set-top boxes
- Video recorders and players
- Home audio and home theatre products
- Portable audio and video products
- Desktop and notebook computers and computer accessories
- Video games
- Mobile phones and accessories
- PDAs and handhelds
- In-car information, communication and entertainment products
- Cameras and camcorders
- Cordless telephones and accessories
- Home networking and home office products

The growth in these products in this industry has nearly doubled within five years[xxxxii]. The market is dynamic, highly-competitive and characterised by rapid innovation, significant time-to-market pressures, rapid rates of market penetration, and rapid transition from one technology to another. The key trends are convergence, miniaturisation, transition from analogue to digital and innovation. Energy efficiency is becoming a more important consideration for consumer electronics.

Photonics
The use of photons in optics, laser technology, electrical engineering, materials science, or information storage and processing, has migrated from being almost exclusively associated with research laboratories into mainstream industrial and consumer markets across the economy, including information technology, healthcare, security and safety, and lighting.

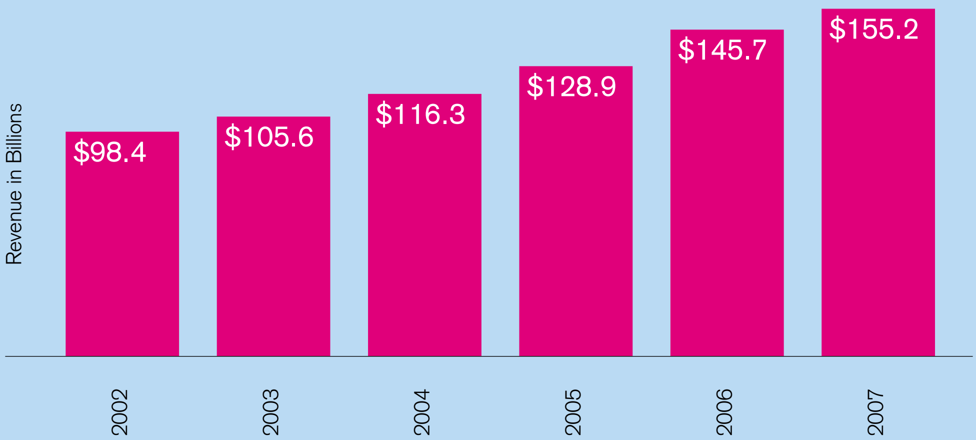
Solid-state lighting is the name given to lighting generated through exciton recombination rather than through standard incandescent, halogen or gas discharge. Solid-state lighting is applicable to both light emitting diode (LED) based lamps, which are composed of traditional semiconductor materials (used in traffic lights), and organic light emitting diodes (OLED's), which are made of conduction and emission organic layers.

The primary driving force for the development of solid-state lighting is the reduction of energy use, with commitment to reductions in chemical pollution, light pollution, and cost to the consumer. Possibly the most important secondary benefit is reliability.

Photonics is now using inorganic materials with the five most urgent research areas being: 1) large area substrates, buffer layers, and wafer research; 2) high-efficiency semiconductor materials; 3) device architecture approaches, structures, and systems; 4) strategies for improved light extraction and manipulation; and 5) phosphors and conversion materials. Further developments may include 1) development of reliability predictions and defect physics for improved LED lifetime; 2) development of improved encapsulate and packaging materials; 3) development of improved electrodes and interconnects; 4) development of measurement metrics and human factors for solid state lighting; 5) improved physical, chemical, and optical modelling for epitaxial processes; and 6) design and development of in situ diagnostic tools for epitaxial processes.

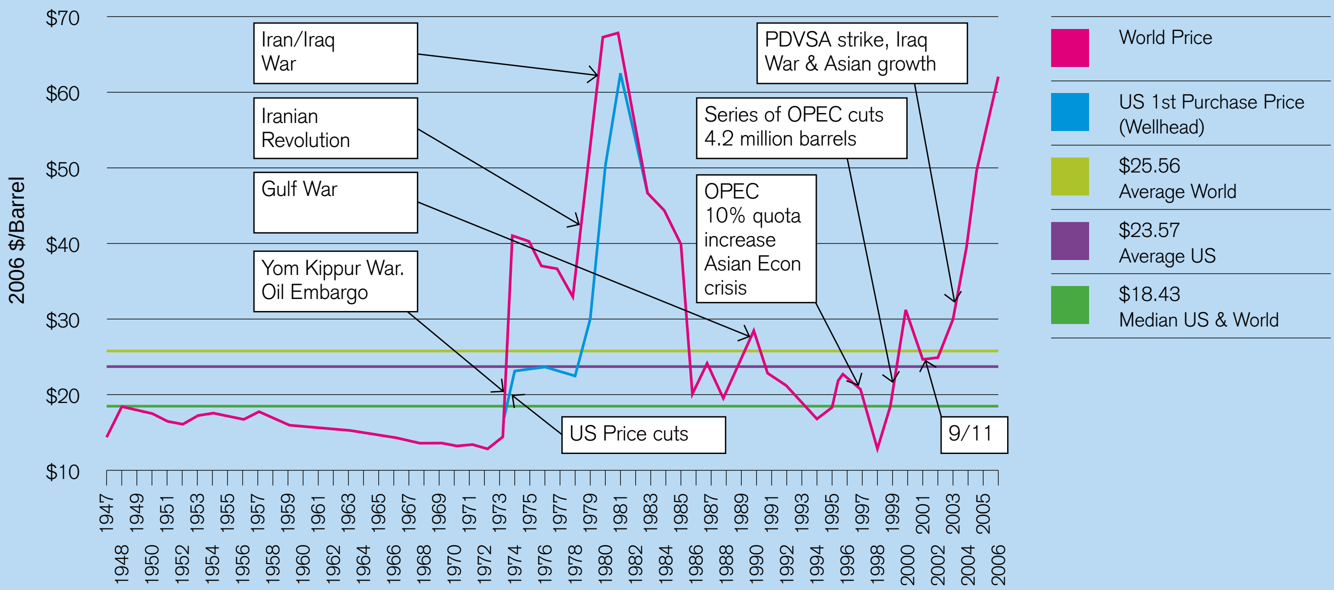
For organic OLED the following is required 1) Research into electro-active organic materials for substrates 2) Improved contact materials and surface modifications for improved charge injection 3) Improved understanding of the fundamental physics associated with OLEDs. 4) Strategies for improved light extraction 5) Integration of electrodes and interconnects 6) Measurement metrics and human factors 7) Improved physical, chemical, and optical modelling.

FIGURE C.21: REVENUE FIGURES FOR THE CONSUMER ELECTRONICS INDUSTRY



Source: CEA Sales and Forecasts 12/06

FIGURE C.22 CRUDE OIL PRICES ILLUSTRATING THE EFFECT UNCERTAINTY/WAR HAS ON OIL PRICES[xxxxiii]



Source: WTRG Economics ©1998-2006 (479) 293-4081

C.8
EMERGING ENERGY TECHNOLOGIES

If the availability of oil increases, it may be difficult for emerging energy technologies to increase their penetration into the global energy sector in the next decade. Key questions have to do with continued oil imports, continued use of coal, new sources of natural gas, and the fate of nuclear power. Global uncertainty of oil supply typically increased the price of oil.

Technology may have significant effects in some areas. Along with investments in solar energy, current investments in battery technology and fuel cells could enable continued trends in more portable devices and systems while extending operating times.

Key energy technologies for Europe have been identified[xxxxiv] as:

- Fuel cells (stationary and transportation);
- Hydrogen technologies (production, storage and utilisation);
- Energy storage technologies and distribution;
- Renewable energies (including photovoltaics, wind, ocean);
- Biomass and biofuels;
- Fossil fuels and cleaner generation; and
- Carbon dioxide capture and storage.

Environmental Drivers

Environmental concerns has dramatically increased in the past decade such that global warming and pollution might shift this direction, but it would likely require long-term economic problems (e.g. a prolonged rise in the price of oil) or distribution problems (e.g. supplies interrupted by military conflicts such as Iraq) to drive significant power consumption from renewable energy within a decade.

Current trends point at the following fossil fuel alternative materials:

Biofuels

Bio-fuels which can be defined as solid, liquid, or gas fuel consisting of, or derived from biomass (growth rate is >15% pa). The Figure below shows the dramatic increase (and predicted) in bio-fuel production (ethanol) for fuel use[xxxxv]. These trends are particularly dramatic in North and South America.

Nuclear Fuel

Britain is investigating the potential of using more nuclear fuel. Currently, nuclear power produces 687 ktoeA (~23% of electricity supply). Without nuclear power almost all energy would come from fossil fuels. The cost of nuclear power is illustrated in the figure below in comparison to fossil fuel types[xxxxvi]. In addition, nuclear power is currently cheaper than sustainable fuels. The projected figures for 2010 show that nuclear and hydro are the only two significant non-fossil fuels used in the production of electricity.[xxxxvii]

Consumption

Sustainable fuels such as wind, water, wave and solar are all being investigated as alternatives to fossil and nuclear fuels. There is a fundamental attractiveness about harnessing such forces in an age, which is very conscious of the environmental effects of burning fossil fuels. Sun, wind, waves, rivers, tides and the heat from radioactive decay in the earth's mantle as well as biomass are all abundant and ongoing, hence the term "renewable and sustainable". Only one, the power of falling

FIGURE C.23: ETHANOL PRODUCTION BY TYPE

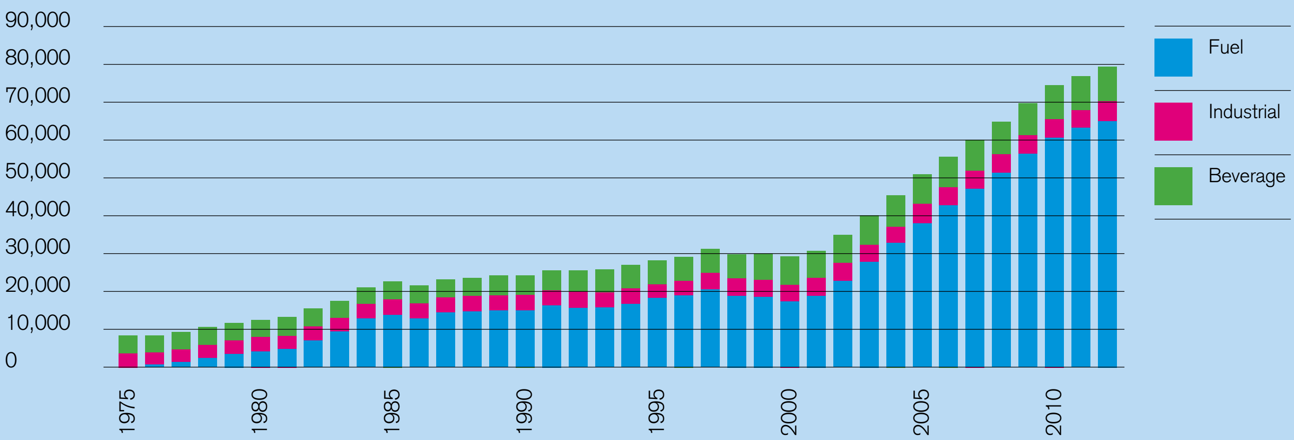
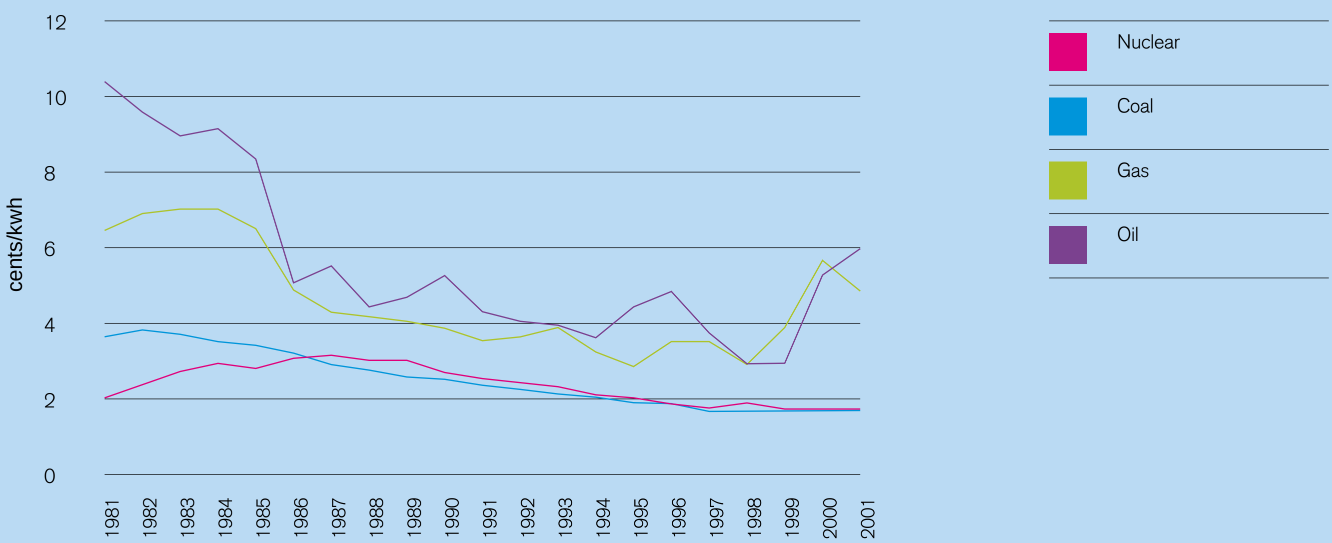


FIGURE C.24: SOURCES OF ELECTRICAL POWER



Source: US Utility Data Inst (pre 1995), Resource Data International (1995)

water in rivers, has been significantly tapped for electricity so far, though wind may one day catch up. Solar energy's main human application has been in agriculture and forestry, via photosynthesis, and increasingly it is harnessed for heat. Biomass (e.g. sugar cane residue) is burned where it can be utilised. The others are little used today. Turning to the use of renewable energy sources for electricity, there are immediate challenges in actually harnessing them. Apart from photovoltaic (PV) systems, the question is how to make them turn dynamos to generate the electricity. If it is heat, which is harnessed, this is via a steam generating system. Hydro-electric power, using the potential energy of rivers, now supplies 17.5% of world electricity (99% in Norway, 57% in Canada, 55% in Switzerland, 40% in Sweden, 7% in US). Apart from a few countries with an abundance of it, hydro capacity is normally applied to peak-load demand, because it is so readily stopped and started. It is not a major option for the future in the developed countries because most major sites in these countries having potential for harnessing gravity in this way are either being exploited already or are unavailable for other reasons such as environmental considerations. Growth to 2030 is expected mostly in China and Latin America.[xxxviii]

The chief advantage of hydro systems is their capacity to handle seasonal (as well as daily) high peak loads. In practice the utilisation of stored water is sometimes complicated by demands for irrigation, which may occur out of phase with peak electrical demands.

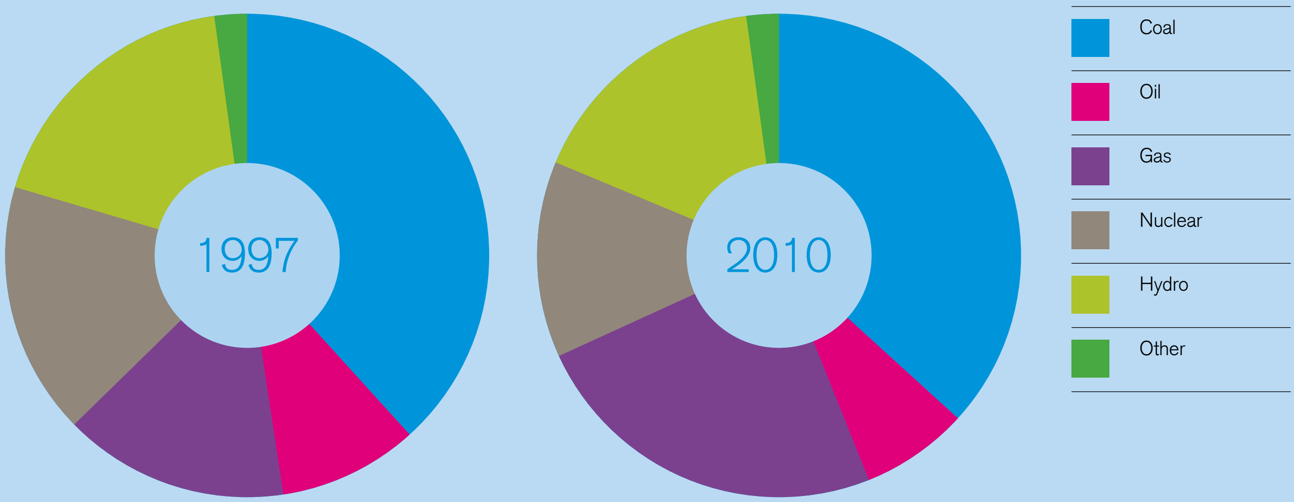
Transportation

An important factor for emerging energy trends is transportation and the development of lightweight materials for automobiles that increase energy efficiency while reducing emissions. Advanced composites with polymer, metal, or ceramic matrix and ceramic reinforcement are already in use in space systems and aircraft. The new Boeing 787 Dreamliner uses extensive use of carbon fibre and plastic which results in reduced fuel consumption[xxxix]. Although innovation in both design and manufacturing is needed before such all-aluminium structures can become widespread, aluminium content in luxury cars and light trucks has increased in recent years. Spurred by California's regulations concerning ultra-low-emission vehicles, both Honda and Toyota have introduced gasoline-electric hybrid vehicles. Hydrogen with a growth of >5% pa may also be used as an alternative energy for vehicles.[L]

Who is Focusing on Energy?

Energy is a priority research area in countries such as US, Canada, Japan and the Nordic countries. Fuel cells research is led by Canada, Germany, the US, China and Denmark. The

FIGURE C.25: WORLD ENERGY GENERATION 1997 AND 2010



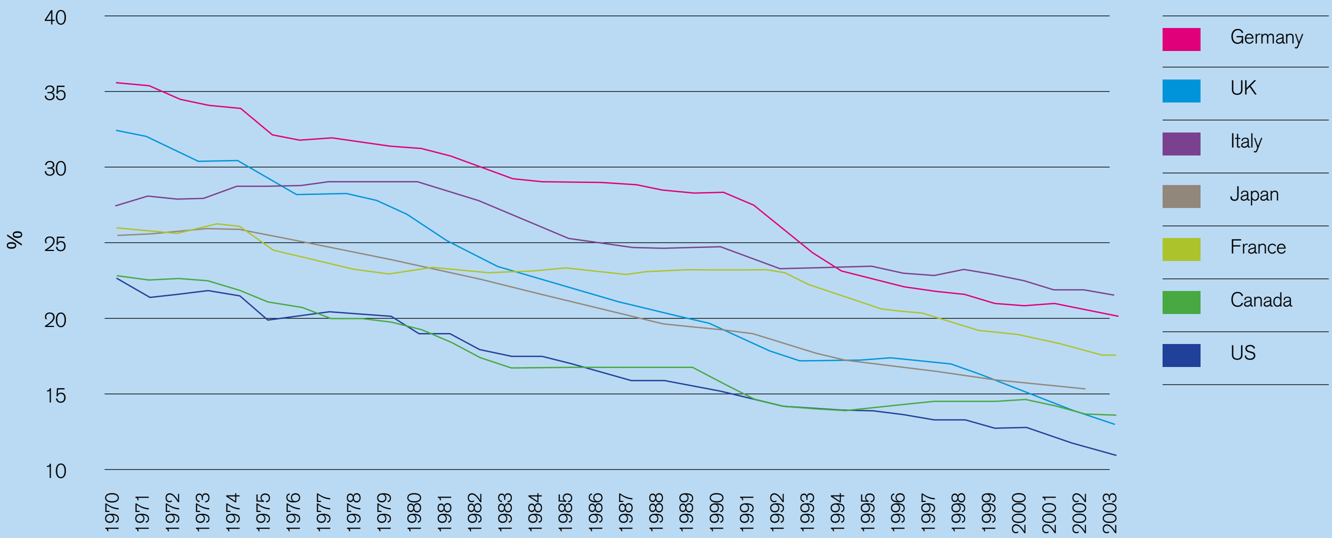
Total 14,000 TWh

Total 20,000 TWh

Netherlands, Switzerland and the US lead the field in photovoltaics. Glazing and thin film deposition research is led by Germany, the US, Australia and the Nordic countries. Wind energy is heavily concentrated in five countries: Denmark, Spain, Italy, US and Germany, with active programmes in China, India and Brazil.

C.9 TECHNOLOGY DRIVERS

FIGURE C.26: SHARE OF MANUFACTURING IN TOTAL EMPLOYMENT, G7 COUNTRIES, 1970-2003, IN %



Source: US Utility Data Inst (pre 1995), Resource Data International (1995)

Analysis of current trends provide a broad understanding of evolutionary technology change, it does not provide information on revolutionary technological breakthroughs. In addition environmental, economic, social, ethical, and political factors significantly effect the technological direction. Other factors such as globalisation, increased off shoring and changing demographics will also pay a role in effecting the pressure on the individual trends.

Economic sub-trends such as the increasing dichotomy between the manufacturing and services sectors will also play a role. While manufacturing production and value added continues to experience strong growth it is declining in terms of overall share of the total value added in the global economy. Manufacturing employment has steadily decreased in most OECD countries. The Figure below illustrates the decrease in manufacturing employment in the G7 countries.[Li]

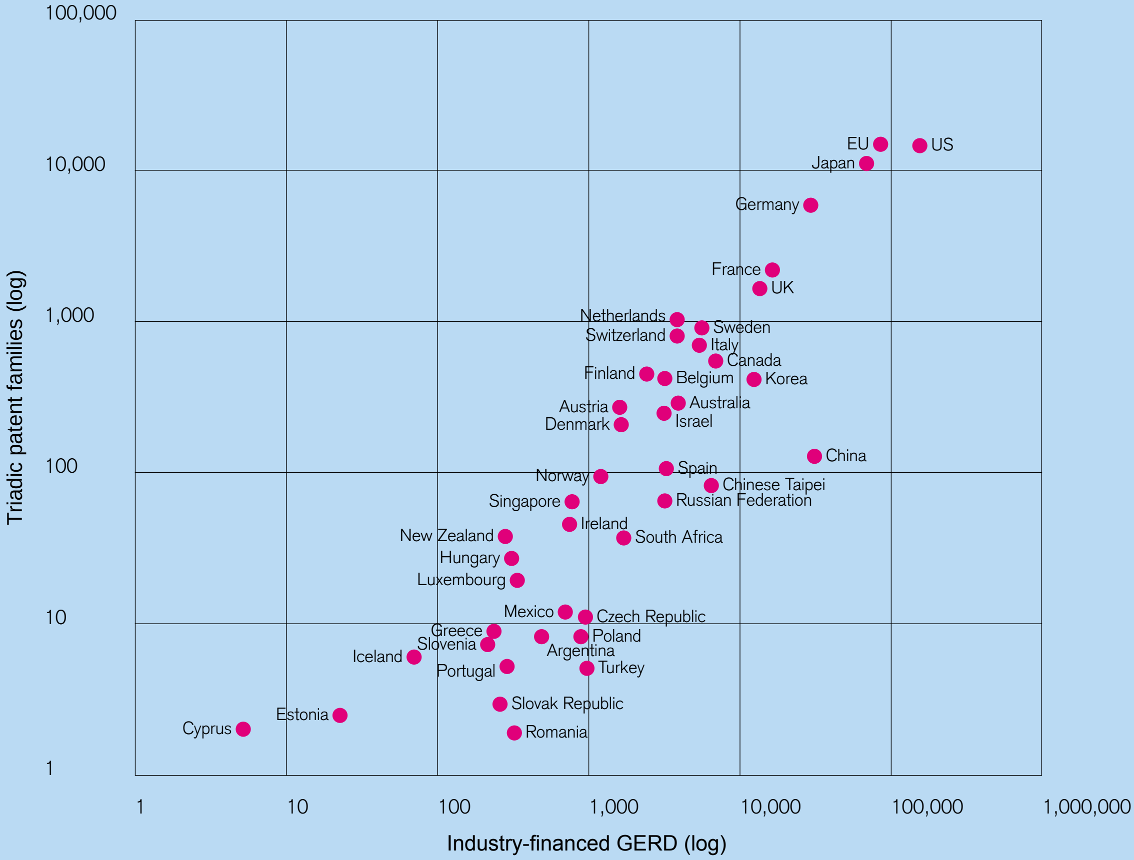
Maintaining intellectual property rights is key to the technology sectors. The R&D undertaken by manufacturing firms can be turned into patentable innovations. OECD patent trends only capture those patents that have been filed at all the three major patent offices, the US Patent and Trademark Office, the Japan Patent Office and the European Patent Office. The Figure shows the position of different countries on this trend. China, Korea and the Russian Federation, have considerable spending on R&D, but make a relatively small contribution to patents. These countries are still primarily oriented towards imitation. Others, such as Japan, Germany, Switzerland, Sweden and the Netherlands make a relatively larger contribution to patents than to R&D. These countries are primarily oriented towards innovation.

Terrorism and crime will further drive technologies such as sensors including biometric, person identification software, enhanced pattern recognition and mage processing.

Social and ethical pressures such as practised freedom of movement for information, people and goods and claims to privacy may restrict some of the technology advancements. For example, extensive research and development has produced the MOSQUITO unit that uses complex high frequency sound to chase away younger people who can hear in this region of the sound spectrum[Liii].

Regulation will also affect the progress of advancement of the technology sector. This may be more prohibitive in the bioscience areas than say the advanced material area. In addition natural disasters and war may also act as the stimulus for the increase in progress of new technologies (e.g. the jet engine or atomic bomb in world war 2)

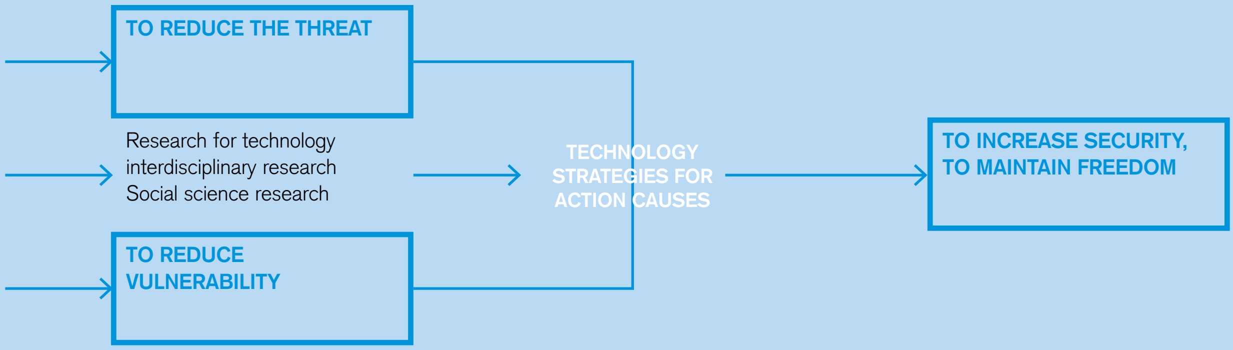
FIGURE C.27 PATENT NUMBERS VS. INDUSTRY-FINANCED R&D, 1996-2002



The population of the western world is ageing. The balance between young and old is shifting. Life expectancy is increasing, as premature mortality rates fall. The average family size now sits below the replacement level in many European countries. The number of single person and single parent households is growing. The number over 60 are expected to grow by nearly a third by 2021, while the numbers of young people under 16 will fall. All of these trends are creating significant uncertainty about the net impact of the ageing population on health care demand.

Lifestyles are now major risks to the future health of the population. Obesity, sedentary lifestyles, sexually transmitted disease, and alcohol consumption are growing, especially amongst the young. This is driving increased incidence in diabetes, heart disease and kidney disease. These lifestyle choices now create a significant burden of health problems.

FIGURE C.28: ILLUSTRATES AN APPROACH TO DEVELOPING NEW TECHNOLOGIES TO AID SECURITY[Lii]



APPENDIX D
FE COLLEGES ORGANISATION

D

Since the launch of "FE means Business" in 2006, the Department of Education has fundamentally changed the purpose, structure and governance of the colleges in NI (this includes how colleges are funded and managed). The emphasis was to enhanced the FE impact on the economy and to create new partnerships between the sector and employers, other institutions and organisations. From this position, a challenge to improve performance in terms of efficiency and effectiveness was developed alongside supporting models of incorporation, a new funding model and a fundamental change in the structure of the colleges.

In 2006 there were 16 colleges, with 2,100 full-time lecturers and 3,465 part-time, facilitating the learning of almost 34,000 students (full-time) and 133,033 part-time. These students were enrolled in vocational courses however an additional 74,000 students were engaged in non-vocational courses such as leisure, culture and hobbies. FE means Business amalgamated these colleges into six larger institutions with broader management remits. This change occurred on the 1st August 2007 and presented major challenges to the overall sector alongside the other changes taking place.

FIGURE D.1: AMALGAMATION OF COLLEGES AND COE

Southern Regional College	Belfast Metropolitan College	Northern Regional College	Southern Eastern College	North West Regional College	Southern West College
Newry and Kilkeel (Hospitality & Tourism) Upper Bann (ICT & Computing)	Belfast Institute (Software Engineering) Castlereagh College	North East (Manufacturing Engineering) North East (Construction & Built Environment)	North Down & Ards (Electronics) (Manufacturing Engineering) (ICT & Computing) (Software Engineering) (Construction & Built Environment) East Down Lisburn Institute	North West Institute (Software Engineering) (Construction & Built Environment) Limavady	East Tyrone Fermanagh Omagh
2000/1	**2002/3**	**2000/1** **2002/3**	**2000/1**	**2000/1**	**2000/1**

FOOTNOTES

i Carey, John, Naomi Freundlich, Julia Flynn, and Neil Gross, “The biotech century—there’s a revolution brewing in the lab, and the payoff will be breathtaking,” Business Week, No. 3517, March 10, 1999, pp. 78–90.
ii http://www.biodesign.asu.edu/biotech/history/
iii http://www.nano.gov/html/res/smwonder_slide.pdf
iv Friedman, Thomas L., The Lexus and the Olive Tree, Anchor Books, New York, April 2000.
v http://www.publications.parliament.uk/pa/cm200304/cmselect/cmsctech/56/56.pdf
vi http://www.intel.com/technology/mooreslaw/index.htm
vii http://www.itrs.net/Links/2005ITRS/Linked%20Files/2005Files/FEP 2005%20FEP%20Starting%20Materials%20450mm%20Position %20Paper%20Link%20v090105.doc
viii Heath, James R., Philip J. Kuekes, Gregory S. Snider, and R. Stanley Williams, “A defect-tolerant computer architecture: opportunities for nanotechnology,” Science, Vol. 280, No. 5370, June 1998, pp. 1716–1721.
ix http://archives.sensorsmag.com/articles/0203/14/main.shtml
x http://images.google.co.uk/imgres?imgurl=http://www.memx.com/images/ratchet.jpg&imgrefurl=http://www.memx.com/&h=933&w=950&sz=89&hl=en&start=1&um=1&tbnid=IYBGQLqnBJTa8M:&tbnh=145&tbnw=148&prev=/images%3Fq%3Dmems%2Bdevices%26svnum%3D10%26um%3D1%26hl%3Den%26rlz%3D1T4GZEZ_en-GBGB227GB227%26sa%3DN
xi http://images.google.co.uk/imgres?imgurl=http://www.memx.com/images/mems-thermal-actuator-pic.gif&imgrefurl=http://www.memx.com/image_gallery.htm&h=314&w=315&sz=81&hl=en&start=2&um=1&tbnid=N0P533yXQyjyIM:&tbnh=117&tbnw=117&prev=/images%3Fq%3Dmems%2Bdevices%26svnum%3D10%26um%3D1%26hl%3Den%26rlz%3D1T4GZEZ_en-GBGB227GB227%26sa%3DN
xii http://www.cubesatkit.com/
xiii http://home.att.net/~castleisland/
xiv http://www.chem.rdg.ac.uk/dept/staff/phys/iwh.html
xv http://www.nature.com/materials/nanozone/newsandviews/020103/nbt0102-30_f1.html
xvi http://www.grc.nasa.gov/WWW/RT/2003/5000/5120noebe.html
xvii http://sciencelinks.jp/j-east/article/200207/000020020702A0098508.php
xviii http://news.bbc.co.uk/1/hi/technology/6412057.stm
xix http://www.msnbc.msn.com/id/8976160/
xx http://www.sciencemag.org/sciext/globalvoices/bai/slide07.html
xxi http://www.sustainable-development.gov.uk/key/sustainable.htm
xxii http://www.royalsoc.ac.uk/displaypagedoc.asp?id=11518
xxiii Hansen, Nanette (2004). Organic food sales see healthy growth (html). MSNBC. Retrieved on 2006-06-20.
xxiv http://www.regional.org.au/au/roc/1992/roc1992031.htm
xxv http://statistics.defra.gov.uk/esg/indicators/overview.htm
xxvi http://www.conventionscotland.com/content/mediaassets/images/Green%20Tourism%20Fact%20Sheet%20.pdf
xxvii http://www.forester.net/mw_electronic/mw0304recycling.pdf
xxviii Future Health Care Trends – an overview. Candace Imison. Strategy Unit. Available at http://www.nationalleadershipnetwork.org/public/NLN-FutureTrendsFutureHospitals.ppt
xxix http://www.oecd.org/dataoecd/51/59/36760212.pdf
xxx http://www.dpag.ox.ac.uk/research/cardiac_science/denis_noble
xxxi http://www.nature.com/nature/journal/v445/n7130/full/nature05664.html
xxxii http://biomed.brown.edu/Courses/BI108/BI108_2004_Groups/Group05/Drug%20Eluting%20Stents/implications.htm
xxxiii A New Era of Diagnostics, Institute for the Future Health Horizons Program, December 2003
xxxiv http://www.oecd.org/dataoecd/51/59/36760212.pdf
xxxv http://ec.europa.eu/information_society/eeurope/i2010/docs/info_sheets/7-2a-i2010-innovation-en.pdf
xxxvi http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2006/04/20/000012009_20060420105118/Rendered/PDF/359240PAPER0In101OFFICIAL0USE0ONLY1.pdf
xxxvii http://www.comminit.com/trends/ctrends2004/trends-29.html

xxxviii http://www.mwjournal.com/Journal/article.asp?HH_ID=AR_1467
xxxix http://www.jiwire.com/search-hotspot-locations.htm
xxxx http://www.govexec.com/dailyfed/0803/082503td1.htm
xxxxi http://www.manageability.org/blog/stuff/mid-year-recap-2005
xxxxii http://aceee.org/conf/mt07/r1_johnson.pdf
xxxxiii http://www.wtrg.com/prices.htm
xxxxiv Jitex SWOT analysis for the European Commission (2005); FP7 priority areas; SWOG (Strategic Working Group under the Advisory Group on Energy); EurEnDel Delphi Survey, Wehnert et al (2004); see "Key Technologies for Europe" – Energy prepared for the European Commission (2005)
xxxxv http://www.distill.com/World-Fuel-Ethanol-A&O-2004.html
xxxxvi http://www.uic.com.au/nip11.htm
xxxxvii http://www.uic.com.au/nip38.htm
xxxxviii http://www.world-nuclear.org/info/inf02.html
xxxxix http://www.businessweek.com/magazine/content/05_25/b3938037_mz011.htm
L http://findarticles.com/p/articles/mi_m3165/is_2000_June/ai_65162840
Li THE CHANGING NATURE OF MANUFACTURING IN OECD ECONOMIES STI WORKING PAPER 2006/9
Lii http://www.etrics.org/keynotes/etrics2006-keynote-Bernd_Hunger.pdf
Liii Extensive research and development has produced the MOSQUITO unit that uses complex high frequency sound to chase away those annoying teenagers!

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