Environmental RTDI Programme 2000–2006

Environmental Technologies:

Guidelines on How to Take a Pilot Project to Market

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Final Report

Prepared for the Environmental Protection Agency

by

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ENVIRONMENTAL TECHNOLOGIES

The Environmental Technologies Section of the Environmental RTDI Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in this area. The reports in this series are intended as contributions to the necessary debate on environmental technologies and the environment.

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Table of Contents

Acknowledgements **ii**

Disclaimer **ii**

Details of Project Partners **iii**

Executive Summary **ix**

1 Introduction **1**

1.1 Purpose of Study 1

2 Environmental R&D **3**

2.1 Defining Environmental R&D 3

2.1.1 Exploratory research 3

2.1.2 Monitoring 3

2.1.3 Problem-solving research 3

2.1.4 Technology-based research 4

2.1.5 Related environmental research 4

2.2 Drivers for Conducting Environmental R&D 5

2.2.1 National environmental R&D infrastructure 5

2.2.2 National and international regulation 5

2.2.3 Environmental efficiency 5

2.2.4 Public awareness 5

2.2.5 EU Eco-Label 6

2.2.6 Green public procurement 6

2.2.7 User grants/financial supports 6

2.2.8 Grants to industry 6

3 Environmental Products and Processes **7**

3.1 Range of Environmental Products 7

3.2 Market for Environmental Products 8

3.2.1 Market size and employment for environmental products and services 8

4 Position in Ireland and Abroad on Commercialising IP **11**
4.1. Historical Background 11
4.2 Codes of Practice for IP 12
4.3 Capacity for Commercialisation 13
4.4 IP Experience in Other Countries 14
5 Commercialisation Experience in Other Countries **16**
5.1 Denmark 16
5.1.1 Wind energy 17
5.1.2 Other initiatives 17
5.2 Australia 18
5.3 Germany 19
5.4 USA 19
6 Irish Attitudes to Commercialisation **21**
6.1 Commercialisation Opportunities 21
6.2 Motivation/Cultural Aspects 21
6.3 Knowledge of Commercialisation and Support 21
6.4 Issues and Barriers 22
6.4.1 Publications vs commercialisation 22
6.4.2 Evaluation of commercialisation potential 22
6.4.3 Gaps in progressing to commercialisation 22
7 Performers of R&D **23**
7.1 Scale of Activity 23
8 Funders of R&D **24**
8.1 Environmental Protection Agency 24
8.1.1 CGPP 24
8.1.2 Advanced technologies for environmental protection 25
8.1.3 Analytical monitoring and forecasting 25
8.2 Enterprise Ireland 25
8.2.1 RTI Initiative 26
8.2.2 ESP support initiative 27

8.2.3 Environmental R&D projects funded under the RTI and ESP initiatives 27
8.3 IDA Ireland 28
8.4 Shannon Development and Údarás na Gaeltachta 28
8.5 Sustainable Energy Ireland 28
8.6 Health Research Board 28
8.7 InterTrade Ireland 29
8.8 Science Foundation Ireland 29
8.9 Marine Institute 29
8.10 Higher Education Authority 29
8.11 The Irish Research Council for Science, Engineering and Technology 30
8.12 The Department of Transport 30
8.13 European Union 30
8.14 Other Potential Funders of Environment-Related R&D 32
8.14.1 Teagasc 32
8.14.2 Electricity Supply Board 32
8.14.3 Bord Gáis Eireann 32
8.14.4 Private sources 32
9 The Commercialisation Process 33
9.1 Background to Commercialisation 33
9.2 Summary of the Commercialisation Process 33
9.2.1 Recognising the opportunity 34
9.2.2 Assessing the commercial value 36
9.2.3 Assessing patentability 36
9.2.4 Assessing commercialisation options 37
9.2.5 Commercialisation success 39
10 Conclusions 40
11 Recommendations 41
References 42
Abbreviations 43
Appendix 1 45

Executive Summary

Ireland, like many other developed countries, makes considerable investment in support of environmental research and development (environmental R&D). This investment is made for a variety of purposes, all of which relate to a general objective of protecting and improving environmental quality. The output of most of this research is properly in the public domain.

There are some areas of R&D, most notably in relation to environmental products and processes, that are potentially capable of being commercialised. However, within Ireland there are indications that the level of commercialisation of research output is less than might reasonably be expected. To investigate this issue, the Environmental Protection Agency (EPA) commissioned this background study to establish the current level of commercialisation in Ireland and to compare that level with the position in other jurisdictions.

1 Drivers for Environmental R&D

There are various drivers for undertaking environmental R&D, principal among these are:

- The desire to create a national environmental R&D expertise
- The requirement to meet national and international environmental regulations
- Achieving savings though environmental efficiency
- Increasing public awareness of 'green' issues
- EU eco-labelling of products as a marketing tool
- Green public procurement
- User grants/financial supports for environmentally friendly products
- Grants to industry and institutes to undertake R&D.

The market size and trends for various environmental products and processes was investigated in the case of the USA, the EU and SE Asia. These investigations show that the principal market is for environmental equipment and processes that relate to the treatment of water, air and waste. Overall the market is of a very significant scale and is expected to continue to expand for the foreseeable future. Demand for monitoring equipment, including associated software, for use in the various treatment processes, monitoring of emissions and of the receiving environment is also expanding.

In September 2006, a major study was undertaken by Ernst & Young for the EU (DG Environment) entitled *Eco-Industry, its Size, Employment, Perspective and Barriers to Growth in an Enlarged EU*.

The key points in the Ernst & Young study are:

- The European market for environmental goods and services is worth €227 billion
- The EU's environment industries represent around 3.4 million jobs
- Traditional activities such as waste management continue to account for the vast majority of expenditure on resource and pollution management
- More recent markets such as renewable energy and eco-construction are growing fast but remain fragmented, except for the wind power sector, which is being taken over by global energy firms.

2 Protection of Intellectual Property

A key factor in the commercialisation of R&D is the provision of adequate protection of intellectual property (IP) through patenting.

Ireland's actual patenting activity is low by European and other comparators. The number of European Patent Office applications in 2002 was 311 or 80 per million inhabitants. This is below the EU average of 140 per million inhabitants. This is due in part to the relatively low level of R&D carried out by multinational enterprises (MNEs) in Ireland. The number of patents granted in Finland, a country with a comparable population, is about eight times higher than that in Ireland. The increases are predominantly in newer high-tech sectors, not in traditional sectors.

It is also to be noted that the numbers of patents originating from publicly funded research is very low. This is due in part at least to the fact that it is directed at public-good research and as such is disseminated widely and freely. Several other reasons for the low level of such patenting are reported, such as the lack of funding for commercialisation, low levels of awareness of the value of IP, lack of staff with expertise in IP management and little commitment in higher education institutes to producing patents. Thus, even if new knowledge is forthcoming, Ireland's capacity to commercialise it is limited.

3 Commercialisation Experience in Other Countries

In order to gain an understanding of the opportunities that may exist for the commercialisation of Ireland's environmental R&D, it was considered useful to examine the experience of other countries. The principal countries chosen were Denmark, Australia and Germany. Briefly the findings were as follows:

Denmark supports environmental R&D with a number of small commercialisation initiatives some of which are comparable to those operated in Ireland. In one instance, a comparatively modest financial support in wind turbine R&D resulted in Denmark becoming the world leader in that technology. A particular feature of the commercialisation process that was noted in Denmark is the role played by large consultancy companies. These companies play a key role in the technology transfer process in environmental technologies by acting as brokers.

In **Australia**, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is achieving some degree of success in commercialising its R&D output including environmental R&D. This is seen to have arisen as a consequence of the increasing emphasis within the CSIRO in recent years on the commercialisation of its research, an objective that is now supported by almost 200 specialist staff.

In **Germany**, the reduction of emissions of greenhouse gases is an important goal of their environmental policies. By providing significant grant support for the installation of photovoltaic (PV) panels on domestic rooftops under the so-called *100,000 Rooftops Solar Electricity Programme*, the country has become a world leader in this technology. This emphasis on a single research theme has resulted in German PV-related R&D achieving notable success and is now being translated into industrial output and job creation.

4 Irish Attitudes to Commercialisation

An investigation of the attitudes of researchers towards commercialisation of research findings was undertaken. Some of the key findings were as follows:

- While accepting that they (the researchers) have gaps in their knowledge, they considered that suitable knowledge supports were readily accessible through established networking with colleagues, in-house industrial liaison/technology transfer officers and IP/commercialisation specialists within Enterprise Ireland.
- Researchers considered that career advancement within the higher education institutes was highly dependent on the number and quality of publications. This presents a dilemma for researchers insofar as it means that if they divert effort into commercialisation their career advancement will likely suffer.
- It was considered that assessing the true commercial potential of a research finding was a real difficulty for the researcher/research body and for which no readily accessible support exists.
- The commercialisation step required a dedicated effort on the part of the researcher and this was not seen as mainstream to their functions or abilities as researchers.

5 Performers of R&D

Unlike almost every other EU country, Ireland has very few R&D institutes (e.g. Teagasc) that conduct R&D and provide technical services for industry. The Irish knowledge base is conspicuously deficient in applied research institutes (Austria has 40 applied research laboratories and Denmark has 30+) and, in general, Ireland does not have the knowledge production structures specifically designed to facilitate commercialisation of research outputs.

6 Funders of R&D

There is a wide range of organisations that provide funding for performance of R&D, some or all of which may be environmental. Some of the principal funding agencies of relevance are presented below.

While it is not a core function of the **EPA** to provide support to the industrial sector, the Agency does provide R&D funding to industry and others through the *Cleaner*

Greener Production Programme (CGPP). The CGPP aims are focussed on avoiding and preventing adverse environmental impact through cleaner production rather than by means of ‘end-of-pipe’ treatment. The CGPP is a sub-programme within the overall Environmental Research, Technology, Development and Innovation (ERTDI) programme. Nationally, the ERTDI programme has developed co-operative funding links with other sectoral R&D agencies (COFORD, Teagasc, Sustainable Energy Ireland and the Marine Institute), with the National Roads Authority and with higher education institutes.

Enterprise Ireland (EI) is responsible for the development of indigenous industry and offers the widest range of R&D supports. Part of EI’s overall brief is to develop an R&D capability within the higher education sector that will be relevant to economic development. In this connection, EI supports a range of applied R&D programmes designed to assist the creation of new technologies (including environmental technologies) and their transfer to industry.

EI provides two main support initiatives for technology-based research. These are the *Research Technology and Innovation (RTI) Initiative* (the principal scheme) and the *Environmentally Superior Products (ESP) Programme*.

The RTI Scheme offers a number of supports from initial research though to IP protection and commercialisation. These supports are as follows:

- Initial information support
- Training for innovation and R&D
- Tailored R&D support (significant R&D projects)
- Initiatives in specific advanced technologies
- Industrial technologies
- Innovation partnerships – companies and colleges working together
- Commercialisation fund
- Company creation
- IP fund for higher education.

The ESP Initiative aims to support industry to incorporate eco-design approaches in the development of their products and services without compromising product functionality, quality, ability to manufacture or cost. To date, 50 Irish SMEs from a range of industry sectors have participated.

The **Higher Education Authority** (HEA) administers a significant budget for R&D under the *Programme for Research in Third Level Institutions* (PRTLI). Between 2000 and 2006 some €605 million were administered with an approximate split between capital allocations (buildings and equipment) and current (research programmes and staff) of two to one. PRTLI funding is allocated across a broad range of disciplines and research topics including some that relate to the environment.

The **Irish Research Council for Science, Engineering and Technology** (IRCSET) provides funding for R&D, some of which relates to the environment. Over the funding period of 2002–2005, seven projects from a total of 25 were considered as possibly having some potential to ultimately lead to products or processes of commercial interest.

7 The Commercialisation Process

A generalised process for commercialisation of the outputs from research, with a particular emphasis on highlighting the elements of relevance to environmental researchers, has been prepared as part of this overall study and is presented as a plain language guide. Briefly the commercialisation process can be broken down into five definable stages as follows:

1. Recognising the opportunity
2. Assessing the commercial value
3. Assessing patentability
4. Deciding on a commercialisation strategy
5. Implementing commercialisation.

1 Introduction

Ireland, like many other developed countries, makes considerable investment in support of environmental research and development (environmental R&D). This investment is made for a variety of purposes, all of which relate to a general objective of protecting and improving environmental quality. Within this overall objective, issues that require research include:

- Monitoring environmental quality parameters
- Investigation of the cause of environmental change
- Finding solutions to known environmental problems
- Establishing practices and standards (e.g. for industry, agriculture) that are consistent with the needs of environmental quality maintenance.

The output of most of this research is properly in the public domain. Information on changes in environmental quality, and on means to address these changes, will be used to inform good environmental practice by farmers, industry, other sectoral groups and the general public. Standards will be used to frame legislation and planning guidelines. However, a proportion of this research will also result in technology or materials whose use is best achieved through their commercialisation. Examples include specialist filters, material used for pollution abatement, machinery and reagents used in recycling and instrumentation for environmental monitoring.

Within Ireland, there are indications that the level of commercialisation of environmental research output is less than might reasonably be expected. One possible explanation is a lack of awareness among researchers as to how best to progress research findings to a point where they can be commercially exploited. Lack of awareness of this process has been reported among Irish researchers in other areas of research. To investigate this issue, the Environmental Protection Agency (EPA) made a call for proposals to conduct a background study to establish the current level of commercialisation in Ireland and to compare that level with the position in other jurisdictions, particularly in those where commercialisation has been more effectively achieved. The second requirement was to prepare a clear plain-language guide to commercialisation for environmental researchers entitled *Guidelines on How to Take a Pilot Project to Market*.

1.1 Purpose of Study

Until very recently, government funding for third-level research was very limited. That situation has now radically changed due to a significant expansion in the range and funding of research programmes under the National Development Plan (NDP). The total budget for R&D in the current NDP is over €2.5 billion. A significant feature of the Irish Research and Technological Development (RTD) infrastructure is the high dependence on Higher Education Institutes (HEIs). The vast bulk of the public research funded in Ireland will be conducted within universities and Institutes of Technology (ITs).

There are indications that the level of commercialisation of the outputs of Irish research remains low by international standards. Concern has been expressed on this point by the Irish Council for Science, Technology and Innovation (ICSTI) and has been a finding of two previous studies by CIRCA for the Department of Enterprise, Trade and Employment (DETE) and Forfás, respectively. One of the factors in the low level of commercialisation is a relatively low awareness of patenting practices among academic researchers, which inevitably reduces the level of patenting of research outputs. As patenting is critical to successful commercialisation in most fields, a low level of patent output will reduce the potential for commercialisation. A second issue is the low level of interaction between HEIs and industry. In other words, even where patents exist, there is a low level of interaction with the industries that might be interested in using these patents. While there is increasing activity by the HE sector in creating start-up companies, this is usually not a feasible route for commercialisation of environmental technologies.

A concern to increase the rate of commercialisation of R&D results is not unique to Ireland. The European Commission launched its Environmental Technologies Action Plan (ETAP) early in 2004 precisely to address the need for new environmental technologies to reduce the pressure on environmental resources. This EPA action is therefore entirely in harmony with EU policy and plans.

In terms of the potential market for commercialised environmental R&D, it is noted that Ireland's investment in the environmental sector is of the order of €1 billion annually with employment of 6,000 throughout the public and private sectors (DETE, 2006).

The terms of reference for this EPA-sponsored study require the contractor to:

1. Review the options and steps involved in bringing research outputs to market

2. Identify the costs involved in protection of Intellectual Property Rights (IPR)

3. Describe the government and institutional resources available to researchers

4. Provide examples of what other countries have achieved

5. Produce a clear plain-language guide to commercialisation for environmental researchers.

This document is in two parts. The first part addresses items 1 to 4 while the second part consists of item 5 – the plain-language guide, which has been published previously (Ryan and Kelly, 2007). It should be noted that the nature, extent and rules of the programmes and supports provided by the various funding agencies described in this document will inevitably change over time. It is important therefore that where a potential area of support is identified the relevant agency should be contacted to obtain the most up-to-date funding position that applies at that time.

2 Environmental R&D

2.1 Defining Environmental R&D

The nature of environmental R&D is such that it covers a very wide diversity of research topics and objectives. For the purposes of this study, these topics/objectives can be conveniently classed as falling into any of five categories as follows:

1. Exploratory research
2. Monitoring
3. Problem-solving research
4. Technology-based research
5. Related environmental research.

2.1.1 Exploratory research

An example of exploratory research is research into the behaviour and pathways for carbon in the environment, or research into the feeding habits of particular bird or mammals species. Such exploratory research may be conducted in order to obtain a greater understanding of natural environmental mechanisms or as a basis for providing inputs to more specific exploratory research, such as in gaining a better understanding of global-warming mechanisms or of the effects of agricultural changes on wildlife. While the benefits of exploratory research are potentially very significant (or as in the case of global-warming research even fundamental in maintaining national and global economies and the human lives those economies support), it is usually difficult to assign a quantified monetary value as a return for research investment except in the broadest of terms. Commercialisable outputs from this type of research are extremely rare.

2.1.2 Monitoring

Although purists might dispute its classification as research, monitoring of air or water quality is ongoing and is important in the detection of environmental change. Included in this category is the ongoing search for better indicators of environmental change or environmental quality, and for new mechanisms for monitoring. The output of monitoring research is typically information used for establishing current quality and quality trends and also general information on environmental changes that informs other areas of research.

2.1.3 Problem-solving research

Allied to monitoring research is problem-solving research intended to address the environmental changes and problems through researching and formulating necessary intervention and correction measures. The outputs are very varied, and include technology-based solutions addressed in Section 2.1.4. However, the major form of output is the form of information. An example is information on the absorption capacity of rivers or air, or may equally be information that will support the restriction of certain practices or materials that are shown to be environmentally deleterious. To date, Ireland has invested considerable resources in this type of research, and the output is of benefit to society at large in that it commonly protects public health and protects important and valuable natural resources such as water and air.

Other problem-solving research can include research into, for example, the application rates of animal wastes on agricultural lands. Here the intention is to maintain the competitiveness/commercial viability of farming while also maintaining environmental quality. In such instances, the problem-solving research gives a direct commercial/ financial return that can be measured if necessary but is unlikely to be capable of being marketed or sold.

It is apparent therefore that virtually all such exploratory research and monitoring/problem-solving research findings are **not** likely to be, nor expected to be, commercialised. Research of this nature is commonly termed research for the **'greater good'** and it is widely agreed that it must be freely accessible to all and therefore free of patent protection.

Exceptions to the principle of free access include situations where the public investment in generating the information can be recouped through commercial exploitation. Examples include the sale of marine baseline environmental data to oil and gas exploration companies or sale of weather monitoring/forecasting data to specific end-users such as airlines. In some cases, monitoring/problem-solving research may extend to the development of computer software such as, for example, in the case of air dispersion modelling, where improved applications can be protected (as intellectual property, IP[1]) and give a commercial return to the developer(s) and or research funders/investors.

2.1.4 Technology-based research

As noted above, the solution to environmental problems may come in the form of technology, i.e. products or processes. There are many examples including enzymes, microbial cultures or other materials for degradation of waste, materials or filters for removing pollutants from waste streams and equipment for recycling waste or for its safe disposal. Environmental technology-based research essentially entails the research and development of **products** and **processes** with an environmental application. It is this area of research, i.e. environmental technology R&D, that has the greatest potential for commercialisation (see Chapter 3).

In some instances, a middle ground may exist between 'greater good' and commercial research. An example of such research is where it is instigated and part-funded by an industry association such as exists for many industry sectors (textile dyeing, brewing, dairy). These industry associations often identify common problems facing their members and conduct joint research into technical solutions to address them. The output from this research is, in some instances, preferentially or freely licensed to its members. It may also be made available to the wider community, at less financially favourable rates. Enterprise Ireland (EI) also offers funding for such joint research through its industry-led research projects scheme.

An important difference between environmental technology research and that of exploratory and monitoring/problem-solving research is that it does not necessarily originate as environmental R&D *per se*. For example, there are many chemical and electronics firms whose research departments will from time to time develop a product or process with an environmental application. Chemical firms may develop a product or process for application in the food or pharmaceutical sectors that can also be usefully applied in the environmental field. Similarly, electronics firms engaged in the research, production and sale of sensors for industry may find that some of their products have an environmental application. For instance, an improved pH meter for industrial process monitoring/control might equally be used/adapted for environmental monitoring/control. Essentially therefore environmental technology embraces a wide range of, often unrelated, industry sectors that are associated only by the fact that their products have an application in the environmental sector.

A subset of environmental technology is Advanced Technologies for Environmental Protection. In this instance, the nature of the research is more fundamental or pioneering and consequently has inherently less potential for leading to an output that can be commercialised. Nonetheless it is often through such research that breakthrough technologies are developed and which, when patented, have the potential to provide the greatest commercial return.

2.1.5 Related environmental research

Both energy research and transport research can clearly yield environmental benefits. Both fields are regarded as key areas of research necessary in addressing significant environmental problems that are of increasing concern. These problems include global warming, urban air quality, consumption of natural resources and the generation of wastes. However, while research in these fields can yield outputs of direct environmental importance/benefit, and potentially a commercial return, the environment is not the primary focus of the research. Consequently, most countries have dedicated research and funding arrangements in place under headings of Energy and Transport that are distinctly separate from that for environmental research. This is the case in Ireland also where energy research is promoted by the Department of Communications, Marine and Natural Resources and the state agency Sustainable Energy Ireland (SEI).

Transport research may be sponsored by the Department of Transport. Similarly, agricultural research undertaken or sponsored by Teagasc and/or the Department of Agriculture & Food may have a significant environmental dimension. In response to this situation, the EPA-sponsored environmental research programme has developed co-operative funding links with other sectoral R&D agencies (COFORD, Teagasc, SEI and the Marine Institute (MI)), with the National Roads Authority (NRA) and with HE-based research.

1. IP refers to creations of the mind (inventions, literary and artistic works, images and designs) that can be protected under law. IP is divided into two categories: industrial property, which includes inventions (patents), trademarks, industrial designs, and geographic indications of source; and copyright, which includes literary and artistic works.

For the purposes of this study, therefore, these potentially related research fields can be conveniently classed collectively as Related Environmental Research. While the main focus of this study is not on these topics they have been included in an overview context.

2.2 Drivers for Conducting Environmental R&D

There are a number of drivers for environmental R&D. An understanding of the nature and extent of these drivers provides an insight into the available supports for environmental R&D that are likely to have commercial potential. Such an understanding also provides an insight into the effectiveness of these drivers and how best they might be reinforced or improved. The principal drivers are as follows:

1. National environmental R&D infrastructure
2. National and international regulation
3. Environmental efficiency
4. Public awareness
5. EU Eco-Label
6. Green public procurement
7. User grants/financial supports
8. Grants to industry.

2.2.1 National environmental R&D infrastructure

Most developed countries regard an environmental research capability as an essential component of the overall national research infrastructure. This capability will be developed through funding of specific research teams within HEIs, or through funding of environmental R&D institutes under direct state control.

The research capability within these groups is utilised in protecting national environmental resources and in addressing environmental issues/problems. The output of such research is normally for the greater good and is non-commercialisable. The majority of grant support in environmental R&D in Ireland is of this nature.

Some of these research groups will inevitably have influence outside their home countries and will become internationally recognised Centres of Excellence for a particular environmental research field. Examples include Danish research expertise in the field of waste/waste-water treatment and in wind turbines, German research expertise in photovoltaic (PV) power, and French research expertise in harnessing tidal energy. As noted above, several of these fields are relevant because of their indirect effect on the environment. These often involve the provision of very significant financial supports by the state both in the R&D and in 'demonstration projects' for the R&D output.

2.2.2 National and international regulation

Regulatory drivers for environmental R&D typically originate as emission standards put forward by the EU, often as Directives giving rise to corresponding national regulations. These emission reduction/controls requirements are applied to manufacturing industry, various products including transport products and energy generation/use. EU Directives and national regulations may also extend to manufactured products in terms of their manufacture, use and disposal such as is imposed indirectly on electrical/electronic goods by way of the Waste Electrical and Electronic Equipment (WEEE) Directive and on a wide diversity of car components by way of the End-of-Life Vehicle (EoLV) Directive. Such Directives provide a significant stimulus to the market demand for environmental products and processes, which in turn generates a requirement for highly focused environmental R&D for improvement of both product design and manufacturing process design that are capable of being commercialised.

2.2.3 Environmental efficiency

In many industrial processes, building construction, transportation, etc., there may be an associated environmental inefficiency (e.g. the unnecessary consumption of materials including energy, excessive emissions, problematic disposal of waste by-product or disposal at end of product life). Such environmental inefficiency can represent a corresponding, significant, financial inefficiency for which there is to be an expected commercial demand for correction either by new/ improved product design or processes.

2.2.4 Public awareness

Research has been conducted across the EU and elsewhere that strongly indicates that within developed economies there is a clear demand from the public for products that have a reduced adverse impact on the environment. Many companies competing for market share will use environmental performance as a selling feature for their product.

There appear to be at least three prerequisites for this to succeed. Firstly, the goods must be capable of functioning equally well; secondly, the public must be environmentally educated/aware; and, thirdly, they must have the necessary disposable income to disregard the (usually) slightly higher product price. While these factors may restrict the size of the global market they also potentially allow for higher profit margins capable of more than offsetting the R&D expenditure.

2.2.5 EU Eco-Label

The EU Eco-label is a certification mark indicating that the product bearing the label meets specified environmental criteria. It is a voluntary scheme designed to encourage businesses to market products and services that are kinder to the environment and allows European consumers – including public and private purchasers – to easily identify them. The Eco-label applies to a wide range of products that, to date, include cleaning products, appliances, paper products, home and garden products, clothing, lubricants, and tourism. While use of the label, a voluntary system, has achieved little penetration of the market compared to the mandatory EU Energy Label for certain goods it does have the potential to influence product design and provide market advantage.

2.2.6 Green public procurement

A number of proposals for non-mandatory green public procurement initiatives have been developed at EU level. This concept is based on the recognition that the public bodies within the various EU Member States are collectively major purchasers of goods and services (estimated by the Commission to represent 16% of EU-wide GDP or a sum equivalent to half the GDP of Germany). As such, these purchasers are in a strong position to influence the environmental acceptability/ performance of products/services by including environmental performance as a consideration when choosing suppliers/contractors. The intention is that this will stimulate the research and development of ‘greener’ products in their supply chain and which, in turn, will transfer into the wider and larger products/services market to the public.

2.2.7 User grants/financial supports

Grants for users of environmental technologies may be provided in some countries, usually for limited periods. These tend to be in the area of energy rather than strictly environment although their impact can be to the benefit of the environment. Current examples of supports in the energy area in Ireland include grants for domestic use solar collectors, wood pellet burners and tax reductions in the case of the purchase of hybrid cars and biofuels. These grants stimulate consumer demand and can lead directly to R&D for product design improvement and subsequent manufacture and sale. Complementary agricultural grant structures also exist, or are being developed, for growing biofuels such as elephant grass and willow that ultimately create a reinforcement feedback loop into the drivers for products that utilise these fuels. Other examples include the extensive grant support in Germany for the widespread installation of PV panels in the domestic sector, with the ultimate objective of lowering emissions to air, reducing dependence on imported energy and also, importantly, in making Germany the world leader in the application and commercialisation of this technology both at home and abroad (see Chapter 5).

2.2.8 Grants to industry

Numerous countries, including Ireland, provide grants to industry in various forms to stimulate R&D of products and processes. While some grants may be specifically focused on environmental products/processes, most simply support technical R&D in industry that may be environmental in nature but is not required to be so and is not funded under that heading. Examples of the latter include EI’s *Research Technology and Innovation (RTI) Initiative*. Successful examples of strictly environmentally focused R&D grant supports include EI’s *Environmentally Superior Products (ESP) Programme* and the EPA’s *Cleaner Greener Production Programme* (CGPP).

3 Environmental Products and Processes

In assessing the types of environmental products that are likely to be capable of being commercialised, the most reliable indicator is to look at those currently available on the market.

3.1 Range of Environmental Products

An examination of the range of environmental products and processes available clearly shows that they represent a very wide diversity of products, based on often unrelated technologies. Examples are given in Table 3.1.

Clearly this diverse range of products and processes is most likely to be researched and developed by commercial companies already operating in their respective markets. Such companies have the advantage of familiarity with their product/process, a thorough knowledge of its application, the specific market potential and needs, development and manufacturing capability, IP protection issues and marketing strategies/costs. Where research capacity/capability is not available in-company it may be subcontracted to an outside research organisation. In such a case, the commissioning company keeps the research tightly focused on company-specific needs and maintains close control of research output and costs.

For much of the environmental research directly funded by government to lead to commercial success, the process must flow in the opposite direction for several or all of the steps described above. That is, the researcher identifies the market need, initiates and conducts the research, puts the IP protection in place and identifies a commercial partner with the necessary manufacturing capability and desire/need to bring it to market, all with a pre-agreed acceptable return to both parties (the research organisation and the manufacturer).

It is not surprising therefore that the overwhelming majority of commercialised environmental R&D, i.e. products/processes on the market, were developed by companies rather than independently by research organisations.

In some areas of technology, a more collaborative approach has proved successful. For example, in an earlier study conducted by CIRCA on IP for Forfás (Forfás, 2005), the investigations indicated that the medical devices industry was the most proactive in establishing links with the users of its products (medical doctors and surgeons). In this instance, a company would have regular routine consultations with specified users in order to identify new products or to improve existing ones, all with a view to gaining competitive advantage. This collaborative approach ensures that the product is researched and developed by both manufacturer and user and the need/suitability of the product for use established at an early stage, all factors contributing significantly to the chances of market success. The same process does not appear to occur to the same extent in the case of the manufacturers of environmental technology products and processes.

Table 3.1. Examples of the range of environmental products available.

Chemicals	Water treatment chemicals, environmentally preferable solvents, toxic chemical substitutes, biodegradable pesticides, biodegradable detergents
Paper and packaging	Reusable packaging, single material packaging to facilitate end-of-life recycling, biodegradable packaging
Construction products	Hardwood and uPVC substitutes, insulation products based on recycled paper, low solvent paints, cement based on blast furnace slag
Domestic use products	Domestic waste composting units, water saving devices, sound or heat insulation
Commercial/industrial use products	Oil skimmers and booms, waste processing/handling equipment, water and waste-water treatment equipment
Electronics/instrumentation	Environmental sensors, data recorders, process efficiency controllers/enhancers
Software	Geographical Information Systems, environmental data manipulators, monitoring and pollutant dispersion modelling packages

3.2 Market for Environmental Products

Numerous figures as to the value or size of the market for the various environmental products and processes exist in the wider literature. However, upon investigation these figures were found to vary wildly depending on the source and means of measurement. There appears to be no consistent approach as to how the reported values are assigned and, if included at all, tend not to be defined or elaborated in any useful way. Some, for example, appear to include the knock-on commercial value to the economy through downstream effect. An example is renewable energies in Germany with a claimed employment level of 150,000 and sales of some €11.6 billion for 2004 alone (Vince, 2006). Others refer to market size but give no indication of the likely level of market penetration. (These can be based on simplistic analysis such as that for PV technology where the number of households suitable for adopting the technology could theoretically be regarded as the potential market size whereas in reality only a fraction of those would translate to an actual purchase/installation.)

Reliable 'hard' data on the market for environmental technologies are available through specialist market analyst companies. This information is only available on a direct fee basis or to licensed users. As an EI client company (Internationally Traded Services – Consultancy), CIRCA was given access to these databases. The most relevant database in the context of this study is that of Frost & Sullivan. This company has 26 offices worldwide and more than 1,500 industry consultants, market analysts, technology analysts and economists. As such, it is a world leader in growth consulting and the integrated areas of technology research, market research, customer research, competitive intelligence and corporate strategy. It has an extensive database on the nature and value of the environmental products market in the major trading regions of the world.

Tables 3.2–3.5 provide a summary of some of the major environmental product sectors and market regions covered (all values are in US dollars). Researchers and manufacturers requiring a more detailed analysis of market trends, etc., for specific products should consult the Frost & Sullivan database directly (http://www.frost.com).

3.2.1 Market size and employment for environmental products and services

In September 2006, a major study was undertaken by Ernst & Young for the EU (EC, DG Environment, 2006) The report includes a detailed examination of what it calls the 'eco-industry market' in terms of employment,

Table 3.2. Markets for environmental products – United States of America.

Market size and trends	The US commercial water treatment sector is regarded as one of the most dynamic of the international environmental technology markets. The US market in 2005 was estimated at $770 million with an annual growth rate of 4.4%.
Market characteristics	• High rates of product substitution with newer technologies replacing older more traditional ones. • Market scepticism of newer technologies slowing transition rate to new technologies. Also competing technologies confusing users. To be successful, the technologies must be both reliable and easy to use. • Highly competitive. Increasing competition putting downward pressure on prices and margins.

Table 3.3. Markets for environmental products – SE Asia (Australasia/Philippines/Singapore/Malaysia/Korea).

Solid waste recycling/recovery	Market for electronic, industrial, domestic and commercial waste recycling/recovery.
Market size and trends	The SE Asian market in 2005 was estimated at $155 million and an annual growth rate of 7.7% overall but the market for electronic waste is regarded as having the highest potential growth, achieving $300 million by 2012.
Market characteristics	Market is largely driven by: • Rising virgin raw materials costs. • Consumer demand for 'greener' goods. • Expanding electronics industry in the region requiring increased recycling/recovery options.

Table 3.4. Markets for environmental products – SE Asia (excluding China).

End-of-pipe industrial air pollution control equipment (APCE) – fabric filters/electrostatic precipitators/wet scrubbers.	
Market size and trends	The current APCE market is estimated at $109 million with an annual growth rate of 11%.
Market characteristics	• End-user resistance to spending significant sums of money on APCE. Low technology retrofits often preferred. • Growing market for spare parts. • Overall technology trend is towards sophisticated fabric filters including catalyst-coated filters and away from electrostatic precipitation and wet scrubbers.

Table 3.5. Markets for environmental products – European Union.

(i) Sludge-related technologies	
Market size and trends	Sludge treatment equipment is estimated at $1.8 billion for 2003 with a growth rate of 6.6% until 2012. Market for novel solutions is regarded as embryonic at a little over 7% of market revenue but that component is expected to show up to 10% annual growth.
Market characteristics	• Expected to show continued growth in response to the ongoing implementation of the Urban Waste Water Directive. • More developed sludge market now directing resources to advanced technologies in the area of dewatering and drying.
(ii) Water quality monitoring instruments (including pH, BOD, N, P and multi-parameter systems)	
Market size and trends	Market is estimated at $420 million in 2005 (40,000 waste-water treatment systems to be built or renovated in the EU in 2005).
Market characteristics	• The EU Water Framework Directive, the EU Urban Waste Water Directive and the Nitrates Directive are major drivers. The market requires equipment that can operate reliably for long periods without the need for intervention. • Increased emphasis on software elements.

Note: Where manufacturers wish to export to the European Union, they must meet the requirements of the RoHS Directive (“the restriction of the use of certain hazardous substances in electrical and electronic equipment”) which bans the placing on the EU market of new electrical and electronic equipment containing more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants. Exporters to the EU must also comply with the WEEE Directive. This Directive ensures that such equipment is recycled/recovered. Both of these Directives strongly influence the ‘Design for the Environment’ aspect of the research and development of electronic, electrical equipment. (In the EU alone, in 1998, some 6 million t of WEEE arose and this is set to double by 2008.)

markets, value and growth trends for a wide range of products and services. The eco-industry covers the major product and services activities such as water treatment, waste management and air pollution control. However, the report largely treats these as both products and services combined and consequently does not give much direct information on the market for environmental product categories. It is environmental products/processes rather than services that are of relevance in the context of this commercialisation study. Nonetheless, researchers of a particular environmental technology could usefully consult this report to get an overview of the level of commercial activity in the particular product/process field they are researching.

The key points in the Ernst & Young study are:

- The European market for environmental goods and services is worth €227 billion, equivalent to 2.2% of the EU's GDP.
- The EU's environment industries represent around 3.4 million jobs.
- Traditional activities such as waste management continue to account for the vast majority of expenditure on resource and pollution management.
- More recent markets such as renewable energy and eco-construction are growing fast but remain

fragmented, except for the wind power sector, which is being taken over by global energy firms.

- Over 90% of all expenditure was made in the old EU15, where the market grew by 7% between 1999 and 2004. The largest national markets are France and Germany, which together account for nearly half of total EU spending.
- The main near-term driver of growth in the EU eco-industry will be environmental legislation. A second key driver will be investments made in new eastern European Member States to comply with existing laws.
- Strong demand is expected in areas such as soil remediation and cleaner technologies for waste incinerators.

4 Position in Ireland and Abroad on Commercialising IP

4.1. Historical Background

Summaries and recommendations of the documents indicating the historical background to the commercialisation of IP in Ireland are given below. While this relates to IP in general, the issues and findings apply equally to IP arising from environmental R&D.

In **2000**, the Office of Science, Technology and Innovation (OSTI) commissioned CIRCA to carry out a study on *The Exploitation of Intellectual Property Rights (IPR) Arising from Publicly Funded Research* (CIRCA, 2000). The key findings of the report were:

- There were inconsistent policies on the ownership of IPR, exploitation and reward for inventors.
- Patent production in Ireland is cost-effective compared to the US: the average cost per patent in Ireland was IR£2 million (€2,539,476) compared to $3–4.5 million in the US.
- Irish state investment in research is both too small and too dispersed to achieve critical mass and produce a portfolio of patents in any one business area.
- Patent revenues in the long term are unlikely to exceed 3% return on investment, but the state receives other returns in the form of increased turnover, increased VAT and income taxes, development of skilled research teams, output of skilled researchers, increased research grants from the private sector and spin-off companies.
- Patent revenues are slow to build up, especially in the health and life sciences, where typically 14 years elapse between first patent filing and first product sales.
- No targets have been set for the numbers of patents produced. All those interviewed said that that it would be inappropriate and impractical to attempt to do so. It is better to encourage and stimulate the production of IP.
- Barriers and constraints noted in the conclusions in this study agreed with those in the 2001 ICSTI/Forfás study on *The Commercialisation of Non-commissioned Research in Ireland.*

The CIRCA report made the following recommendations:

- Continuing increasing investment is required to build up patent portfolios in several business areas.
- Goals should be set in terms of strategic areas for concentration.
- Studies should be undertaken to better understand the operation of IP in state organisations.
- Uniform IPR policies are required for all public funding, including ownership, exploitation and rewards for inventors.
- Funding is required for proof-of-concept development.
- At the operational and management levels, there are needs for standard contracts, best-practice laboratory operation, education for researchers on IP, specific support for Institutes of Technology and the development of indicators for IP production.

The ICSTI published a statement on *Commercialisation of Publicly Funded Research* in **2001,** recognising the importance of technology transfer (TT) from the HEI to the private sector. An issue was underfunding by government of such transfer. The ICSTI also recognised that only a proportion of R&D is suitable for commercialisation and that the policy environment must be favourable. In 2001, this policy environment was not seen as favourable to commercialisation. In particular, the then massive increases in public funding for R&D were not seen to be matched by actions by all the stakeholders, statutory and HEI, in support of commercialisation.

Recommendations of the report included:

- Government departments and their agencies should make a clear statement of intent, establish objectives, set adequate procedures in place and commit sufficient resources.

- Funding agencies should encourage commercialisation of R&D that they sponsor and provide funding for the initial stages of commercialisation.

- The HEI and research organisations should see commercialisation of R&D as an essential mission, involving encouragement of researchers, establishing policies and allocating sufficient resources. Provision of incentives and removal of unnecessary barriers should be part of a commercial approach to utilising R&D results.

- Much increased resources should be made available to the HEI industrial liaison officers.

- Proof-of-concept funding should be provided to the HEI, research organisations and industry.

- An adequate source of first-stage venture capital should be provided. Seed venture capital is needed to progress beyond the proof-of-concept stage, especially for projects with long lead times, in which capital is at risk for longer periods. Special funds should be established for such projects.

- Training should be provided for all researchers in commercialisation activities. All public bodies involved in R&D should support and encourage this training.

The ICSTI produced a statement in **2003** on *Utilising IP for Competitive Advantage*, which highlighted several interesting points, not all previously accepted by government departments. These included the view that the commercialisation of IP by public bodies should not be a primary objective of state funding for research, as this could adversely affect the quality of research and the formation of human capital through education and training. Nonetheless, the need was recognised for greater coherence and co-ordination of commercialisation activity and for adequate supports.

The statement also echoed international experience that commercialisation of research does not directly yield high returns to the public purse but does yield other returns. In fact, royalties from patent licensing are often small and it is often more realistic to allow free use of IP.

Unlike some other countries, e.g. the USA, Ireland had at that time no consistent national system for managing IP arising from publicly funded research. Public bodies had a diverse range of policies on all aspects of commercialising IP. The ICSTI concluded that many important factors have to be balanced in developing a system for managing IP. These include:

- Maximising national socio–economic benefits.

- Balancing the rights of researchers to carry out research freely and to use and disseminate the results against the right of the taxpayer to see a return on funds.

- Enabling industry to gain access to research results in a timely manner and with a return to the research sector.

- Ensuring that IP can be used for further research.

- Protecting the rights of employees and employers.

4.2 Codes of Practice for IP

In **2004**, the ICSTI published a *National Code of Practice for Managing Intellectual Property from Publicly Funded Research*. This code was not to be a rigid set of rules but rather a series of guidelines and a framework for commercialisation of public investment in R&D, to be revised from time to time. It was not intended to provide a comprehensive account of the legal rights or obligations of research organisations, researchers or other interested parties. The code emphasises that it is the responsibility of the research organisation to commercialise the results of R&D, to ensure that adequate resources are available for this purpose and that this principle should be part of their strategic planning. The ICSTI paper saw protection of IPR as merely a step in the commercialisation process.

The code was structured under three separate parts:

1. Principles for the management of IP from publicly funded research.

2. The national code of practice for the management of IP.

3. Implementation of this code.

In **2005**, the Advisory Council for Science, Technology and Innovation (ACSTI) published a *National Code of Practice for Managing and Commercialising Intellectual Property from Public–Private Collaborative Research*. This code complements the ICSTI publication referred to above (ICSTI, 2004) and together these two codes form an integral part of the commercialisation infrastructure in Ireland. The key objectives of this code of practice are to foster collaborative research between enterprise and academia in Ireland and the commercialisation of research output.

The code is presented in two parts. It provides a set of principles and a consistent starting point for negotiation that the partners should adopt in establishing agreements including a flexible approach to the issues of ownership and rights of exploitation of IP.

Part 1: Principles for the management and commercialisation of IP from public–private collaborative research. These cover:

- IP strategy and roles of partners
- IP management
- Ownership
- Commercialisation
- Incentives and benefits
- Conflicts of interest
- Relationship management and conflict resolution
- Monitoring and evaluation

Part 2: The code itself, which covers the practical implementation of the above points of principle.

The Commercialisation Steering Group, comprising representatives from EI, Forfás, the Health Research Board (HRB), the Higher Education Authority (HEA), the IDA, the Irish Research Council for Science, Engineering and Technology (IRCSET) and Science Foundation Ireland (SFI), published a set of guidelines for *Funding Agency Requirements and Guidelines for Managing Research-Generated Intellectual Property* in **2006**. Some funding agencies, notably the EPA, the MI and the Irish Research Council for the Humanities and Social Sciences (IRCHSS) were not represented in this group. The guidelines present requirements of the funding agencies for managing commercially useful IP generated by funding recipients, with or without private-sector funding.

The requirements reflect policies established by the ICSTI in its two earlier codes and conform to Irish and EU laws. The Group had a number of objectives:

- To stimulate economic and regional development at home and in the EU by providing access to research in Irish research performing organisations (RPOs).
- To advance Irish RPOs as partners of choice for collaborative research with the private sector.
- To promote government, business and industry investment in RPO research.
- To build the intellectual foundations of Irish RPOs.
- To establish a framework to facilitate TT between RPOs.
- To facilitate access to RPOs by providing guidelines and information about RPO commercialisation practices.

The abstracts above, covering a period of 6 years that saw unprecedented state funding for research, show a rapid realisation of the true role of research and of the potential for commercialising some of the results for socio–economic benefit. This was a new departure for Ireland, largely due to the paucity of public research funding before 2000. The papers and reports summarised above variously sought to dispel misunderstandings about the commercialisation process and the potential of IP to contribute directly to the public purse. It is fair to say that policy makers recognise that returns on investment come more in the enhanced quality of research and teaching and learning and in the provision of trained manpower, vital to any knowledge-based economy. Financial returns come in the form of increased personal, corporate and value-added taxes.

4.3 Capacity for Commercialisation

In 2005, Forfás published a note entitled *From Research to the Marketplace*, describing patent registration and TT in Ireland. This was based on the data and analysis gathered in CIRCA's earlier reports provided to Forfás by CIRCA in 2003, which were based on extensive desk research, field work and data analysis. The purpose of this report was to examine the ways in which knowledge is commercialised in Ireland and to identify ways in which these processes could be enhanced. Having described the knowledge generators, intermediaries and users in Ireland, the Forfás report provides statistics on patent registration in Ireland. This is one, partial, measure of knowledge creation and commercialisation in Ireland as not all patents will be successfully exploited and some ideas can have a significant impact whether patented or not.

Ireland's actual patenting activity is low by European and other comparators. The number of European Patent Office applications in 2002 was 311 or 80 per million inhabitants. This is below the EU average of 140 per million inhabitants. This is due in part to the relatively low level of R&D carried out by multinational enterprises (MNEs) in Ireland. The number of patents granted in Finland, a country with a comparable population, is about eight times higher than that in Ireland. The increases are predominantly in newer high-tech sectors, not in traditional sectors.

It is also to be noted that the numbers of patents originating from publicly funded research is very low. This is due in part at least to the fact that it is directed at public-good research and as such is disseminated widely and freely. Several other reasons for the low level of such patenting are listed in the report, such as the lack of funding for commercialisation, low levels of awareness of the value of IP, lack of staff with expertise in IP management and little commitment in HEIs to producing patents. Thus, even if new knowledge is forthcoming, Ireland's capacity to commercialise it is limited.

CIRCA carried out a study for InterTrade Ireland in 2002 on the commercialisation staff and skills in major R&D performing institutions. The purpose of this baseline study was to more precisely define the current status of commercialisation staff, skills, budget and other supports. It revealed a large variation in approaches to commercialisation across the HEIs. In general, larger institutions with more R&D activity also have more commercialisation activity and better developed infrastructure for this purpose. Many institutions are reviewing and changing their policies and approaches.

In 2002, the resources dedicated to commercialisation were limited, reflecting a lack of interest. Thanks to the increased funding since then for research, this situation has improved, though the availability of trained staff is still a limitation to commercialisation.

4.4 IP Experience in Other Countries

One of the most recent set of guidelines on ownership, protection, publication, dissemination and use and access rights to background and foreground information and exploitation of IP is contained in the rules for participation in Framework Programme 7 (FP7) [COM (2005) 705 final]. Changes are outlined on page 5. The objectives were to keep as much continuity as possible with Framework Programme 6 (FP6), with only minor fine-tuning. Certain definitions were changed, giving participants more flexibility as their project progresses. Additional or different provisions are included for specific actions with special requirements (e.g. for frontier research actions, security research or research for the benefit of specific groups).

In the United States, academic research had made a major contribution to national defence during the Second World War. It was not until 1945 that the potential contribution of basic research to the national economy began to be recognised, firstly in a memo by Dr. Vannevar Bush to the President. This led to much increased funding and the establishment of the National Institutes of Health, the National Science Foundation (in 1950 with a budget of $15 million) and other agencies. Patenting policy during the 1960s and 1970s was that IPR arising from publicly funded research was vested in the government, who granted non-exclusive licenses to any who wished to exploit the results. Not surprisingly, few patents were taken up on this non-exclusive basis. What is available to everyone is of no interest to anyone.

Following a lot of discussion and refinement, the Bayh–Dole Act was passed by Congress in 1981. The amount of associated legislation and related bureaucracy should not be underestimated. The major change was that ownership of IPR could now be vested in colleges and SMEs, who now had certainty of title and could build on research to gain funding from other agencies. They were also free to grant exclusive licenses to industry. Thus the US government opted for indirect returns on investment. As a consequence, colleges began to be much more active in TT and to recruit and support appropriate staff. In 1979, the Association of University Technology Managers had 113 members: this rose to 2,178 in 1999. In addition, the Bayh–Dole Act encouraged university–industry collaboration and reconciled the interests of academia, funding agencies and industry. It has served as a model for other countries.

Worldwide, most RPOs now have an Office of Technology Transfer (OTT) or its equivalent that collaborates with inventors in the RPO in locating potential customers for IP. The better developed OTTs actively cultivate their clientele through visits and seminars. Examples outside

Ireland include Temple University, University of Tennessee (USA), Tel Aviv University (Israel) and CUTEC of Cambridge University, which is a joint venture with Massachusetts Institute of Technology.

It is not always best for an RPO to undertake the commercialisation of its IPR. This is an expensive and specialised process. There are private-sector companies that will take a relatively immature discovery from an RPO and progress it to full commercialisation with a producer. Examples are Kruger in Denmark, Alper Associates in California and Hokkaido Venture Capital in Japan.

5 Commercialisation Experience in Other Countries

In order to gain an understanding of the opportunities that may exist for the commercialisation of Ireland's environmental R&D, it was considered useful to examine the experience of other countries.

The first choice for comparison with Ireland was Denmark. Denmark is in many respects similar to Ireland insofar as its general economy, population size and area are of a comparable scale and, by virtue of being a member of the EU, it is subject to the same regulatory environmental drivers. While with EI, D. Kelly (now of CIRCA) established that agency's ESP Programme. In establishing that initiative, a number of countries were investigated at that time to determine what mechanisms for commercialisation might exist that could be applicable or adapted for use in Ireland. Of the countries investigated, Denmark was identified as a lead example in regard to commercialisation effort. Also, the European Innovation Scoreboard for 2005 shows that the Nordic countries, Germany and Switzerland are ahead of the rest of Europe in terms of innovation.

5.1 Denmark

J. Codd of CIRCA was based in Denmark over the period of this current study and this provided the opportunity to gain access to the key players in that country. While no central record was available on the extent to which environmental research and commercialisation has been successfully carried out, some useful insights into and information on the environmental research and commercialisation processes were established.

The Danish investigations were primarily based on a mix of:

- A questionnaire prepared and circulated to all main research organisations likely to have an interest in environmental technologies. This questionnaire was also placed online on the website of the Danish National Network for Technology Transfer.
- Consultations with selected experts mainly by face-to-face meetings, with follow up e-mail and phone calls.
- A review of relevant documents suggested by the contributing experts.

In all, some 15 experts were consulted. These were based in the following agencies/organisations:

- European Environment Agency, Copenhagen
- The Danish EPA, Industry Division, Copenhagen
- The Danish National Environmental Research Unit (NERI), Rosskilde
- The Danish Technical University, Lyngby (Departments of Mechanical Engineering, Technology Transfer, Patents and Commercialising)
- The Institute for Product Development (IPU), based at the Danish Technical University, Lyngby
- Energy Consulting Network, Vanløse
- The Confederation of Danish Industries, Copenhagen.

A wide diversity of views, sometimes conflicting, were expressed as to how best to promote the commercialisation of environmental research. These views have been assessed and summarised by CIRCA in an attempt to establish the key lessons from that country for commercialisation of environmental research. The key lessons were as follows:

- Encourage networking of all actors in the process from researchers to end-users.
- Encourage low-tech incremental developments rather than looking for high-tech expensive solutions.
- Involve end-users from an early stage in the process by bringing them in on the development process to test and contribute to further improvement of the research outcomes. (This will need to be encouraged by the use of financial incentives such as a contribution towards the cost of the equipment required which makes it economically attractive for them to participate in the development.)
- Ensure that projects are not stand-alone by encouraging networking and co-operation between projects and avoiding duplication of topics.

- Consider allocation of resources to supporting environmental research by providing test facilities on a large scale, through public–private partnership arrangements, to facilitate the validation of research results and thus make a positive contribution to fast and effective transfer of new technology.

Many of these Danish findings are consistent with the views obtained from the focus group discussions in Ireland (see Chapter 6) and with those encountered in the course of preparing this report generally. In particular, the need for significant up-scaling of pilot plant to bridge the gap between laboratory scale and operational scale is noted, as is the necessity to involve the end-user of the technology in the research and development from the outset.

A particular feature of the commercialisation process that was noted in Denmark is the role played by large consulting companies such as Cowi, Ramboll, Kruger, Carl Bro and Hedeselskabet. These companies play a key role in the TT process in environmental technologies by acting as brokers. They operate mainly with contracts where they sell knowledge.

5.1.1 Wind energy

Wind energy supplies about 3% of Europe's electricity, a figure that the European Wind Energy Association (EWEA) hopes will rise to 23% by 2030. The country closest to achieving this goal is Denmark, which already gets some 20% of its electricity from wind power, and is now acknowledged as the global leader in offshore wind power technology. This lead position has been based on wind turbine technology developed in Denmark rather than imported. This success was achieved in direct competition with a major wind turbine technology development effort being undertaken in the US at the time. The Danish views for the reasons for this success are worth noting.

The cash injection in the whole process of developing the Danish wind turbine industry was very modest. In total, over a 12-year period from 1978 to 1990 some €15 million in grants were provided. The test centre for wind turbines was a central part of this process and was funded with €1.3 million in total over a 5-year period. Today this centre is considered to be the best wind turbine R&D centre in the world. The financial support came, by and large, as ‘seed money’ from a product development scheme for SMEs operated by the Ministry of Industry since the 1960s. This scheme granted small amounts (some €30,000–40,000) towards the cost of developing specific improvements to existing technologies. Also, at the user end there was a 30% subsidy granted against the cost of purchasing a wind turbine approved by the test centre, and this encouraged early use, test and further improvement in design of the latest developments.

Parallels to this approach could potentially exist in Ireland in that subsidies in the energy area include grants for domestic-use solar collectors and wood pellet burners which, if additionally supported at the technology R&D stage, could provide the necessary synergy between supports for promoting further innovation of these technologies.

A number of evaluations of the reasons for the Danish success over its US rival in wind technology have been carried out. In summary, the important difference in the approaches was that the US expected their engineers to find the answers with technology breakthrough while the Danish approach was more one of involving all the actors, from the researchers to the end-users, together in a process that explored and exploited simple improvements over time. It is considered also that one of the keys to this success was that the end-users were part of the process of finding the solutions and as a result of these inputs were committed to the solutions.

5.1.2 Other initiatives

Denmark has also pursued a cleaner production programme that parallels that operated by the Irish EPA. Under the Danish scheme grants totalling €80 million over a 6-year period were provided.

Under a more recent initiative (June 2006) the Danish Department of the Environment has launched a programme through the Nordic Innovation Centre called Clean, Clever & Competitive – commercialization of Nordic know-how. The aim is to make environmental technology a new focus area to be supported by €1.2 million in grants. Industry and industry organisations, researchers and research institutes, authorities and others in the Nordic and Baltic countries have been invited to submit project proposals. Funding will be confined to four to six projects with a focus on innovation and commercialisation of Nordic integrated environmental technology solutions.

In addition to Denmark, other countries were also investigated (through web-based research in this instance). These included Australia, Germany, the USA, Canada and the United Kingdom. Of these, the UK (e.g. University of Nottingham), the USA (e.g. New York State Department of Economic Development) and Canada (e.g. Industry Canada) were found to promote commercialisation of R&D through the targeting of industry in much the same manner as either EI's ESP Programme and/or the EPA's CGPP. Consequently, the findings in relation to some of these countries are not elaborated on further. Australia and Germany however were considered to have some characteristics of note and are reported on below. Also, for completeness, a brief summary of the US EPA Small Business Innovation Research (SBIR) Program is provided.

5.2 Australia

CSIRO, the Commonwealth Scientific and Industrial Research Organisation, is Australia's national science agency and one of the largest research agencies in the world (its R&D budget for 2003–2004 was AUS $569. Its research is dispersed over some 57 locations and spans seven research sectors, namely:

1. Agribusiness
2. Energy and Transport
3. Health
4. Information, Communication and Services
5. Manufacturing
6. Mineral Resources
7. Environment and Natural Resources

Useful details of the organisation's performance in the area of commercialisation of R&D can be found in the *CSIRO Research Commercialisation Report for 2003–04* (CSIRO, 2005). While not specific to CSIRO's Environment and Natural Resources Division, it does provide overall data on total expenditure on R&D, number of patents, licenses or similar IP protection measures adopted.

A key indicator of patent activity is the trend in the number of Patent Cooperation Treaty (PCT) filings in recent years provided in the report. These are presented in Table 5.1.

Income from LOAs for the period 2003–2004 was AUS $23 million or 4% of the R&D budget. During that period some AUS $5.5 million was expended on IP protection (reduced by about AUS $1.5 million when reimbursements by licensees and assignees is taken into account).

The four largest active LOA categories (June 2004) were based on:

1. Environmental sciences (23%)
2. Maths, information and communications (22%)
3. Biological sciences (15%)
4. Engineering sciences (15%).

For the period 2001 to 2004, the number of LOAs per year relating to purely environmental science was: 91 (2001–2002), 133 (2002–2003) and 135 (2003–2004).

The CSIRO report provides a sample of the new products and processes released in 2003–2004 and now used in the marketplace. Of the 22 examples provided in the

Table 5.1. CSIRO licenses, options and assignments (LOAs) from 2000 to 2004.

	2000–2001	2001–2002	2002–2003	2003–2004
Executed with CSIRO acquiring equity	3	4	0	3
Exclusive	41	20	14	21
Non-exclusive	127	138	174	125
To CSIRO start-ups	18	4	0	5
To small companies	28	30	58	18
To medium companies		26	52	24
To large companies	71	98	78	99
All active LOAs as at 30 June each year	**394**	**535**	**577**	**594**

report, seven could be considered as environmental. These related to:

- Remote sensing of volcanic ash and sulphur dioxide
- Air quality modelling
- Substitute for ozone-depleting fumigants
- Less toxic wood preservatives
- Enzyme bioremediation technology for pesticide residue clean-up
- Naturally sourced pyrethrins (insecticides)
- Software (planning/management) for water utilities.

It is clear from the report that Australia is achieving some degree of success in commercialising its R&D output including environmental R&D. This has arisen as a consequence of the increasing emphasis within the organisation in recent years on the commercialisation of its research, an objective that is now supported by almost 200 specialist staff.

5.3 Germany

The reduction of emissions of greenhouse gases is an important goal of environmental policies in Germany and the Federal Government formulated a target of doubling the share of renewable energies in gross energy consumption from 2000 until 2010. The development of PV technologies and their installation is expected to contribute to this target. Currently, installed PV systems account for 0.8% share of the renewable power generated.

Both the R&D for PV technologies and their installation across Germany are actively supported by the Federal Government, the Federal States, local authorities and utilities. This initiative is part of the International Energy Agency (IEA) Photovoltaic Power System (PVPS) Programme of which Germany is an active member (IEA, 2005).

As noted elsewhere in this report environmental- and energy-related R&D can have common objectives, as in this instance, where the reduction of greenhouse gases is the key objective. An important objective also is to become an internationally recognised Centre of Excellence for PV technology with a view to placing Germany in a strong position to develop and exploit this technology worldwide.

From January 1999 until the end of 2003, the so-called 100,000 Rooftops Solar Electricity Programme provided soft loans for the installation of grid-connected PV systems. Designed to provide 300 MW, approximately 65,700 systems with a total capacity of 345 MW was achieved by the end of 2003.

R&D support was significant and, in 2004, federal support for R&D projects on PV amounted to almost €25 million shared by 121 projects in total. This funding was provided for the creation and support of cluster projects. Cluster projects start from a common technology problem formulated by two or more PV-related companies and these agree to solve the selected problem together with research groups and to share the results among each other. The transformation of the research findings into products will take place in individual processes of the companies after the cluster project is terminated.

The German PV industry and the German market experienced a period of strong growth over recent years. In 2004, the German market achieved the same level as the Japanese market, which was the world’s largest during previous years. Today, the range of companies dealing with PV is expanding along the entire value chain and German equipment and production companies are now among the most experienced worldwide and are expanding into new markets, most notably south-east Asia including China.

In conclusion, German PV-related R&D is achieving notable success in being translated into industrial output and job creation as an increasing number of home-based companies enter the business. As highly focused R&D output continues to emerge the industry is set to further expand globally in an increasingly commercially favourable market that is being created by significant environmental- and energy-related pressures.

5.4 USA

The US EPA operates a programme of support for small companies seeking to commercialise novel, and strategically useful, environmental R&D. This is the SBIR Program which is also operated by other federal agencies in other sectors. An SBIR small business must have no more than 500 employees, be independently owned and operated, be at least 51% owned by US citizens and have its principal place of business in the United States, and not have market dominance in the field of proposed research. A significant complexity of the programme is that each state may offer differing levels and mechanisms of support (albeit co-ordinated as far as possible by the US EPA). Information on the scheme is available on the http://www.epa.gov/ncer/sbir website, which outlines the various programmes and organisations (with reference to each state) that offer technical and financial assistance, as well as information and other resources, to small businesses and entrepreneurs. The following text from the guide document provides an overview of the programme.

"*The SBIR Program solicits proposals on cutting-edge research on advanced concepts that address EPA priority needs. The goal is to promote technology innovation and commercialisation. The Program is intended to spawn commercial ventures that improve the environment and quality of life, create jobs, increase productivity and economic growth, and enhance the international competitiveness of the U.S. technology industry.*

Federal agencies such as the EPA designate R&D topics and make SBIR awards based on small business qualification, degree of innovation, technical merit, and future market potential. Successful applicants receive awards or grants within a three-phase programme:

***Phase I** is the start-up phase. This is intended to determine the technical feasibility and quality of performance of the proposed innovation. Awards of up to $100,000 for approximately 6 months are awarded to explore the technical merit or feasibility of an idea or technology.*

***Phase II** awards are based on the technical merit and commercial potential of the innovation which arise from the results of Phase I. Only Phase I award winners are considered for Phase II. During Phase II, R&D work is undertaken and the developer further evaluates commercialisation potential. Phase II awards may be up to $750,000, for up to 2 years.*

*In **Phase III**, the Phase II innovation moves from the laboratory into the marketplace. No SBIR funds support this phase. The small business must find funding in the private sector or other non-SBIR federal agency funding. Local units of government have begun to provide "Phase 0" support to encourage and support locally relevant SBIR proposals.*"

6 Irish Attitudes to Commercialisation

In seeking to understand the attitudes of researchers towards the commercialisation of research findings, CIRCA sought to convene two focus groups with participants drawn from the research community.

Focus groups are used to understand the 'why' of issues. They are a highly developed research tool developed by psychologists working mainly in the areas of market research and political polling over the past four/five decades. Participants are carefully selected as representative of a specific sector or age group. At the outset, an outline list of the topics to be researched is prepared that includes numbers of open or semi-structured prompts/questions to encourage and open up discussion. A skilled moderator facilitates these discussions, which are recorded. Great care is taken to manage the process and the group dynamics, as well as content. In focus groups, participants are encouraged to share their views, feelings and perceptions about the issues under review. Participants are also urged to explore issues beyond normal conventions or logic. With careful selection and management of the process and subsequent analysis, focus groups have a very good record regarding the reliability and validity of their findings.

It was CIRCA's intention to have one focus group drawn from researchers located in the Sligo/Galway/Athlone region and a second, separate group, drawn from the Dublin/Eastern region. This proved extremely difficult and on two occasions the agreed time and venue had to be called off due to last-minute cancellations by participants. Ultimately it proved possible to convene only one focus group (NUIG and AIT) within an acceptable time frame and this is reported on below. However, as part of an earlier study for Forfás (Forfás, 2005), CIRCA convened a focus group of researchers that addressed many of the same issues that arise in this instance. That group was drawn from TCD, UCC, UCD, DCU and DIT and, where relevant, the summary findings of that session are also presented by way of supplementing the findings of the NUIG/AIT group.

The focus group was convened in Galway and was attended by two researchers from the NUIG and one from the AIT. To facilitate relevant discussion, a set of predetermined topics in questionnaire format were used. Participants were encouraged to explore the wider issues of commercialisation and not to confine their views to their own specific field of research. The findings were as follows.

6.1 Commercialisation Opportunities

Participants were asked to comment on what were the main areas of environmental science they considered to have the most commercial potential and to expand their comments beyond their own specific field of research.

Participants considered that technologies aimed at water quality protection and waste and resource management were likely to be the most promising. This was closely followed by environmental sensor technologies (*in situ* or remote) that could be applied in a variety of fields such as river water quality, waste-water treatment, air quality, etc. Environmental biotechnology was also regarded as having potential particularly for such applications as biofuel yield/performance enhancement, nutrient removal, environmental remediation techniques and recovery of high-value materials from wastes.

Unsurprisingly research fields such as climate change, environmental economics and biodiversity were viewed as offering the least potential for commercialisation.

6.2 Motivation/Cultural Aspects

When asked, the researchers appear, in principle, to have no difficulty with the concept of working closely with industry. However, there is some anecdotal evidence to suggest that while many view such co-operation as acceptable, or desirable, they may regard it as applying to researchers other than themselves.

The view was also expressed that the output of research should not be viewed simplistically with patenting (and possible later commercialisation) as the primary motivation for undertaking the research.

6.3 Knowledge of Commercialisation and Support

Participants considered that they had sufficient knowledge of IP and commercialisation issues. While accepting that they had gaps in their knowledge, they considered that suitable knowledge supports were readily accessible through established networking with colleagues, in-house industrial liaison/TT officers and IP/commercialisation specialists within EI. The latter was considered to be very supportive and relevant, particularly in more recent years.

Financial reward to the researcher from commercialisation was not regarded as an expectation or an issue and it was generally recognised that, where a financial return did result, most or all would be rightly assigned to the research organisation.

6.4 Issues and Barriers

A discussion was developed around the issues and concerns/barriers that researchers considered would have to be addressed for them to explore (more fully) the commercial potential of their research. The principal issues raised were as follows.

6.4.1 Publications vs commercialisation

All were agreed that career advancement within the HE sector was highly dependent on the number and quality of publications. This presents a dilemma for researchers insofar as it means that if they divert effort into commercialisation their career advancement will likely suffer. This issue is not confined to the particular institution they are retained by and consequently also adversely impacts on the researchers' career mobility to other institutions. It was acknowledged however that this emphasis on publications is somewhat less in ITs than in universities. Publication of research findings was known to be a barrier to subsequent patenting and, in the absence of which, progression to commercialisation would be unlikely. These findings are entirely consistent with that expressed by the focus group convened for the Forfás study.

It was also recognised that the emphasis on publications has advantages for the organisation in that it provides a suitable and comparable measure of performance. Similarly, the advantage for the researcher is that the ability to generate publications is more of a certainty compared to the very high-risk area of achieving one or more commercial successes.

6.4.2 Evaluation of commercialisation potential

In the Forfás study, it was considered that assessing the true commercial potential of a research finding was a real difficulty for the researcher/research body and for which no readily accessible support exists.

The view was expressed that the correct route to exploitation was to have the 'market' working properly, i.e. where new ideas with potential are actively identified by commercial interests. In that regard, it was the strong view of one individual that we are working in the wrong direction, that is from the research findings to commercial exploitation when it should be the other way around, namely the utilisation of commercial 'miners'. (A miner was described as essentially an individual who seeks out IP to meet known commercial needs. Such an individual is seen to be more a marketeer – presumably with a technical bent – rather than a mainstream technologist.) These miners would identify specific commercial needs and then locate suitable research findings that will meet that need. To some extent, this is what appears to happen with hospital researchers/consultants where medical technology companies assign specialist individuals to establish a long-term relationship with particular researchers.

6.4.3 Gaps in progressing to commercialisation

It was considered that an important gap existed in supporting the progression of research findings to a commercial reality. The view was that while support for researching a technology could include laboratory-scale development support for the next necessary step, that of building a working prototype or large-scale pilot facility was lacking. The focus group for the Forfás study was of a similar view in that many considered that the funding agencies do not apply a sufficiently long-term approach such as would provide the necessary staying power/support through the various stages of an idea through to patenting and to commercialisation.

It was also viewed by the NUIG/AIT group that the commercialisation step required a dedicated effort on the part of the researcher and that this was not seen as mainstream to their functions or abilities as researchers. This finding is also largely consistent with that of the Forfás study, if expressed somewhat differently, in that they considered that the originators of the research would understandably tend to move on to other research projects and apply their efforts in areas more appropriate to their skills and duties.

7 Performers of R&D

Unlike almost every other EU country, Ireland does not have R&D institutes to conduct R&D and provide technical services for industry. The Irish knowledge base is conspicuously deficient in applied research institutes (Austria has 40 applied research laboratories and Denmark has 30+), and, in general, Ireland does not have the knowledge-production structures specifically designed to facilitate commercialisation of research outputs. The only significant exception is Teagasc, which serves most of the food and agriculture sector, while limited RTD services are also provided by the MI, the EPA and other agencies. In short, Ireland is highly dependent on the HEI system for RTD service provision. In many countries, the HEI system is one of several resources in which industry can access R&D expertise. In Ireland, the HEI sector is almost the only national provider of RTD services.

The HEI sector is being dramatically upgraded, and several of the major universities now aspire to becoming world-class research performers. The purpose of the current national science and technology investment is to develop a HE sector that will support economic development by creating new technologies, and by assisting existing industry through collaborative research.

In general, Irish colleges are perceived by industry as unwilling to engage in research where the IP is not owned by the college. This has significant implications for the range of RTD services that are likely to be provided by academic institutions in the future. In effect, it suggests that, where industry collaboration is sought at all, HEIs are far more likely to favour collaboration with big industry. Smaller industry, whose focus is on access to technical assistance for development of solutions, will be an increasingly less attractive partner as the scale and quality of HEI research develops.

7.1 Scale of Activity

Since 2000, state spending on R&D has dramatically increased. Our HEIs have been experiencing the difficulties often associated with rapid organisational growth. These include a shortage of competence in large-scale RTD management, and significant temporal imbalances in availability of facilities, staff and organisational systems within many institutions. The limited data available show that this increased resource has not resulted in an equivalent increase in industry collaboration. Indeed, it can be argued that the greater availability of funding for basic research has resulted in a reduction in interest in applied research, and a withdrawal from provision of small-scale technical support for industry.

On the other hand, if Irish HEIs were to target Irish industry as research partners, there is still a relatively small market on which to depend. Although both the IDA and EI are investing in the development of industry R&D performance, the cohort of companies interested in such collaboration is still small. Nevertheless, the clear view from the industry focus groups is that industry would invest more in HEI-based research if the conditions for doing so were improved.

8 Funders of R&D

There is a wide range of organisations that provide funding for R&D. The purpose of the funding is very variable and in the case of environmental R&D is essentially reflected in the description of the drivers for conducting environmental R&D (Section 2.2). Thus EI or the IDA may fund companies to achieve compliance with environmental standards, or to develop commercially viable environmental products; SEI may fund research whose primary purpose is to enhance energy supply, but that also has an environmental aspect; SFI may fund research in some element of basic biology, but that is also relevant to understanding environmental mechanisms.

The R&D field to be supported depends largely on the funding agency in question with most only providing funding in relation to that particular agency's core function, e.g. agriculture or forestry. However, many of these agencies' functions may also have an associated environmental dimension as in the case of the latter two examples.

Within the following sections data are provided on public funding for environmental research by source of funds and by sector of the economy separately. Inevitably, this leads to some double counting. Where available, data were obtained from the agencies' websites and otherwise directly. The data are not fully robust as sets from different sources may cover somewhat different periods. They should therefore be taken as indicative rather than as an audit. It should be noted also that there is increasing co-ordination and collaboration between agencies with environmental and related interests. For example, the Irish Energy Research Council (IERC), while concerned primarily with energy also includes the environment, climate change and marine resources. To avoid duplication of effort, representatives of the relevant agencies are members of the IERC.

The principal funding agencies, and their relevant R&D funding programmes are presented in the following sections. It should be noted that the nature, extent and rules of the various funding agencies will inevitably change over time. It is important therefore that where a potential area of support is identified the relevant agency should be contacted to obtain the most up-to-date funding position that applies at that time.

8.1 Environmental Protection Agency

While it is not a core function of the EPA (http://www.epa.ie) to provide support to the industrial sector the Agency does provide R&D funding to industry and others through the CGPP. The programme aims are focussed on avoiding and preventing adverse environmental impact through cleaner production rather than by means of end-of-pipe treatment. The programme has been open to a variety of sectors including chemicals, construction, food, metals, service, etc. The CGPP programme will be continued in the new EPA research (STRIVE) programme.

To date (27 February 2007), some €55 million have been allocated by the EPA under the Environmental Research, Technological Development and Innovation (ERTDI) Programme which includes the CGPP (Table 8.1).

Nationally, the EPA programme has developed co-operative funding links with other sectoral R&D agencies (COFORD, Teagasc, SEI, the MI and the EPA itself), with the NRA and with HE-based research.

Research in the area of environmental technology is viewed as the category most likely to present some prospect for commercialisation. Under the ERTDI Programme there are a number of specific areas of environmental technology that are targeted for funding; these are as follows:

- CGPP
- Advanced Technologies for Environmental Protection
- Analytical Monitoring and Forecasting
- Studies & Support to Aid National Uptake of Environmental Technologies.

8.1.1 CGPP

In common with the EI ESP Initiative, this programme targets industry and service providers with a view to encouraging companies in Ireland, particularly SMEs, to adopt a high standard of environmental performance by

Table 8.1. Summary of EPA R&D funding by environmental theme (up to 27 February 2007).

Theme	Number of projects	EPA funding (Euro)
Capability development	13	10,900,698.65
Centre of Excellence	1	133,681.37
Contributory scholarship	17	120,598.77
Cleaner Production, full project	59	3,631,061.48
Desk study	35	1,453,786.84
Doctorate	88	6,742,776.53
Fellowship	45	7,109,068.52
Large-scale study	47	11,448,430.22
Medium-sized study	55	12,217,102.83
Scholarship	27	851,320.00
Short-term research mission	22	20,762.33
Small-scale study	55	343,077.79
Approved totals	**464**	**54,972,365.33**

adapting or improving production processes and services in order to minimise negative impact on the environment. While often supported by university-based research, the primary recipients of the funding and initiators of the research are in the commercial sector.

The CGPP was launched by the EPA in 2001. Under the programme, the National Development Plan 2000–2006 has provided €3.6 million in grant aid. These projects relate to a wide range of sectors including food and drink, chemicals, engineering products, construction, surface coatings, services, etc.

The research findings from this programme will in many instances be capable of being brought to market. However, as these are essentially 'demonstration projects', with the findings normally freely available to the wider commercial community, they normally have little potential of being protected through patenting.

8.1.2 Advanced technologies for environmental protection

A number of environmental issues were identified that require innovative research and development solutions. Examples of funded research include E-diesel benefits and barriers, high-rate anaerobic digestion, nitrogen reduction, membrane technologies, etc. The primary recipient of funding in this instance is research institute based.

8.1.3 Analytical monitoring and forecasting

Examples of funded research include the development of novel wireless/web-enabled interfaced sensors for water quality monitoring, bacterial and viral counters for water- and optical/respirometry-linked sensors for water pollution detection. As in the case of advanced technologies (Section 8.1.2), the recipients are research institutes.

8.2 Enterprise Ireland

EI (http://www.enterprise-ireland.com) is responsible for the development of indigenous industry and offers the widest range of R&D supports. Part of this overall brief is to develop an RTD capability within the HE sector that will be relevant to economic development. In this connection, EI supports a range of applied R&D programmes designed to assist the creation of new technologies, and their transfer to industry.

EI is also responsible for supporting Irish involvement in international programmes of relevance to industry. This includes provision of grants for research in a range of fields, including environmental technology. EI also supports protection of IP derived from research. Funding from EI is only open to 'client companies'. These are typically indigenous Irish companies (i.e. Irish owned) with 10 or more employees and having an export focus. (There are some exceptions, e.g. some foreign-owned food and natural resources companies.)

As an agency responsible for supporting industrial development, including support through industrial research, EI can be expected to have a key role in the commercialisation of research, which, in some instances, can be classed as environmental research.

EI provide two principal support initiatives for technology-based research. These are:

1. ***The Research Technology and Innovation (RTI) Initiative*** (which represents the principal scheme) and supports Irish companies in a broad range of technology-based R&D, some of which may relate to environmental R&D; and

2. The comparatively minor ***ESP Programme*** which was specifically designed to support environmental technology-based R&D within SMEs.

An overview of these two support initiatives is provided below. A more detailed assessment of the specific environmental projects that have been supported under these schemes is provided in Section 8.2.3.

8.2.1 RTI Initiative

The RTI Initiative is managed by EI on behalf of IDA Ireland, Shannon Development and Údáras na Gaeltachta. This initiative is designed to stimulate company R&D performance through supporting commercially focused, industry-led product and process development. The initiative offers comprehensive support in terms of advice, training and grants relating to the various steps starting from initiating R&D through to commercialising the R&D findings. Applications for support in respect of environmental R&D under this initiative are considered on their relevance to industrial development/commercialisation and not on the basis of any environmental benefits they may have. In summary, the supports are as follows:

8.2.1.1 Initial information support

Up to 3 days technical consultancy support for client companies. This covers aspects such as understanding the R&D process, identifying the right strategy and project(s), developing a plan and where and how to access funding.

8.2.1.2 Training for innovation and R&D

A range of training courses in this field can be provided, including training for the management of R&D.

8.2.1.3 Tailored R&D support (significant R&D projects)

These relate to R&D projects in excess of €3 million extending over 2–3 years. For projects to be eligible, they must represent a significant 'step-up' in the development of R&D activity/capability over existing levels.

8.2.1.4 Initiatives in specific advanced technologies

This is used to assist client companies to access new technology, improve competitiveness of existing production and move into higher value areas. It facilitates access to strategic expertise in more than 30 centres within Ireland's universities and ITs.

8.2.1.5 Industrial technologies

The aim is to move Irish companies into a strong global market position through the commercialisation of innovative technologies. This is to be achieved through funding programmes supporting industry-led, industry-relevant applied research in HEIs.

8.2.1.6 Innovation Partnerships – companies and colleges working together

The Innovation Partnerships Initiative can provide financial support to encourage companies to undertake research projects with Irish universities and ITs. By using its connections with industry and universities, EI can assist in finding a suitable project partner. Under the initiative the participating HEI prepares and submits a full R&D proposal to EI for technical and commercial peer evaluation, following upon which a decision on funding support is made.

8.2.1.7 Commercialisation fund

EI supports the findings of research technology progressing to the marketplace in the areas of biotechnology, infomatics and industrial technologies (the latter includes environmental technologies). That support is provided by EI teams that will work with researchers that are interested in seeing their research put to commercial use. The team can advise on key aspects such as company formation or on seeking industry partners to which to licence the research findings. Support extends to advice on all aspects of patenting, including financial assistance with patenting costs.

8.2.1.8 Company creation

EI has an incubation programme whereby it offers space and support to entrepreneurs who want to develop their projects within the supportive structure of a HEI campus.

8.2.1.9 IP fund for higher education

This scheme provides advice on the protection and commercial development of the research findings of researchers in the HE sector. The scheme also provides financial support for the protection of that IP where EI is of the view that it has commercial potential. Financial support will only be considered where an application is made by the Industrial Liaison Office (ILO), or equivalent, of that organisation. The scheme applies to researchers in HEIs and associated teaching hospitals.

Funding is as follows:

- ***Stage 1***: Up to €7,000 to assist with the costs of preliminary patent protection.
- ***Stage 2***: Up to €20,000 to support patenting costs arising in the continuing prosecution protection of an already filed initial application or extension of patent coverage to other countries.
- ***Stage 3***: Funding to provide support for the later stages of the patenting process. The amount is determined by EI in each case but is normally not more than €50,000.

Funding is restricted to costs directly associated with the protection of the invention concerned. It will normally cover 100% of the cost.

8.2.2 ESP support initiative

The ESP initiative aims to support industry to incorporate eco-design approaches in the development of their products and services without compromising product functionality, quality, ability to manufacture or cost. The initiative was developed to respond to three of the listed drivers (see Section 2.2) for conducting environmental R&D namely: national and international regulation (e.g. producer responsibility laws – WEEE, RoHS, EoLV Directives, etc.), environmental efficiency of products and services and increasing public awareness of environmental performance among consumers.

The initiative was developed by EI and commenced in March 1999 to respond to these drivers and currently has an annual budget of €250,000. Under the ESP initiative, a package of supports to include information and advice on designing more sustainable products and services, as well as financial supports, is available. Financial support of 50% up to a maximum of €32,000 may be made available to suitable companies. To date, 50 Irish SMEs from a range of industry sectors have participated. The projects by industry sector that have participated to date are listed in Section 8.2.3 (a detailed listing is provided in Appendix 1).

8.2.3 Environmental R&D projects funded under the RTI and ESP initiatives

As described above there are two schemes operated by EI that can provide support to developing commercial environmental products or processes – the RTI and ESP initiatives.

8.2.3.1 Environmental R&D projects funded under the RTI initiative

EI has an in-house screening mechanism whereby those RTI projects considered to fall within the definition of environmental technologies are forwarded for evaluation by environmental technical specialists. Details of those environmental technologies projects that were approved for funding were made available to CIRCA. Recent examples[2] relating to a 5-year period of environmental R&D projects are:

1. Anaerobic biofilms and bioreactors for waste-water treatment
2. Horizontal flow biofilm systems for small-scale waste-water treatment
3. Soil and groundwater transport modelling (computer software)
4. Development of manufacturing technology for improved mining industry chemicals
5. Development of gas and leachate collection/reuse system for anaerobic digestion and landfill sites
6. Solubilisation of biological treatment plant sludges
7. Biological treatment of organic sludges.

These seven environmental technology projects involved an R&D fund of approximately €2 million. By contrast, available data on the overall RTI initiative approvals and funding levels for 2000–2004 show that some 667 projects were approved and attracted funding of €140.9 million for the same period. The RTI initiative is a primary vehicle for the commercialisation of R&D and it is apparent from the above data that only a very small fraction of RTI initiative projects seeking and/or obtaining funding are in the field of environmental technology. This contrasts to the industry-targeted, environmental technology focused, ESP initiative also operated by EI (see Section 8.2.3.2).

2. The period approximates to 2000–2004 depending on progression rates between application/assessment/ approval dates.

8.2.3.2 Environmental R&D projects completed under the ESP programme

The ESP projects by industry sector are listed below:

- Paper Packaging
- Building products
- Timber / Furniture
- Electronics /ICT/ Software
- Chemical
- Consumer Products
- Engineering
- Waste
- Energy

It is clear from the above listing that this initiative has been highly successful in assisting companies to significantly increase their potential to fully exploit environmental R&D output, all across a very broad range of Irish industry (a detailed listing is provided in Appendix 1). Under the ESP initiative the research output is not required to be original or novel such as would be capable of being patented. It is considered that the resultant technological up-skilling of indigenous industries and the associated competitive advantages gained are the primary benefits. A more detailed analysis of the output of the various participants, while not elaborated here and not within the scope of this study, strongly suggests that the initiative has had a disproportionate commercial impact relative to the comparatively modest resources provided. A detailed listing of participant companies is provided in Appendix 1.

The success of the initiative can be attributed to a number of key elements, principal among these are:

- Proactive targeting of potential participants
- Provision of technical support and guidance by EI environmental specialists directly linked to additional specialists within EI in the areas of technology and IP protection relevant to the applicant
- Financial support to both assist in the R&D and in providing the initial incentive and impetus for companies to participate
- The environmental technology R&D is industry driven and consequently the R&D elements subcontracted to external researchers are relevant to and tightly focused on achieving specific commercial objectives.

8.3 IDA Ireland

In simple terms, IDA Ireland (IDA) (http://www.ida.ie) supports overseas companies to locate in Ireland. One of the major purposes of the current national programme of investment in RTD is to support these overseas companies, and to provide an innovative environment that will attract further companies. The IDA is significantly involved in the process of developing an RTD environment that will support industry. IDA companies can access all of the R&D grants offered by the national agencies (although as noted earlier some IDA companies may not be SMEs). The IDA also offers direct RTD support to its companies to develop facilities and expertise.

8.4 Shannon Development and Údarás na Gaeltachta

These agencies (http://www.shannon-dev.ie and http://www.udaras.ie) also provide R&D funding to companies within their regions. In general, however, these programmes are jointly offered with EI.

8.5 Sustainable Energy Ireland

SEI (http://www.sei.ie), formerly the Irish Energy Centre, is Ireland's national energy authority. SEI's remit relates mainly to improving energy efficiency, advancing the development and competitive deployment of renewable sources of energy and combined heat and power, and reducing the environmental impact of energy production and use, particularly in respect of greenhouse gas emissions.

8.6 Health Research Board

The HRB (http://www.hrb.ie) is a state agency that promotes, funds, commissions and conducts medical, epidemiological and health services research. Its purpose is to fund research that "t*ranslates into improved diagnosis, understanding, treatment and prevention of disease and improves efficiency and effectiveness of the health services*".

The HRB mainly funds clinical and university-based research and does not directly fund industry under any grant scheme, either as applicants or as co-applicants.

While not specifically excluded, there is only limited scope for environmental research.

8.7 InterTrade Ireland

A cross-border trade and business development body (http://www.intertradeireland.com) established under the Good Friday Peace Agreement, InterTrade Ireland is involved in initiatives to develop cross-border trade and business development activities. To this end, it is engaged in providing and developing information sources on North/South trade and business development, and supporting joint marketing initiatives, joint research and development and other ventures. It has also encouraged collaborative research between firms and third-level institutions throughout Ireland. Of particular relevance are the:

- **Innova Programme** for promoting and supporting R&D co-operation between firms, North and South.
- **Fusion Programme** for supporting strategic collaborations between companies and academia, enabling knowledge and TT across the island of Ireland.

Further information on these and other initiatives can be seen on the organisation website.

8.8 Science Foundation Ireland

SFI (http://www.sfi.ie) was established to enhance the quality and extent of Irish research in two priority areas: biotechnology, and information and communication technology (ICT). SFI is essentially engaged in developing the expertise base for research. It does this by funding high-quality researchers, many of whom have been attracted from overseas, and are now located in Irish universities. SFI is also concerned to ensure transfer of the output of these research groups to industry. SFI notes that "*Encouragement of an entrepreneurial science culture is also a key feature. It helps promote Ireland as a centre for industrial biotechnology research and build academic–industrial partnerships*".

In addition to funding research and fellowships, SFI also funds the establishment of Centres of Excellence with industry links. These are called Centres for Science, Engineering and Technology (CSETS) and six have been funded to date. SFI funded one project of environmental relevance, but in the period 2005–2009. This concerned the development of advanced biofilms for anaerobic digestion of wastes with a grant of €499,000.

8.9 Marine Institute

The MI (http://www.marine.ie) operates three sub-measures under the NDP:

1. Sub-measure 1, deployment of an enhanced research vessel
2. Sub-measure 2, improvements in MI laboratories' equipment and facilities
3. Sub-measure 3, applied Industry projects for new product development in SMEs.

The MI also provides research funding under a number of programmes. Funding for some of these was authorised outside the period of this study. Eight projects (listed below) have a significant environmental research content, a portion of the outcome of which may be of commercial interest:

1. Ocean energy (2004) €1,125,000
2. Water quality monitoring (2004) €903,780
3. Influence of climate change on flora and fauna (2001) €174,365
4. Ecosystem and climate change (2005) €81,400
5. Review of marine environmental indicators (2001) €47,213
6. Prediction of ocean wave energy (2002) €66,563
7. Wave energy converters (2002) €100,000
8. Wave energy converter (2003) €59,925.

Total MI funding for the period 2001–2005 was €2,558,246.

8.10 Higher Education Authority

The HEA (http://www.hea.ie) administers a significant budget for R&D under the Programme for Research in Third-Level Institutions (PRTLI). Between 2000 and 2006 some €605 million were administered with an approximate split between capital allocations (buildings and equipment) and current (research programmes and staff) of two to one.

PRTLI funding is allocated across a broad range of disciplines and research topics including some that relate to the environment. Figures for funds provided for environment-related R&D themes over the period 2000–2004 are presented in Table 8.2.

8.11 The Irish Research Council for Science, Engineering and Technology

The IRCSET (http://www.ircset.ie) provides funding for R&D some of which relates to the environment. These projects are presented in Table 8.3. Total IRCSET funding for environmental research was €1,403,450. Of the 25 projects listed, seven (marked with an asterisk) are considered as possibly having some potential to ultimately lead to products or processes of commercial interest.

8.12 The Department of Transport

The Department of Transport (http://www.transport.ie) and others support transport-related research. While for the purposes of this study this is not considered to be environmental research, it could be considered as such when taken in the broader view. For completeness, therefore, it is included here. The various recent sources and amounts of funding were as follows.

The Department of Transport established a fund through the NDP to facilitate the growth of academic research in areas of interest to the surface transport sector. This programme was managed by the HEA. Four projects were funded over 2002–2005; these were:

1. TCD: Passenger perceptions of inter-urban passenger transport: €154,000

2. UCD: Implication for Ireland's roads of heavier trucks: €150,000

3. TCD: Public transport journey data analysis: €97,500

4. TCD: Sustainable freight distribution in an historic urban centre: €127,500.

This gives a total of €529,000 for the four projects.

As noted under the EPA above, the EPA awarded €690,677 for transport-related research. In addition, the Urban Institute of Ireland Transport Cluster earned research income of €1,699,737 over the period 2002–2005 from a variety of sources. Transport research was also carried out in DIT with research earnings of €300,000 in the period and in the UCD Mechanical Engineering Department with an income of €50,000.

The overall total for transport research is therefore €3,269,414 including EPA funding.

8.13 European Union

EU support for R&D is provided through Framework Programmes (FPs) of 5-year duration. We are currently at the end of FP6 which has a total budget of €16.27 billion, and FP7 has recently been launched. The research topics and mechanisms of participation change between successive FPs. It is important to understand that FPs are not designed to benefit individual companies or countries. The overall objectives of FPs can be summarised as:

- To develop collaboration between European researchers, and between researchers and industry (particularly SMEs). An overall objective is to develop a 'European Research Area' (ERA) in which there will be much greater interaction between Member State

Table 8.2. Funding under PRTLI: Environment and Natural Resources (2000–2004).

Institution		Capital (€)	Current(€)	Total (€)
UCD	Urban Institute (with TCD)	3,022,000	3,174,000	6,196,000
NUIM	Institute for Bioengineering & Agroecology (with DIT, IT Sligo, WIT, GMIT)	4,414,000	1,086,000	5,500,000
IT Sligo	Biosolids Research Programme (with NUIG, UCD, UL, TCD)	1,542,000	1,640,000	3,182,000
NUIG	Marine Science Research Programme (with TCD, UCC, UL)	10,421,000	8,713,000	19,134,000
NUIG	Environmental Change Institute (with TCD, UCC, UL)	4,487,000	4,997,000	9,484,000
UCC	Environmental Research Institute (with NUIG, UL, UCD, IT Tralee, Cork IT, Carlow IT, DIT)	16,791,000	10,207,000	26,998,000
IT Carlow	Research Programme in Environmental Sciences	245,000	959,000	1,204,000
Cork IT	Research Programme in Ecotoxicology & Waste Reduction (with UCC, NUIG)	1,232,000	1,206,000	2,438,000
Totals		**42,154,000**	**31,982,000**	**74,136,000**

Table 8.3. IRCSET-funded environmental projects (2002–2005).

Institution	Project theme	Funding
UCC	Postdoc: Biodiversity and ecosystem functioning	€33,000 for 2004–2005
UCD	Basic grant: Lean-burn engine diagnostics*	€56,000
Postgrads		€57,150 for each project over a period of 3 years
UL	Energy from biomass*	
	Vortices in the Earth's ocean and atmosphere	
	Biodiversity and population structures	
	Sustainable development policies	
	Dynamic model of Irish carbon sinks and flows	
	Environmental management solution for SMEs	
	Scenario planning in the Shannon Estuary	
NUIG	Models and tracer in Galway Bay	
	Biodiversity in turloughs	
	Digital perspectives of the natural Connemara landscape	
	Tourism as a conservation tool	
	Control of American mink in Ireland	
	Role of soil type and condition in transport of pathogens to groundwater	
UCC	Contribution of planting schemes to biodiversity	
	Heat shock proteins as indicators of environmental stress*	
UCD	Alternatives to anti-microbial growth promoters in animal nutrition*	
	Role of plant biostimulants in turfgrass management	
	Impact of zebra mussels on Lough Sheelin	
	Forest parameter estimation using remote sensing data*	
TCD	Spatial modelling for lake water management*	
	Combining GIS with multivariate analysis for habitat identification*	
	Partitioning total soil respiration into heterotrophic and autotrophic components	
	Ecology and native status of *Pinus sylvestris* in Ireland	

*Possible potential for commercial interest.

agencies and organisations in the administration and performance of RTD.

- To develop technologies and knowledge that is of economic benefit to the EU, or which is relevant to the socio–economic needs of the community.

FPs typically define Priority Thematic Areas of Research, of which several are of relevance to the chemical and pharmaceutical sectors. The FPs therefore fund the development of new technologies (in defined areas), a wide range of collaborative activities, including transfers of staff between EU countries, and various other activities. Thus, while the overall purpose is not to benefit individual companies, the net effect is that individual companies can benefit significantly. The benefit is both from funding over (usually) a 4-year period, and also from participation in large multinational research teams of companies and researchers. IP generated within such projects is governed by an agreement between the project partners. The R&D contract with the European Commission will only specify certain general principles to ensure that the technology is made available and commercialised.

While FP projects have major advantages for certain companies in certain sectors, there are disadvantages. Most of the projects are notoriously complex in their mechanisms of operation, and in the processes for reporting and payment. Nevertheless, many companies are regular participants in these programmes and have derived major benefits in the forms of technologies and partnering.

FP7 will run from 2007 to 2013 and has a budget of €50.5 billion. Overall responsibility for supporting the involvement of Irish organisations in FP7 is with EI (see http://www.fp7-ireland.com), which has established a specific unit for this purpose. EI has involved several sectoral and specialist agencies in the overall promotion and support process. This unit will provide information, training and various other forms of support to interested companies during the course of FP7.

A further EU programme of relevance is the Competitiveness & Innovation Programme (CIP) which was set up specifically to advance the objectives of the Lisbon Strategy. The CIP contains a wide range of measures designed to assist innovative activities in all aspects of EU society and economy. Among these are:

- **Eco-innovation**: €23 million are available for the area of eco-innovation. This aspect of the programme will not commence until 2008, and the details of its implementation are not yet clear.

- The **Intelligent Energy – Europe Programme**: €727 million are available to encourage the wider uptake of new and renewable energies, improvement of energy efficiency, and compliance with the energy regulatory framework. The programme aims at accelerating action in relation to the agreed EU strategy and targets in the field of sustainable energy, increasing the share of renewable energy and further reducing our final energy consumption.

8.14 Other Potential Funders of Environment-Related R&D

8.14.1 Teagasc

Environment-related research is carried out by Teagasc, in some cases with the collaboration of universities. These projects are captured in the EPA data set in Table 8.1.

8.14.2 Electricity Supply Board

The Electricity Supply Board (ESB), as the electricity transmitter/distributor and the biggest player in the field of energy generation, has almost never carried out research unless on a problem specific to its operations in Ireland. These generally relate to transmission and grid operation, which can present specific problems due to the small size and isolated nature of the Irish grid. Improved economy in system operation clearly has environmental benefits. Other research support is normally provided by ESB suppliers.

Research is in progress in the UCD Electrical Engineering Department. Revenues in the period under review amounted to €614,000 from public sources and as much from the private sector.

8.14.3 Bord Gáis Eireann

Bord Gáis Eireann (BGE) carries out no research that might have an environmental impact. Fleets of vehicles have been in operation for some years, but these have been used to demonstrate state-of-the-art technology in using compressed natural gas (CNG) rather than as research.

It must be remembered that there is little industry in Ireland producing equipment for electricity or gas production or transport vehicles. Consequently, there is little research carried out in these areas by the utility companies or their suppliers.

8.14.4 Private sources

Individual companies, or groups of companies, may also be prepared to fund environmental research of relevance to the solution of environmental problems they experience, or expect to experience due to impending legal changes.

In addition, charities and other benevolent foundations may also be prepared to fund research that is consistent with their objectives.

9 The Commercialisation Process

This section outlines a generalised process for commercialisation of the outputs from research, with a particular emphasis on highlighting the elements of relevance to environmental researchers.

9.1 Background to Commercialisation

Some preliminary remarks may be useful.

1. It is important to emphasise that commercial outputs are only a very small proportion of the useful outputs from environmental research. However, outputs will occasionally be of a nature that requires that private industry becomes the mechanism to ensure their widespread usage. Typically, they are technologies or products that require a manufacturing step. Examples include recyclable materials, chemicals or materials that can be used to ameliorate pollution (e.g. filters, enzymes), or equipment to measure or modify wastes (bio-digesters). While the output may be of a wide range of types, in this document these outputs will be collectively known as environmental technologies for the sake of brevity.

2. The vast majority of environmental researchers do not become involved in this area of research in pursuit of commercialisation. Their motivation is that of most researchers, which is a fascination for discovery. They usually have a high level of concern for environmental quality and conservation. Yet, commercial opportunities will inevitably arise in any form of research. The researchers involved should therefore be aware of the commercialisation procedure and be prepared to ensure that these opportunities are assessed and acted upon.

3. Ireland is unusual in that the vast majority of our publicly funded researchers are within the HEIs. The only other significant public R&D institution is Teagasc, which serves most of the food and agriculture sector, while limited supports are also provided by the MI and the EPA. In short, our research is highly concentrated in the HE system. A guide for commercialisation of research must therefore be significantly directed towards HE researchers.

In summary, the path taken by a technology from the bench to the market is long and difficult. The main reason for failure is that the technology simply does not have all of the characteristics required to be commercially viable. However, another major reason is that one or more of those involved in the research or commercialisation process may not play their appropriate role at the right time.

The pitfalls in the commercialisation process include the failure of researchers to recognise useful developments, or to observe IP protection practice, the inability (for resource or other reasons) of the ILO to properly commercialise the technology, or the inability of the recipient company to complete the commercialisation process. These pitfalls will be described in the following description of the process.

9.2 Summary of the Commercialisation Process

The commercialisation process can be simply broken down into five definable stages (1 and 2 may be in the reverse order).

1. ***Recognising the opportunity.*** Research creates novelty and some of this novelty has useful applications. However, some of these valuable opportunities are never used because the researchers involved in the research fail to recognise the opportunity, or do not take appropriate action to ensure that it is fully assessed and protected. These issues are explored in Section 9.2.1.

2. ***Assessing the commercial value.*** Presuming that the opportunity is recognised, the full extent of the commercial value of the new technology must be assessed to determine whether it is worth pursuing further. As noted above, this will generally be done within the HE sector by the ILO. In some cases, the potential commercial value may be obvious enough to warrant patent submission before a full assessment of the commercial value is conducted, in which case Stage 3 will precede this stage.

   The major purpose at this stage is to get a better understanding of the technology so as to better assess the likelihood that it might be of real commercial relevance. This involves an assessment of the cost, efficacy, regulatory, environmental and competitive nature of the technology. Many technologies fail at this stage because they are more costly or less effective than existing technologies, or because there are attendant issues of safety, user-friendliness or manufacturability which would make them unlikely to succeed. This process is described in Section 9.2.2.

3. ***Assessing patentability.*** Presuming that a commercial value is shown, a decision to pursue a patent will be made. If a patent application has already been made, then the decision will be whether to maintain the patent application or to let it lapse. Assessing patentability is essentially a process of establishing whether a patent already exists, or whether the concept is already publicly known. To be patentable, a technology must be novel and also have a utility. Some technologies can be commercialised without patent status, but they are exceptional. This process is described in Section 9.2.3.

4. ***Deciding on a commercialisation strategy.*** If the technology successfully reaches this stage, the technology owners will know that they have a technology with a potential value, and that they have a patent position (usually in the form of a patent application). A decision must now be made as to how to exploit the technology. The options are to form a start-up company around the technology, or to licence it to an existing company or companies. There may also be a combination of these two for different applications or territories. The issues here are described in Section 9.2.4.

5. ***Implementing commercialisation.*** When the decision on strategy has been made, it must then be implemented. The skills and funding required to implement a start-up strategy are very different to those involved in a licensing strategy. Different implementation routes therefore are specific requirements for funding and expertise. These issues are outlined in Section 9.2.5.

9.2.1 Recognising the opportunity

The commercialisation process generally starts in the laboratory with a development (planned or otherwise) that is regarded as being of potential commercial value. When this happens, the recommended process is that the researcher should disclose the finding to the TTO or equivalent office within the research organisation (see below).

All universities and research institutions have support staff that can assist the process of patenting of technologies and also the further commercialisation steps described below. Within the universities, the personnel in charge of the commercialisation process are those within the TTOs or ILOs of the colleges. These offices are the main conduit through which technologies developed within the colleges are transferred to industry. Their ability to effectively perform this role is critical to the realisation of the national strategy to develop an innovation society by major investment in R&D performance.

It should be noted that the staff within these offices are entirely dependent on researchers to disclose useful developments that arise in their research activities. Only then can they apply their skills to the assessment and exploitation of commercial opportunities.

In recent years, the staffing levels and competence of these offices have received significant attention and support, particularly from Forfás and EI. The most recent initiative to develop the ILO infrastructure is a fund of €30 million made available by EI to provide additional staffing.

In addition, Forfás and other agencies have issued several documents designed to set out the steps expected of HE researchers in dealing with IP derived from their research activities. These are:

- National Code of Practice for Managing Intellectual Property from Publicly Funded Research. Forfás, January 2004.
- National Code of Practice for Managing Intellectual Property from Collaborative Research. Forfás, November 2005.
- Funding Agency Requirements & Guidelines For Managing Research-Generated Intellectual Property. Commercialisation Steering Group (of the Funding Agencies), February 2006.

The above guidelines and codes of practice are all co-ordinated to ensure consistency of approach.

The staff in these offices, however, are dependent on the researchers at the bench to inform them of commercialisable and patentable developments that arise. This will usually be done using an Invention Disclosure Form which is made available by the TTO. Examples of these are available on college websites. These forms seek a wide range of information such as:

- Nature of the 'invention' and its technical significance
- Persons contributing to the development
- Date and place of invention and documentary and material evidence
- Source of funding for the research
- Any publications[3] made or planned
- External collaborators involved and any relevant agreements for sharing of materials or information.

This information will be of value at various stages in the commercialisation process. If the patent is successful and proves valuable, others will often seek to overturn the patent on the basis of technical or legal details. As this is likely to be many years after the invention date, it is important to detail all of the information as soon as possible.

As will be evident from the description above, the first pitfall for a potentially commercialisable new technology is that the researchers involved will not recognise the opportunity. The adage that "*chance favours the prepared mind*"[4] was never more apt than in the research laboratory. Researchers who are not mindful of their responsibility to seek potentially useful developments are very unlikely to do so. Even when researchers do become aware of opportunities, they must also begin the process leading to patent protection on the technology.

There is a significant concern about the low level of awareness of IP among Irish researchers. Training and awareness programmes are being developed on some campuses to address this issue. It is nevertheless a major issue for research funders, and was a major motivation for the publication of the codes of practice noted above.

3. Publication in the context of a patent submission can include a conversation, letter, e-mail, poster or any other means by which an external party may have been informed of the key elements of the invention.
4. Louis Pasteur.

The commercial outputs from funded research can only be captured if the researchers at the bench have the competence and motivation to recognise any opportunity that arises, and to take the appropriate steps to realise the opportunity. Many commercial opportunities are lost because the researchers involved do not use the recommended process for assessing the commercial potential of their findings.

There are several possible reasons why this is so. A major reason is lack of awareness of the procedures required. New researchers, such as postgraduate students, are often unaware of the requirements for IP management, and many institutions do not provide training for new researchers on a mandatory basis, or at all. Even experienced researchers are often unaware of these procedures. There is also a school of thought within academia, albeit declining, that holds that commercial involvement is not an appropriate activity for researchers. For whatever reason, some potentially patentable discoveries do not enter the commercialisation pathway due to the failure of researchers to make the appropriate disclosure. This issue is explored in the focus group sessions reported in Chapter 6.

A further basic requirement of researchers is that potentially patentable developments are kept confidential until after the patent submission has been made. Invalidation of patent applications because of prior disclosure by researchers is a common occurrence. This is because publication of results is a fundamental requirement for a successful researcher. Timely publication of useful results is the benchmark of success in the research world. Delay in the publication of results, even for the purposes of ensuring a successful patent, is resisted by many researchers. There is also a common misunderstanding among researchers that patenting prevents publication at any time.

A potential pitfall in the patent process is therefore that the researchers will publish the patentable concept before the patent application is made. A fundamental requirement for patent status is novelty. If the idea is in the public domain before submission of a patent application, a patent cannot be granted. Many patent opportunities are lost because researchers choose to publish their work before patent submission. The disclosure may also be inadvertent. A further misconception among researchers is that 'publication' can only take place through a formal paper in a scientific journal. In reality, publication of a discovery can occur by means of a poster or abstract, an e-mail or even a conversation with an external party.

Whether the result of failure to seek patent status, or of failure of the patent due to prior disclosure, lack of patent status is a major reason for failure of the commercialisation process.

9.2.2 Assessing the commercial value

As noted above, the technology is sometimes submitted for patenting in advance of a detailed technical assessment. The advantage of doing a pre-assessment is that the costs of patent submission can sometimes be avoided if it is established that there is no real commercial value in the technology.

A detailed assessment is required to establish commercial relevance. The kinds of questions to be asked in this process include:

- Who are the intended end-users for the 'invention'?
- Can they afford it, and do they need it?
- Is it better than the product or process that they are using now (if there is a competitor product)?
- Who can manufacture it? If it is difficult to manufacture, this may limit the licensing possibilities to those with the capability to make it.
- Does it require specialist marketing or service supports?
- Are there regulatory issues (safety, environmental or otherwise) that might limit its use, or increase the costs required to put it on the market?
- Can it be manufactured less expensively, or with greater regulatory or other benefits than existing products?

Very often some of these questions cannot be answered with certainty, as they require a more in-depth knowledge of manufacturing or market realities. If the product has been patented in advance, it is possible to present the idea to industry insiders and obtain a more informed view.

Many inventions fail at this stage. Cost, regulatory issues, competing technologies, restricted market size are all issues that may prompt a decision not to proceed with the commercialisation process.

However, if the commercial opportunity withstands this scrutiny, the next step will be to assess patentability (noting that this process sometimes precedes the commercial assessment).

9.2.3 Assessing patentability

Assessment of the patentability of a new technology is generally conducted with the support of a patent agent. A patent agent acts on behalf of an applicant in drafting a patent application and then taking the patent application through the various stages needed to grant the patent. A description of the role of patent agents, and a listing of the agents registered in Ireland is available on the Irish Patent Office website.[5]

To assess patentability, a detailed description of the technology must be provided to the patent agent by the researchers who originated the idea. This will describe the technology and will also include the claims that are felt valid for the technology. In other words, what are the unique things that the technology can do? These claims and the underlying technology are used to conduct searches of:

- The patent literature to establish if there is an existing or expired patent, or patent submission that is essentially equivalent, and
- The published literature to establish whether the idea has already been disclosed.

If the technology has not been patented or published, and the commercial opportunity is attractive, a patent application can be submitted. The outcome of the searches may mean that the claims are modified because it is found that some elements of the technology have already been patented. There may also be territorial differences. EU and US Patent Law differs in certain respects so that it may be possible to patent in the EU and not in the USA, or *vice versa*.

An issue for research organisations is the costs of making and maintaining patent submissions. The elements of these costs are the fees for the patent agents in preparing and advancing the submission, and the fees to patent offices. The patent agent's fees will be dependent on the extent of search required, and of the time required to address the issues that arise in the course of examination of the claim.

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5. See http://www.patentsoffice.ie/en/patent_agents.aspx.

The patent may not be granted for up to 7 years, but the submission will nevertheless provide effective protection as no later claim for the same technology can be granted patent status.

A patent is an important element of the commercialisation process. It is effectively the 'deeds' of the technology in that it confers ownership of the technology to the patent holder. In some sectors, e.g. software, patents are of less concern simply because the useful life of a new software element is very short and patents are designed for long-term protection.

As a general rule, any invention that requires further investment in its development prior to marketing will require patent protection. Highly regulated products such as pharmaceuticals, biologics, chemicals and many devices require significant investment to (a) create the data required to satisfy regulatory authorities so as to obtain market approval, and (b) develop the manufacturing process and final product formulation. In the case of pharmaceuticals, these costs are probably greater than €500 million. Few companies, and no investors, will be prepared to make the investment required without the protection of their return. A patent will provide this protection and is therefore very important.

There are situations where patent protection is less important. If the unique nature of the invention can be protected by confidentiality, that is an option. The most famous example is Coca Cola, whose formula has been kept a secret for many decades. If the market opportunity is likely to be short-lived, then a first-to-market strategy combined with strong marketing and branding may be an option. These options are unusual, however, and patent protection is the desirable option in most cases.

9.2.4 Assessing commercialisation options

Most Irish research institutions are unwilling to engage in commercial activities, and exploitation of a technology opportunity directly by a research institution is very rare. While some HEIs facilitated the provision of analytical and other services by their laboratories in the past, most now discourage or veto such activities for insurance or policy reasons.

Commercialisation of an invention by a HEI will therefore involve transferring the rights to the technology to one or more commercial entities that have the expertise and facilities to put the product on the market. HEIs will, however, usually reserve the rights to use their technology for the purposes of further research. This point is discussed above in relation to the Bayh–Dole Act.

The options for the HEIs therefore are:

- Support formation of a spin-off company to exploit the technology, or
- Licence the technology to an existing company.

Formation of a spin-off company is not suitable for all technologies. Formation of a company to make a single product, for instance is not often advisable. Many technologies are only relevant when combined with other technologies to create a new component. In the engineering industry, for instance, new equipment will often involve bundling of many technologies (materials, software and processes) into components of the final product. Nevertheless, there are technologies that are suitable as the basis of a spin-off, and Irish HEIs have been actively involved in encouraging their creation in the last decade.

In the creation of a spin-off company, the management team is arguably more important than the technology. Formation of a spin-off will therefore require that some individual or team has an interest to go this route. A member of the research team that originated the technology is often involved in such a team.

If this route is chosen, there are significant supports available for technology-based start-up companies at all stages of their development. The major support agency is EI, which has developed a wide package of supports. EI is particularly targeting high-potential start-ups (HPSUs) [6] that are defined as companies that are:

- Based on technological innovation
- Likely to achieve significant growth in 3 years (sales of €1.0 million per annum and employment of 10 or more)
- Export oriented
- Ideally, led by an experienced team, with a mixture of technical and commercial competencies.

6. See http://www.enterprise-ireland.com/CommonPages/High_Potential_Start_Ups.htm

The EI support package can be seen as a continuum from R&D grants for research in developing the underpinning technology, to feasibility and commercialisation grants for the stages in defining company business plans, grants for start-up creation, and further grants for different growth stages.

Many HE campuses now have incubator buildings to house start-ups. These are usually funded, or part-funded, by EI or by private investors. Examples include:

- NUI Galway
  http://www.nuigalway.ie/tto/contact.html
- University College Dublin
  http://www.ucd.ie/nova/
- Dublin City University
  http://www.invent.dcu.ie/home.php
- Dundalk Institute of Technology
- Athlone Institute of Technology.

These centres will provide a premises for the start-up company during its early years, and often a range of central office and technical services.

EI has also facilitated the development of venture capital funds which provide the bulk of funding for most start-ups. The range of venture capital providers in Ireland can be seen on the website of the Irish Venture Capital Association (http://www.ivca.ie/).

As a result of the increasing interest in start-up companies, and of the range of supports available, EI reports that, from 1989 to 2004, 470 companies have been started with their support, and that 357 (75%) were still trading in early 2005.[7]

Technology-based start-up companies may develop from research conducted within HEIs, or from technologies sourced from other companies. The founders of such companies may be the researchers that originated the technology, but more commonly they are executives who have previously worked in other companies in the same markets.

Licence the technology to an existing company. The most likely route of commercialisation of a technology is to transfer the rights to a company that has the capabilities required to put it on the market. For instance, if the invention is a single component or material, it may be sensible to transfer it to a company that markets a full range of components or materials to the same market. Equally, if the technology requires specialised manufacturing, it will make sense to license to a company that has the required capabilities.

If there are many companies with a potential interest in the technology, decisions may be required as to which of the companies to prioritise. Some HEIs may have a policy of support for local or national industry and therefore make first approaches to these companies. Others may adopt an approach of obtaining the best commercial deal. The technology owner (usually the HEI in the Irish context) must therefore decide on the strategy to adopt before proceeding.

When this decision has been made, an information package on the technology is prepared. This is generally a 1-page synopsis of the technology on offer including:

- Description of the technology
- Potential applications
- Information on the research team originating the technology
- Any scientific publications
- Patent status.

This sheet is used to promote the technology to target companies. Target companies will be identified and approached with information on the technology. This will usually be done by TT staff by phone or e-mail.

A less effective mechanism is to list the technology offer on specialist websites. HEI TTOs usually list the technologies available for license on their own websites, for instance. There are also central sites that offer technologies, sometimes on a fee basis. An example of a site that lists technologies from Irish HEIs at no charge is http://www.expertiseireland.com.

If one of these processes is successful in attracting a licensee, the process of agreeing a license will be started.

A license is simply an agreement with a company under which they obtain rights to exploit the technology, and the technology owner receives one or more forms of payment.

7. *Review of EI Supported High Potential Start-ups 1989–2004.* Unpublished document received from EI.

These payments may include an upfront fee at the start of an agreement, royalties based on the sales of the product, or service milestone fees based on achievement of defined technical targets. R&D institutions may also seek R&D funding for further development of the research that led to the technology. Within every HEI there is a process under which the researchers involved in developing successful technology will receive a proportion of the funds received. There is therefore a reward system for researchers.

The rights obtained by the company may be worldwide exclusive rights to all applications, or they may be non-exclusive, restricted to a specific territory (e.g. EU, USA or Asia) or to a specific application of the technology.

9.2.5 Commercialisation success

In practice, only a minority of technologies are licensed, and only a minority of these receive a significant level of funding. No figures are available for Ireland or the EU, but figures for the USA show the following:[8]

- The cost of an effective TT system is about 1% of R&D investment.
- There is an average investment of $2 million in research for each invention disclosure made by HEI researchers. This figure is remarkably consistent across countries.
- The average conversion rate of invention disclosures into a patent or license ranges from 15 to 30%.
- Income from licensing activities varies from 1% to 4% of research expenditures. Worldwide, the average is about 1.7%. Approximately 50% of university TTOs in the US operate at a net loss.

8. Statistics are derived from information from AUTM – see http://www.autm.net.

10 Conclusions

- Much of the research funded by the EPA is for the public good. It is disseminated freely and as such is not patentable, even if it were of commercial value.
- The issue of commercialising publicly funded research has come alive only in the recent past, as public funding was at a low level until 2000.
- There was however an expectation in some quarters of significant direct financial returns to the public purse from research by way of royalties and other income streams. It is now better appreciated that this is unlikely to be so and that most of the returns will be in the form of a trained research community, an advanced capability in the state and indirect revenues such as taxes resulting from commercialisation.
- The proportion of publicly funded environmental R&D in other countries that lends itself to commercialisation is not significantly different to the position in Ireland.
- Initially, funding agencies took differing views on the ownership and exploitation of the results of publicly funded research, some having little interest provided some efforts were made to exploit results.
- Consequently, there has been little awareness among research workers of the potential for commercialising the results of publicly funded research.
- There has been a corresponding dearth of expertise in the commercialising process and little appreciation of the mechanism and of the compatibility of commercialising with the academic need to publish.
- In the last few years, the policy-forming bodies, such as the ICSTI and Forfás, and funding agencies have produced guidance manuals on the ownership and exploitation of the results of publicly funded research, lending order and consistency to the area.
- Targeted supports for the development of environmental technologies by industry such as the EPA's CGPP and EI's ESP Programme have yielded notable results particularly when viewed in the context of the modest scale of the total grant budget provided.

11 Recommendations

- The EPA should ensure that institutions to which research funding is provided are providing awareness and training programmes that will:

    - inform researchers about the process for protecting IP that might emerge from EPA-funded projects

    - make research workers, starting at postgraduate level, aware of the potential for commercialisation of research results and of the practical and legal requirements of this process.

- The EPA should seek information from research funding applicants about the potential for commercialisable and patentable outputs from the proposed research. Where such potential exists, the terms of reference for the funding should be amended to ensure that this potential is fully assessed, and realised where feasible.

- The EPA should include patents as a valid deliverable for its funded research programmes, and introduce awareness and other measures to make the environmental research community aware of patenting as an outcome of their activity.

- The EPA's CGPP and EI's ESP Programme should be further strengthened or, at minimum, retained in the medium term.

- State grants for installation of solar panels and wood pellet burners should be given further impetus through targeted supports for the development of these and related technologies.

- The value of public-good research, and its frequently inherent lack of commercial potential, should be acknowledged by funding agencies and government. Results of public-good research may be freely available, but not necessarily free of charge.

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Abbreviations

ACSTI	Advisory Council for Science, Technology and Innovation
APCE	Air Pollution Control Equipment
AUTM	Association of University Technology Managers
CGPP	Cleaner Greener Production Programme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEHLG	Department of Environment, Heritage and Local Government
DETE	Department of Enterprise, Trade and Employment
EI	Enterprise Ireland
EoLV	End-of-Life Vehicle
EPA	Environmental Protection Agency
ERTDI	Environmental Research, Technology, Development and Innovation
ESP	Environmentally Superior Products
ETAP	Environmental Technologies Action Plan
EWEA	European Wind Energy Association
FP6	The EC’s Sixth Framework Programme for Research
FP7	The EC’s Seventh Framework Programme for Research
HE	Higher Education
HEI	Higher Education Institutes
HEA	Higher Education Authority
HPSU	High-Potential Start-Up
HRB	Health Research Board
ICSTI	Irish Council for Science, Technology and Innovation
IDA	IDA Ireland
ILO	Industry Liaison Office
IP	Intellectual Property
IPR	Intellectual Property Rights
IRCHSS	Irish Research Council for the Humanities and Social Sciences
IRCSET	Irish Research Council for Science, Engineering and Technology
ITs	Institutes of Technology
IUA	Irish Universities Association
LOAs	Licenses, Options and Assignments
MI	Marine Institute
MNEs	Multinational Enterprises
NDP	National Development Plan

NRA	National Roads Authority
OSTI	Office of Science, Technology and Innovation
PRTLI	Programme for Research in Third-Level Institutions
PV	Photovoltaic
RPO	Research Performing Organisations (taken to be all HEIs, Teagasc, etc., anyone receiving public research funding)
RTD	Research & Technological Development
RTI	Research Technology and Innovation Initiative
SBIR	Small Business Innovation Research
SEI	Sustainable Energy Ireland
SFI	Science Foundation Ireland
SME	Small to Medium-Sized Enterprise
TT	Technology Transfer

Appendix 1 List of Commercial Products Supported under Enterprise Ireland's Environmentally Superior Products Programme

Packaging

Reusable jugs and water pouch alternatives to disposable PVC water bottles

Eco-packaging for greeting cards

Eco health-care packaging product

Eco food packaging

Flat-pack reuseable packaging

Pallets for recovery and reuse

Biodegradable shrink wrap

Environmentally superior alternatives to plastic bubble-wrap packaging

Environmentally superior electronics packaging

Building products

Energy-efficient insulation (several projects)

Recovered waste paper in insulation products

Assess feasibility of manufacture of plastic pipes for use as a building product from recycled HDPE plastic packaging

Eco glass fibre products (GFP)

Energy-efficient cladding

Closed-loop recycling of plasterboard

Timber/Furniture

Timber seating made from waste wood

Environmentally friendly coating alternatives for kitchen worktops

Raw material efficiency and sustainable timber sourcing for furniture

Electronics/ICT/Software

Development of a decision-support tool for WEEE compliance tracking and reporting

Environmentally superior PC incorporating raw material, energy efficiency and end-of-life waste environmental improvements

Lead-free electronics design (consumer electronics, white goods, ICT)

Designing consumer electronics for waste electronics recovery

Design of lead-free PCs and design for repair/recovery

Incorporating environmental improvements to gas-leak detectors

Air handling software modelling to ensure greater energy efficiency in buildings

Increasing functionality of building energy management systems

Miniaturisation environmental benefits in consumer electronics

Chemical

Biodegradable industrial oils

Consumer products

Feasibility of a closed-loop industrial solvent system incorporating the take back and recovery of solvent contaminated wipes for cleaning and resale

Wood compost building and street products from waste

Raw material reduction and environmentally superior alternatives in mattresses

Water-free car-wash technology

Paper

Technology for conversion of waste straw as a raw material for paper manufacture

Engineering

Reducing the environmental impact of professional tools (spade, shovel, slasher, etc.) focusing on assessment of raw material substitution (re-sourcing of timber, steel, paints/coating, oils) and production changes to reduce environmental impact

Energy-efficient condensing boilers

Waste

Treated health-care waste recovery to divert recoverable streams from landfill and potentially into higher value products

Energy

Wood fuel pellets from waste wood

Wood fuel pellets for domestic stoves

Biofuel processing technology

Plant oil based biofuel production

Environmental products

Environmental improvements to products used in effluent treatment