BioPolis - Inventory and analysis of national public policies that stimulate research in biotechnology, its exploitation and commercialisation by industry in Europe in the period 2002–2005

National Report of Luxembourg

BioPolis has been funded under FP6, Priority 5: Food Quality and Safety
Contract No. 514174

Gigi Manicad
Christien Enzing

Innovation Policy group
TNO Quality of Life
The Netherlands

March 2007

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Summary

The Grand Duchy of Luxembourg is one of the smallest European countries, with a population of a little over 450 000 (EUROSTAT, 2005). The country has a very high standard of living. In 2005, the gross domestic product (GDP) at market prices accounted for 27 490M EUR (EUROSTAT, 2005), the highest in Europe. Until the mid-1970s, iron and steel was the most important industry in Luxembourg. Following the 1974 oil crisis, the finance sector became predominant. The emergence of Luxembourg as a financial centre was mainly due to its favourable legal and tax regimes. Economic growth has declined since 2001 and, although the economic situation has stabilised, GDP growth rates still fall behind the 2000 rate. The economic slowdown was mainly due to problems in the financial sector, in particular uncertainties and difficulties facing global stock exchange markets.

Luxembourg's Gross Domestic Expenditures on Research and Development (GERD) is 363.9M EUR or 1.71% of its GDP (2000 data). In terms of allocation, 7.67% comes from government and 90.68% from industry (Eurostat, 2005). Whereas Luxembourg ranks very high in for private sector expenditure on R&D, the country ranks last for public expenditure on R&D, which constitutes only 0.13% of its GDP. The government wants to change this situation by investing more in R&D: between 2000 and 2004 the budget had in fact increased by 153% (EU TrendChart, 2005).

The country's biotechnology sector is very limited. There are about 35 private companies in health biotechnology, five of which are engaged in biotechnology research. Moreover, public sector biotechnology research remains underdeveloped in Luxembourg (Krecké, 2006). This should be seen in the context of research and innovation being fairly new initiatives in Luxembourg.

It follows that support for innovation and research in Luxembourg is relatively recent. Currently, the country does not have a formal national innovation plan that provides broad orientation and policy vision. However, the national policy focuses on improving the overall competitiveness of the economic sector by strengthening the science base and raising overall R&D investment levels (OECD, 2004). In 2005, the new government presented several action lines for private and public research, including among others: raising the level of public investment to 1% of GDP; creating centres of excellence by concentrating the national effort of R&D on a limited number of topics; renewing R&D incentive schemes; instituting an action plan that addresses the Barcelona objectives; developing budgetary means to strengthen scientific and technical competence in companies, particularly SMEs; improving the coherence of priorities and the economic agenda of public research centres, as well as the technological needs of companies; and stimulating participation in international cooperation programmes (EU TrendChart, 2005).

At the government level, seven ministries are involved in innovation policy making and implementation. Two ministries are considered to be the most important: the Ministry of Economic Affairs and Foreign Trade, which is responsible for research in the private

sector and the Ministry of Culture, Higher Education and Research, which is responsible for research in the public sector.

The National Fund for Research (FNR) conducts complementary activities at the national level to promote research for the public sector. The FNR initiates multi-annual programmes. The National Agency for the Promotion of Innovation and Research (Luxinnovation) was set up as the 'first on-stop-shop' for enterprises and research centres that wish to apply for assistance and have innovative projects. Luxinnovation provides various services such as information on all innovation and R&D aspects for technology transfer and business start-ups, identification of company needs, and advice on choices of instruments and partners (EU TrendChart, 2004).

As national support to research and innovation is relatively new in Luxembourg, support for biotechnology is also still in its very early stages. Policy directions and objectives have yet to be defined. Support to R&D is restricted to areas that are expected to have high potential socio-economic impact for the country. This includes biotechnology-related research. One of the multi-annual programmes operated by FNR is 'BIOSAN: Health and Biotechnology', which started in 2000 and is due to run until 2008. Four of the seven current multi-annual programmes have a biotechnology research component. Furthermore, three 'Centres de Recherche Public' were established in 1987 and are also engaged in biotechnology research.

Biotechnology research is also carried out at the Faculty of Sciences, Technology and Communication of the University of Luxembourg. This programme is still in its developmental stage, considering the University was only established in 2003. The University's Laboratory for Research into Cancer and Blood Diseases (RCMS) also conducts basic research projects in the field of molecular biology of cancer.

As Luxembourg does not have a national policy on research and development and, consequently, does not have a specific biotechnology policy either, all the biotechnology instruments in Luxembourg are classified as non-policy directed. In the period 2002-2005, Luxembourg spent approximately 6.7M EUR on biotechnology research through the medium of these non-policy-directed programmes. This is the combined result from the four multi-annual programmes of the FNR.

With regard to Luxembourgian performance in biotechnology, publication output has been small and far below EU25 and USA levels. In spite of this, the share of biotechnology publications in relation to the total number of publications Luxembourg produces is similar to the EU25 ratio. When considering the number of citations per biotechnology publication, Luxembourg overtook both EU25 and USA levels in the period of 2002-2004. In terms of number of graduates in life sciences per million capita, Luxembourg has no output up till now. This is because the University of Luxembourg only opened in 2003 and the first students in life sciences have yet to graduate. The dominant subfield for biotechnology publications is human health. In the years 1994-2004, this generic biotechnology subfield grew by 500%, followed by animal biotechnology (300%), plant biotechnology (233%), health biotechnology (105%) and

industrial biotechnology (100%). The growth rates in the animal and plant subfields are particularly surprising considering that agriculture only contributes 0.73% to Luxembourg's GVA. They indicate that, despite its late start, biotechnology R&D is being pursued vigorously.

In terms of knowledge transmission and application, Luxembourg also lags behind EU25 and USA levels. This relatively low performance reflects the country's young R&D sector, which is still in the process of establishing its knowledge base. Hence, to date (2005), no achievements with respect to industrial development and market developments could be recorded.

Funding from the FNR is only available to public research organisations, which do not have to match the grants provided. All FNR programmes focus on three policy goals: high levels of biotechnology research, high levels of industry-oriented (and applied) research, and knowledge flow and collaboration among scientific disciplines. Biotechnology areas that are covered by these programmes include plant, environment, health, food and basic biotechnology. The activities supported by the programmes include basic and applied research, centres of excellence, research networks, and support for public discourse activities.

The future of biotechnology programmes is not yet clear. Government departments are still discussing whether or not Luxembourg should be promoted as a suitable location for biotechnology. Should the government decide to further pursue biotechnology, the Minister of Economic Affairs and Foreign Trade has indicated that this would require substantial government investment. Moreover, Luxembourg would also need to improve the social acceptance of biotechnology; facilitate access of biotech companies, particularly SMEs, to venture capital; and strengthen the biotech sector by attracting new companies that are either leaders or potential leaders in industrial development (Krecké, 2006). If the government decides to stimulate biotechnologies, it is likely to focus on health biotechnology. Immune therapies, diagnostics and research into vaccine development are already prominent in Luxembourg. Therefore, these research activities are likely to be supported in the long term.

1. Introduction and background

1.1 General introduction

The Grand Duchy of Luxembourg is one of the smallest European countries with a land area of 2 586 km² (Wikipedia, 2006) and a population of a little over 450 000. (EUROSTAT, 2005). The country is landlocked between Belgium, France and Germany. One third of the Luxembourg territory consists of woodland and the rest of rolling farmlands and woods.

Luxembourg has a very high standard of living. In 2005, the gross domestic product (GDP) at market prices amounted to 27 490M EUR (EUROSTAT, 2005). The GDP per capita in PPS is the largest in Europe, more than twice the EU25 average and exceeding the GDP per capita of the United States (EU TrendChart, 2005). Historically, the economic growth of Luxembourg was based on its natural resource of iron ore, which provided the foundation for the country's iron and steel industry. This industry was the dominant economic sector until 1974, being responsible for 30% of the national total value added. However, the global oil crisis contributed to the decline of Luxembourg's iron and steel industry. From the early 1980s until the present, the dominant sector has been financial services (STATEC, 2006).

The emergence of Luxembourg as a financial centre was mainly due to its favourable legal and tax regimes. The financial sector is now the main driving force of the country's economy, contributing 20 110M EUR of the Gross Value Added (GVA) in 2000 (Eurostat, 2005). The finance sector employs approximately 12% of the total workforce, and accounts for over 40% of tax receipts. The sector is therefore crucial to Luxembourg's external trade balance, accounting for 77.6% of the surplus on the service balance of trade in 2001. However, as a result of EU harmonisation processes, Luxembourg's former preferential tax and regulatory regimes have either ceased to exist, or are in the process of being eliminated. This necessitates innovation, in terms of the legal framework, and a search for new products in order to achieve an international niche based on alternative competitive benefits (STATEC, 2006).

Luxembourg's economic growth has fallen since 2001 and although the economic situation has stabilised, GDP growth rates still lag behind the 2000 rate. The economic slowdown is mainly due to problems in the financial sector. Worldwide problems affecting stock exchange markets were largely responsible. The slowdown of the economy also resulted in higher unemployment rates (from 2.3% in 2000 to 4.2% in 2004), although unemployment is still very low compared to the EU25 average (9% in 2004). One difficulty is the high inflation rate of 3.2%, which exceeds the EU25 average of 2.1% in 2004. Public expenditure increased considerably, from 39.1% of GDP in 2001 to 46% in 2003. Nevertheless, the public deficit remains limited.

Luxembourg's Gross Domestic Expenditure on Research and Development (GERD) is 363.9M EUR or 1.71% of its GDP (2000 data). In terms of allocation, 7.67% comes from government and 90.68% from industry (Eurostat, 2005). While Luxembourg ranks very

high for private sector expenditure on R&D, the country ranks lowest for public expenditure on R&D, which constitutes only 0.13% of its GDP. The government has indicated its intention to invest more in R&D, and in fact already increased the R&D budget by 153% in the period between 2000 ands 2004. (EU TrendChart, 2005).

Luxembourg's biotechnology sector is very limited. There are about 35 private companies in health biotechnology, five of which are engaged in biotechnology research. Public sector biotechnology research remains underdeveloped. (Krecké, 2006). This should be seen in the context of research and innovation being fairly new initiatives in Luxembourg.

1.2 Characteristics of national S&T and innovation system

Support for innovation and research is relatively new in Luxembourg. Currently, the country does not have a formal national innovation plan that provides broad orientation and policy vision. However, one could say that the country does follow an informal innovation strategy, based on its Framework Law on Economic Development and Diversification of 9 March 1987. Within this framework, national policy focuses on improving the overall competitiveness of the economic sector by strengthening the science base and raising overall R&D investment levels (OECD, 2004). The focus has largely been on strengthening Luxembourg's comparative advantage in financial services through innovations in ICT. At the same time, innovations directed towards agriculture, the environment, human health and space sciences also fall under the economic agenda of diversification.

The first policy on research and development was introduced in 1981, when the Ministry of Economic Affairs and Foreign Trade provided a large credit intended to financially support R&D programmes and projects initiated by Luxembourg companies. The law of 9 March 1987 also set the framework conditions for public research, which can be characterised as being focused on areas with high potential socio-economic impact for the country. The 1987 Law also provided for the establishment of three public research centres (Centres de Recherche PublicP): CRP Gabriel Lippmann, CRP Henri Tudor and CRP Health (OECD, 2004).

Since 2000, the National Fund for Research (FNR) has defined a number of multi-annual research programmes. One of the first four priority themes included biotechnology and health (the BIOSAN Programme).

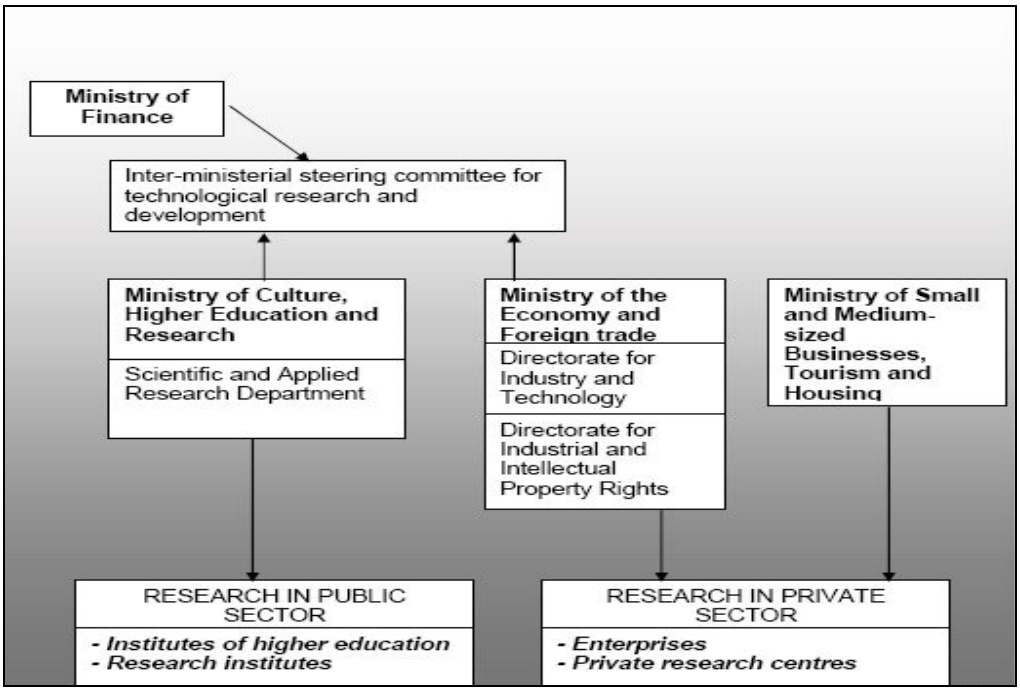
In 2005, the new government emphasized several research and innovation initiatives. For the public sector, this includes: raising public investment to 1% of GDP, while maximizing the effectiveness of expenditure on basic and industrial research; creating centres of excellence, by concentrating national R&D efforts on a limited number of topics within the framework of public-private partnerships; and strengthening research programme synergies between the University of Luxembourg (established in 2003) and the public research centres, *inter alia* by encouraging mobility of teaching personnel and

students between the university and the centres (Ministry of Culture, Higher Education and Research, 2005).

For the private sector, the new government had the following objectives: renewal of R&D incentive schemes; an action plan that addresses the Barcelona objectives; the creation of a business portal; continuing to promote innovation, R&D and human capital in companies; continuing to support SMEs though a policy of information, consultation and stimulation; the development of budgetary means to strengthen scientific and technical competence in companies, particularly SMEs; supporting improved coherence of priorities, economic agenda of public research centres and technological needs of companies; promoting entrepreneurship; and stimulating participation in international cooperation programmes, such as the EU Framework Programme and EUREKA. (EU TrendChart, 2005).

Figure 1.1 provides an overview of the current research and innovation structure of Luxembourg, which is presented in more detail in the rest of this section.

Figure 1.1 Overview of the innovation governance system in Luxembourg



Source: European Trend Chart on Innovation, National Report of Luxembourg, 2004/2005

Mainly due to the small size of the country, there is direct interaction and close collaboration between the various actors at both policy and implementation levels. In particular, there is strong collaboration between the public and private sectors. However, as in many other countries, inter-ministerial coordination is lacking and there are potential overlaps in research competencies within the public sector (EU TrendChart, 2004).

At the government level, seven ministries are involved in innovation policy making and implementation. Two ministries are considered to be the most important: the Ministry of Economic Affairs and Foreign Trade, which is responsible for research in the private sector, and the Ministry of Culture, Higher Education and Research, which is responsible for research in the public sector. Other involved ministries include: the Ministry of Small- and Medium-sized Business, Tourism and Housing, which is prominent given the recent emphasis on SMEs; the Ministry of State, Media and Communication Services, which has initiated a number of ICT-related measures; the Ministry of Health, which co-finances CRP Health; and the Ministry of Finance.

The National Fund for Research (FNR) conducts complementary activities at the national level to promote research for the public sector. The FNR initiates multi-annual programmes, drafted by experts who are selected by the Fund's Scientific Council and Board of Administration; these are then submitted to the Government for financing. So far, there are 7 multi-annual programmes. The FNR also provides small grants via separate means, designed to reinforce the general framework of scientific research in Luxembourg. These measures include small grants for publications, conferences, *etc*.

Professional chambers, business federations and organisations provide structures that influence innovation policy. The Chamber of Commerce and the Chamber of Skilled Crafts provide opinions on draft legislation and regulations. The Federation of Luxembourg Industrialists (FEDIL) examines and defends the professional interests of its members on matters that have economic, social and industrial potential.

The National Agency for the Promotion of Innovation and Research (Luxinnovation) was established by the Ministry of Economic Affairs and Foreign Trade, the Ministry of Culture, Higher Education and Research, the two Chambers and FEDIL. Luxinnovation was set up as the first 'on-stop-shop' for enterprises and research centres that wish to apply for assistance and have innovative projects. Luxinnovation provides various services, such as information on all innovation and R&D aspects for technology transfer and business start-ups, identification of company needs, advice on choices of instruments and partners, and follow-up processes concerning project innovation. (EU TrendChart, 2004).

In 2000, FEDIL, the Chamber of Commerce, the Chamber of Skilled Crafts, McKinsey & Company and Luxinnovation established the Business Initiative, a non-profit association that promotes entrepreneurship in Luxembourg by organising promotional competition, financial platforms and assistance in starting innovative businesses.

The operational level of research organisations is presented in section 1.4.

1.3 National support and framework conditions for biotechnology

As national support for research and innovation is relatively new in Luxembourg, support for biotechnology is also still in its very early stages. The country is pursuing a number of biotechnology research initiatives, but policy directions and objectives have yet to be defined. As mentioned in section 1.2, Luxembourg's does not have a formal national innovation plan. Instead, support for research and innovation is directed by its 1987 Framework Law on economic development and diversification. Within the scope of this law, support to R&D is restricted to areas expected to have high potential socio-economic impact for the country. One of the areas that has been consistently given support, since the inception of innovation and research, is biotechnology-related research. One of the first four multi-annual programmes that was established by FNR was "BIOSAN: Health and Biotechnology", which began in 2000 and is scheduled to run until 2008. The stimulation of biotechnology research continues at present in four of the seven current multi-annual programmes (see section 2.2.). Furthermore, the CRPs that were established in 1987 are also engaged in biotechnology research.

While the government allocates funding and programme support for biotechnology, Luxembourg does not have an explicit policy on biotechnology. Nevertheless, there are indications of active exploration of biotechnology issues by the government. Firstly, the prospects of biotechnology and their potential contribution to national economic diversification and development have been widely debated in the parliament (Watson, 2002). Secondly, in 2005, the Ministry of Economic Affairs and Foreign Trade commissioned a study on the strengths and weaknesses of biotechnology and biomedicine in Luxembourg. Thirdly, the Ministry also commissioned CRP Health to carry out a public opinion poll on the social acceptance of biotechnology. The commissioned studies are intended to help the government decide whether or not to pursue further development of biotechnology and best determine how biotechnology can contribute to the country's economic growth.

Framework conditions

With regard to framework conditions, Luxembourg implements the EU harmonising legislation on biotechnology. It ratified the Cartagena Protocol on Biosafety in September 2003. The Ministry of Health is responsible for coordinating biotechnology regulatory frameworks in the field of medicine and agriculture. The Division for Control of Foodstuffs of the National Health laboratory (LNS) conducts the sampling and analysis of foodstuffs, including traceability and labelling legislation. In addition, the Ministry of Agriculture, Viniculture and Rural Development (MAVD), through its Department of Agricultural Technology, is responsible for quality assurance in the agricultural sector. This includes sampling and analysis of agricultural products and implementation of the coexistence policy. This policy relates to the establishment of terms for the use and cultivation of GM seeds and plants. At present, there are no genetically-modified (GM) plants for commercial production, nor any GM field trials in Luxembourg. Up until 2005, the Luxembourg government had not granted any license for GM field trials (USDA, 2005).

Luxembourg does not have any specific legislation regarding human embryo research. There is no prohibition on the procurement of human embryonic stem cells from human embryo (Matthiessen-Guyader ed., 2004).

The National Advisory Commission of Ethics for Health and Life Sciences (CNE) was established by the government in September 1988. The mission of the CNE is to study, either on its own initiative or at the request of the government, the ethical aspects of developments in the field of health and life sciences. The subjects include genetics, biotechnology, biomedical research and stem cell research. Aside from advice based on their studies, the CNE also provides information to encourage informed public debate.

Public attitude
With regard to public acceptance, a survey conducted by the Eurobarometer showed that 69% of Luxembourgian respondents believe that biotechnology and genetic engineering will have a positive effect on their lives in the next 20 years. Specifically on the issue of medicines and new medical technologies, 96% of the respondents were positive. However, they were far less positive (62%) about high-tech agriculture. With regard to specific applications, Luxembourg stood out for its very strong opinions. Among the countries surveyed that would never approve of certain biotechnology applications, Luxembourg consistently scored very high. For instance, 49% of Luxembourgian respondents said that they will never approve of cloning animals for research into human diseases. This is the highest disapproval rating among the countries surveyed. 83% were against cloning human beings so that couples can have a baby when one of the partners has a genetic disease; again, Luxembourg had the highest disapproval rating. Although only 30% of the respondents stated that they would never approve of cloning human stems cells from embryos for organ transplants, their score is among the most negative of the countries surveyed. 38% did say that they might approve of it, provided it was highly regulated and controlled (Eurobarometer, 2005).

Table 1.1 Extent of Luxembourgian approval of applications of new technologies, expressed in percentages

Topics for consideration	**Never**	**Only in exceptional circum-stances**	**Only if highly regulated and control-led**	**In all circum-stances**	**DNK**
Animal cloning for research into human diseases	49	25	23	0	0
Human cloning so couples can have a baby despite having a genetic disorder	83	13	3	0	0
Cloning human stem cells from embryos for organ transplants	30	21	38	9	0
Growing meat from cell cultures to avoid the slaughter of animals	74	11	8	5	0
Developing GM crops to	48	10	25	12	0

increase the variety of regionally-grown foods					
Developing GM bacteria for cleaning up environmental catastrophes	37	17	25	17	4

DNK: Do Not Know
Data Eurobarometer, 2005
Source: BioPolis Research

With regard to the use of genetic data, the majority of Luxembourgian respondents had very strong opinions. Concerning the development of a genetic test for children that would identify their talents and weaknesses, 73% said that they would never approve. Moreover, 62% said that they would never approve the development of genetic treatments to prolong life. Regarding genetic tests for certain currently incurable diseases and tests to rid people of their bad habits, 52% and 50% respectively said that they would never approve of such procedures. In terms of storing genetic data (of the Luxembourg population) to study the genetic base of diseases, only 29% said that they would never approve, while 25% said that they would approve if the procedure was highly regulated and controlled (Eurobarometer, 2005).

1.4 The main biotech policy and research actors

As mentioned in the previous section, Luxembourg has yet to develop a national biotechnology policy, so there are no biotechnology policy makers as such. This section presents an overview of the main actors engaged in biotechnology research. They include the specific divisions within the three CRPs and the University of Luxembourg. The CRPs are mainly financed through the state budget. In the past, research was essentially financed through projects, but since 2004 there has been a slight shift towards institutional financing. The CRPs also get financing through national and international R&D contracts, as well as from donations and their own revenues (OECD, 2004).

CRP Health coordinates national health-based research and conducts advance biomedical research. It also conducts health-related multidisciplinary research on environmental health, food safety and toxicology. The scope of activities of CRP Health covers fundamental, applied, clinical and public health research. CRP Health hosts eight research laboratories that are all engaged in biotechnology:

- The Laboratory of Molecular Biology, Genetics and Modelling (LBMAGM) aims to further develop the molecular oncology research programme of CRP Health. Its priority areas are cancer research and genomic technologies.
- The Retrovirology Laboratory does basic research on HIV and aims to be a partner of the biotechnology and pharmaceutical industry for external validation of laboratory assays and the development of anti-HIV drugs.
- The StraLux Laboratory of Immunogenetics, Allergology and Plant Molecular Biology (SLIAPMB) conducts research in the field of allergic, immune and immunogenetic diseases.

- The Toxicology Laboratory focuses on two fields: biodisponibility and pharmacokinetics of some xenobiotics in alternative matrixes (hair and sweat). It also develops and validates new analytical techniques, in particular for substances difficult to detect by more traditional methods such as HPLC and GC/MS.
- The Immunology Department's scientific activities include peptide and DNA-based strategies for vaccination against major human infections, novel biomaterials for analytical test systems, development of rapid diagnostic field tests for measles infection and immunity, and development of diagnostic reagents and assays.
- The Laboratory of Hemato Experimental Cancerology studies the regulation of apoptical mechanisms in pathologies, such as chronic lymphoid leukaemia and neoplasm of the colon. It also conducts therapeutic studies on e.g. breast cancer, chronic lymphoid leukaemia and cancer of the colon. This includes anti-tumour vaccination for breast cancer and understanding resistance to known therapeutics. It also conducts research on cell therapy in haematology and cardiology.
- The Cardiovascular Research Laboratory studies heart failure mechanisms. The activities of the laboratory are centred around remodelling after infarction. Research is conducted on three levels: cellular, entire animal and private clinic.
- The NorLux Neuro-Oncology Laboratory aims to use a functional genomics approach to characterise cancer stem cells, and to reveal the mechanisms of angiogenesis independent growth. This involves the use of oligonucleotide microarrays as well as differential-in gel electrophoresis proteomics technologies. Extensive comparisons are carried out between the normal stem cells, the cancer stem cells and the tumour cells that are derived from them.

In 2000, CRP Health established the Biotechnology Institute, a business accelerator to encourage biotechnology companies in their start-up phase and to support already established companies. The core of the accelerator is based on a public-private partnership offering all services needed for the development and growth of biotechnological and biomedical enterprises. This central core will bring together expertise such as marketing, partner search, technological development monitoring, recruitment support, start-up money, and business management.

CRP Gabriel Lippmann promotes the creation of new technological expertise and the transfer of this know-how to companies. Its three major research areas are: innovative material technology (nanotechnologies and instrument development); sustainable development of natural resources; and information society technologies. The Unit for Research on the Environment and Biotechnology (CREBS) of CRP Gabriel Lippmann houses the Forestry and Agricultural Biotechnologies division, which specialises in the applied study of plants to improve production in the forestry, agricultural and horticultural sectors. The division studies the effects of biotic stress (fungus, virus and bacteria) and abiotic stress (effects of heat, cold, drought, salinity and global climate change) using genomics, proteomics and metabolomics (Luxinnovation, 2006).

CRP Henri Tudor promotes technological innovation and transfer between the private and public sectors. Its research areas are ICT, material science and environmental technologies. It hosts a business incubator, TechnoportTM, dedicated to fostering the

creation and development of technology-based companies by providing support at pre-commercial and start-up phases. CRP Henri Tudo**r** has eight departments. One of these departments, the Resource Centre for Health Care Technologies (CR Santec) is active in bioinformatics, including biological database management and image processing for microarray images. The BioInfo project on image processing and the implementation of a high-performance database (data warehouse/data mining) form an integral part of the work designed to create a DNA-chip platform (Henri Tudor, 2003).

The Faculty of Sciences, Technology and Communication is one of three faculties of the University of Luxembourg. Although it is intended that the university should eventually have a strong research arm, it is still in its development stage, which is natural considering that the university was only established in 2003. The collaborative life science research projects of the Faculty of Sciences, Technology and Communication include: the structural and functional analysis of the Jak/cytokine receptor interaction; microglial activation and differentiation; balance between pro-inflammatory secretions and beta-amyloid clearance for defining therapeutic strategies against the Ab cascade for Alzheimer's disease; differentiation and activation of cerebral microglial cells; and the role of the Notch-Jagged-Hes pathway on reactive astrocytes (University of Luxembourg, 2006).

The University's Laboratory for Research into Cancer and Blood Diseases (RCMS) conducts basic research in the field of molecular biology of cancer. It focuses on the resistance mechanisms of cancer and, more particularly, on the resistance of leukemia cells to anti-cancer drugs. The RCMS laboratory has expertise in genetics, molecular and cellular biology and biotechnology. (Luxinnovation, 2006).

2. Funding of biotechnology R&D, transfer and commercialisation

2.1 Introduction

This section of the report reviews the funding of biotechnology research and commercialisation. In the report a distinction is made between policy-directed funding and non-policy-directed funding of biotechnology.

Policy-directed funding includes funding directed by explicit policy decisions about specific instruments, such as R&D programmes, programmes encouraging collaboration, industrial research grants, support for centres of excellence, support for commercialisation of research, support for start-ups, programmes encouraging mobility of researchers, programmes with open calls, *etc*. This policy-directed funding can include biotechnology-specific policy instruments and generic policy instruments. Biotechnology-specific policy instruments have been specifically set up to stimulate biotechnology. Generic policy instruments are not linked to a specific technology, but in principle stimulate all technologies, including biotechnology. The BioPolis project only considers generic instruments that make a reference to (the stimulation of) biotechnology activities in the policy of the funding organisation running the programme, or that of the ministry/government department itself.

Non-policy-directed funding of research includes funding linked to structural governmental support for scientific education, research and research infrastructure. This type of funding is mainly allocated through block grants to universities and (government) research institutes, and through the open-call system of research councils. Research councils, research institutes and government research institutes develop their own programmes through which biotechnology may be supported. The BioPolis project only considers funds allocated through block grants to (government) research institutes and the open-call system of research councils.

Luxembourg does not have a national policy on research and development and consequently does not have a specific biotechnology policy either. Hence, using the BioPolis definition, all biotechnology instruments from Luxembourg are classified as non-policy-directed. These are presented in more detail in section 2.2. Data were collected through desk research (publications, documents, websites of national and regional public funding organisations and/or governmental departments), a survey of funding organisations that manage the generic and biotech-specific programmes, and interviews with representatives of organisations involved in non-policy-directed and policy-directed funding. The website of the funding organisations and their programmes, and the names of the contact persons who participated in the survey and/or were interviewed can be found in Annex 3 (List of contact persons) and Annex 4 (References).

In Luxembourg, charities contribute funding to biotechnology research. These charities include the AIDS Research Foundation and the Foundation for Research into Cancer and Blood Diseases. However, there is no available data on their funding contribution. The final section of this chapter, section 2.3 provides a short overview of the participation of

Luxembourg in biotechnology-related projects of the European 6th Framework Programme.

2.2 Non-policy directed funding of biotechnology research

Table 2.1 provides an overview of the instruments that provide non-directed funding for biotechnology/life sciences research in Luxembourg. The programmes are all from the FNR. Other instruments under the Ministry of Culture, Higher Education and Research have not been included due to lack of data, specifically on budgetary matters. FNR's budget for activities in general or application areas are not available because they are not accounted for in the programmes and depend on the individual projects of ongoing programmes. Consequently, the biotechnology budgets have been calculated approximately, based on project information available from the FNR website.

Table 2.1 Public non-policy-directed biotechnology instruments during the period 2002-2005 (M EUR)

Instrument	Funding organisation	Biotech component of the budget	% of total budget	Use of DF/SF*
EAU	FNR	0.48[1]	7.2	None
NANO	FNR	1.2[2]	18	None
SECAL	FNR	1.2[3]	18	None
BIOSAN/PROVIE	FNR	3.8	56.9	None
Biotechnology Institute	CRP Health	n.a.	n.a.	
Total		6.68	100	

[1] This estimate is based on information that 1 of 5 project areas had a biotechnology research component. Therefore, 10% of 4,804,630 EUR (total funding in 2002-2005) was used to estimate the budget for biotechnology-related research.

[2] The author estimated the biotechnology budget on the basis of funds allocated to the project 'Analysis of biological tissues with Nano/SIMS', 2003-2007, total budget: 2M EUR. The annual budget for biotechnology-related research was estimated at 400,000 EUR.

[3] The author estimated the biotechnology budget on the basis of 3 projects: (1) Novel quantitative protein- and DNA-based methods for tracing of food components, 2004-2007, total budget: 1.199.980 EUR; estimated annual budget for biotech-related research: 299,995 EUR; (2) Development of new genoproteomic diagnostic tools for the toxicological assessment of endocrine disruptors in food (ENDIF), 2005-2007, total budget: € 983.437;estimated annual budget for biotech-related research: 327,313 EUR; and (3) Molecular epidemiology of zoonotic bacteria in the food chain in Luxembourg (EPIFOOD), 2005-2008, total budget: 849.900 EUR; estimated annual budget for biotech-related research: 212,475 EUR.

* DF/SF: (International) Development Funds / (European) Structural Funds

Source: BioPolis Research

In addition to the above instruments, CRP Health's Biotechnology Institute is a business accelerator, which aims to encourage biotechnology companies in the start-up phase and also support well-established companies. The Biotechnology Institute can also be considered as an instrument. However, CRP Health was not able to provide any further information on the institute.

The FNR has four multi-annual programmes that involve biotechnology research. The programmes are exclusively for public research organisation use. FNR states that these funds are not designated to stimulate biotechnology per se but that biotechnology may be involved in these programmes if it enhances food safety, health/medical and biological tissue research.

Food Safety (Sécurité Alimentaire - SECAL)
The SECAL Programme began in 2003 and is scheduled to run until 2009. It has a total budget of 6M EUR. The aim of the programme is to develop a body of scientific expertise and resources in Luxembourg in matters concerning food safety, for the benefit of all sectoral actors involved. It is anticipated that the scientific knowledge base can be widened and that new methods of surveillance and risk avoidance can be developed. Priority has been given to three areas of research. In each case, research ranges from risk assessment to the study of prevention strategies. The three research areas are: traceability of foods (including genetically-modified organisms or GMOs); chemical and microbiological quality of foods (including drinking water); and impact on human health and consumer protection. The first and third of these research areas involve biotechnology.

Health and Biotechnology (Biotechnologie et Santé - BIOSAN) and Medical Aspects of Ageing (Processus de vieillissement - PROVIE)
The BIOSAN Programme began in 2002 and is scheduled to run until 2008. Its total budget amounts to 6M EUR. The PROVIE Programme is an extension of the BIOSAN programme and runs from 2004-2008, with a total budget of 2.5 M EUR.
The objective of BIOSAN is to contribute to the qualitative improvement of prevention, detection and treatment of cancer and cardio- and cerebro-vascular diseases. An additional objective is to develop new strategies for the specific modulation of the immune system. The aim is to reinforce, increase the competitiveness and mobilise the actors involved in biomedical research in Luxembourg - on the fundamental and clinical levels, as well as in the field of new biotechnologies.. The six priority areas selected to support the health system are: cancer; cardio- and cerebrovascular diseases; new strategies for immunology intervention; development of expression libraries for the functional and topographical targeting of complex biological systems; epidemiology; and intelligent data-processing environments in the health field.

The aim of the PROVIE programme is to study the epidemiological, psychosocial and biological aspects of the neurodegenerative diseases of old age in Luxembourg, and to make comparisons with the broader European situation. The objectives are:

- To improve the skills of the biomedical community in Luxembourg and the transfer of knowledge of pathologies linked to ageing of the brain;
- To correlate medical, epidemiological, psychosocial and biological aspects;
- To improve the prevention of cerebrovascular accidents (strokes);
- To acquire innovative detection methods for neurodegenerative diseases, depression, sleep disorders and chronic pain in the elderly;
- To devise new specific treatment strategies for the above pathologies;
- To improve the care of patients and their families;

- To develop new therapies.

New Materials and Nanotechnology (Matérieux innovateurs et nanotechnologie -NANO)
The total budget of the NANO Programme for 2000-2008 is 6.7M EUR; the biological application within this budget amounts to 2M EUR. The NANO Programme aims to create a European Centre specialised in the characterisation of materials on the nanometre scale. The characterisation of a material (plastic, metal, glass, and biological tissue or cell) can be analytical, morphological or functional. NANO supports two research topics in the fields of: (1) innovative materials and (2) medical and biological tissue research, in collaboration with medical research in Luxembourg. The second topic investigates cells at a resolution in the nanometre range to identify their chemical elements (and isotopes). The areas to be covered by the medical and biological tissue research programme include: technological extension of current SIMS technology by high-resolution detection for application to biological systems, and the development and application of nanotechnologies based on high-density arrays, e.g. for bioimpedance measurement and functional analysis of biological systems.

Sustainable Management of Water Resources (Gestion durable des ressources hydriques - EAU)
The EAU Programme began in 2000 and is scheduled to run until 2007. Its total budget amounts to 5M EUR. The programme's general objective is to establish a pool of excellence in the field of water in Luxembourg, capable of grasping the complex mechanisms of the natural water cycle, evaluating the means of protecting water resources and water quality, developing the most appropriate and least expensive innovative technologies for control and water purification, and fighting against water wastage. EAU has five priority areas. One of the five priority areas, the quality of surface waters and aquatic ecosystems, involves some aspects of biotechnology research. This programme area includes: formulation of new methods, based mainly on molecular biology, for monitoring microbial communities in the environment; evaluation of the structure and dynamism of microbial populations; interactions and diversity through labelling, monitoring and identification strategies; development of (bio)chemical microsensors in order to determine online parameters governing water quality and ideas for remote supervision of water quality; and the study of systematics, toxicity and ecotoxicity of cyanobacteria in stagnant water.

2.3 Participation in 6th Framework Programme and use of development funds

Table 2.2 presents the involvement of Luxembourg in the Sixth Framework Programme. So far, Luxembourg's participation is limited to membership in five (of the 8537) projects in life sciences, genomics and biotechnology for health.

Table 2.2 Involvement of Luxembourg in biotechnology/life sciences programmes of the 6th Framework Programme

Sixth Framework Programme[1] Thematic priority	**Participation as project coordinator**	**Participation as member of the project team**[2]
1. Life sciences, genomics and biotechnology for health	0	5 (0,06%)
2. Nanotechnologies (section bio-nanotechnology)	0	0
5. Food quality and safety	0	0

[1] First and second call, all types of projects
[2] Persons/groups can participate in more than one project, resulting in greater participation
Source: BioPolis Research

3. Performance of the national biotechnology innovation system

3.1 Introduction

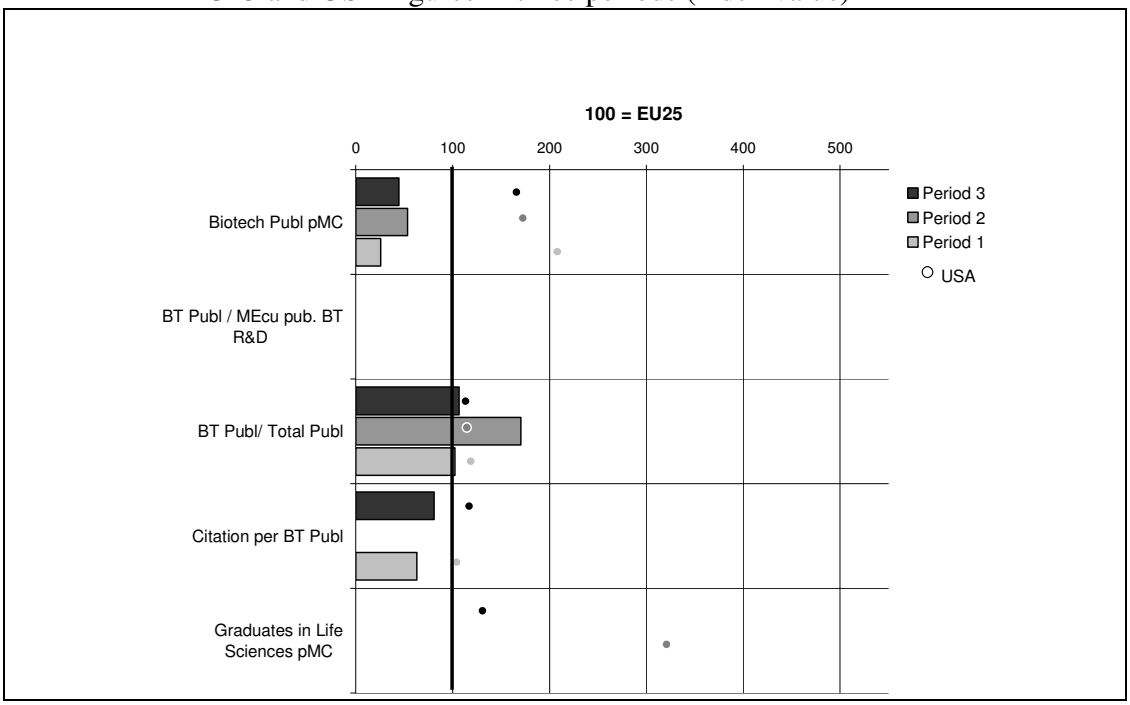
This chapter analyses the performance of the Luxembourg biotechnology innovation system for two or three time periods (depending on data availability), as shown by a range of indicators for scientific and commercialisation performance. Each time period includes several years to avoid capturing erratic trends. National trends are benchmarked against the performance of EU25 member states and the USA.

Depending on data availability, the presentation of the performance of is structured along the four main policy areas being considered in BioPolis project. For each area data are shown of a number of different indicators for Luxembourg, the USA and EU25. The values of EU25 have been chosen as a reference in each indicator. The absolute figures used to calculate the values for the indicators presented and the sources for the data can be found in Annex 5. In principle, for each indicator data are presented for three periods. The periods chosen can vary considerably between the indicators; table A.5.1 presents for each indicator the specific years for each period.

3.2 Performance in creating a knowledge base and supporting the availability of human resources

Considered over a ten-year period, Luxembourg first increased and then decreased its output of biotechnology publications per million capita (from index 26 in 1994-1996. to index 53 in 1998-2000 to index 44 in 2002-2004, see Chart 3.1). Luxembourgian output has been modest and far below EU25 (index = 100) and USA publication levels (index 166 in 2002-2004). Despite its modest output, the country's share of biotechnology publications in relation to the total number of publications it produced is comparable to EU25 levels (index 103 in 1994-1996 to index 107 in 2002-2004 for Luxembourg). Except for the period of 1998-2000, Luxembourg's performance (index of 171) falls below USA levels (index 119 in 1994-1996 to index 113 in 2002-2004). When considering the number of citations per biotechnology publication, Luxembourg performs clearly below both the EU25 and USA, but the index increased from 63 to 81. In terms of number of graduates in life sciences per million capita, it has not yet registered any output. This is because the University of Luxembourg only opened in 2003 and the first groups of life sciences students have yet to graduate.

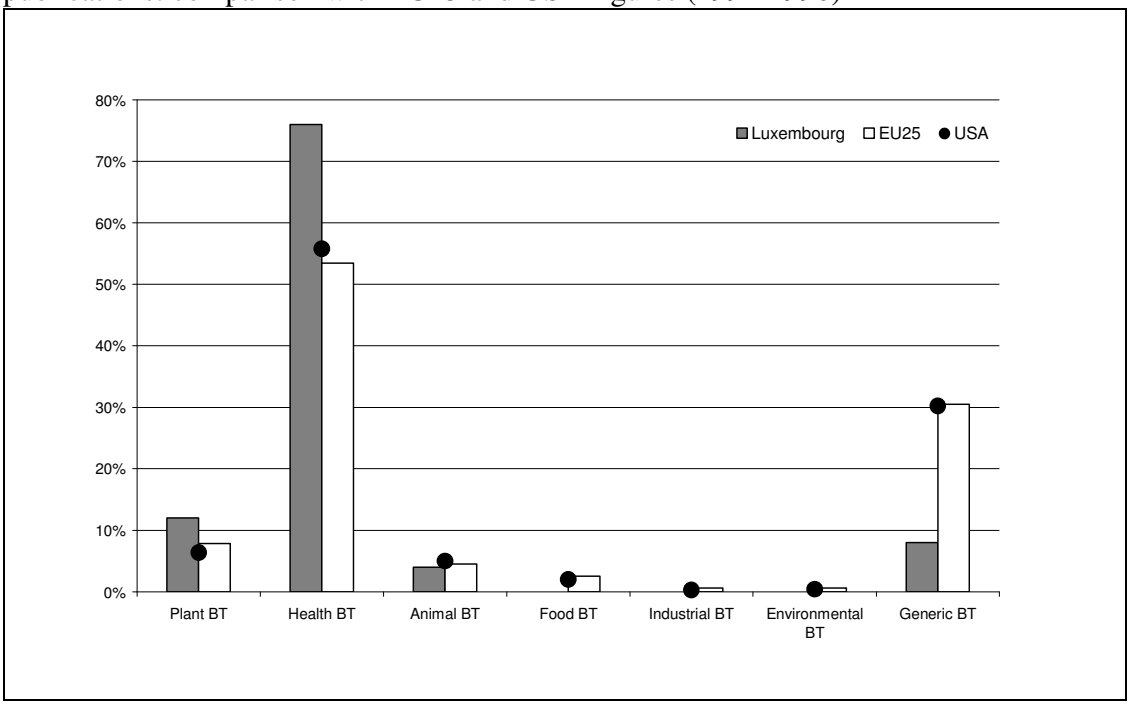
Chart 3.1. Luxembourg biotechnology knowledge base indicators: comparison with EU25 and USA figures in three periods (index value)



Source: BioPolis Research
Data: Science Citation Index

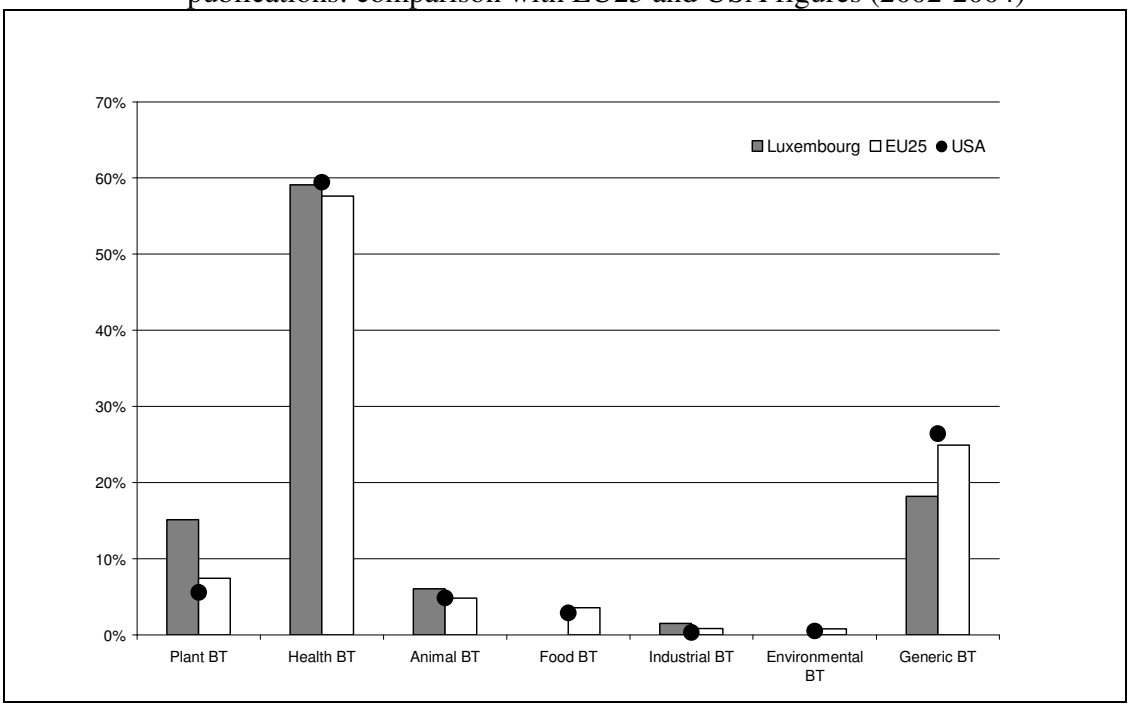
Luxembourgian biotechnology publications are especially numerous in the field of human health. If we compare figures for the periods 1994-1996 and 2002-2004, the picture does not significantly change. Despite showing a decrease from 76% to 59% over the 10-year period, human health biotechnology remains the most significant subfield. The share of generic biotechnology increased from 8% to 18% in the ten-year period. Plant biotechnology, animal biotechnology and industrial biotechnology all had a slight increase, while food biotechnology and environmental biotechnology remained at zero. Charts 3.2.1 and 3.2.2 show the distribution of biotechnology publications across various research fields in Luxembourg, the USA and EU25 in the periods 1994-1996 and 2002-2004.

Chart 3.2.1. Share of biotechnology subfields, as a percentage of total biotechnology publications: comparison with EU25 and USA figures (1994-1996)



Source: BioPolis Research
Data: Science Citation Index

Chart 3.2.1. Share of biotechnology subfields, as a percentage of total biotechnology publications: comparison with EU25 and USA figures (2002-2004)

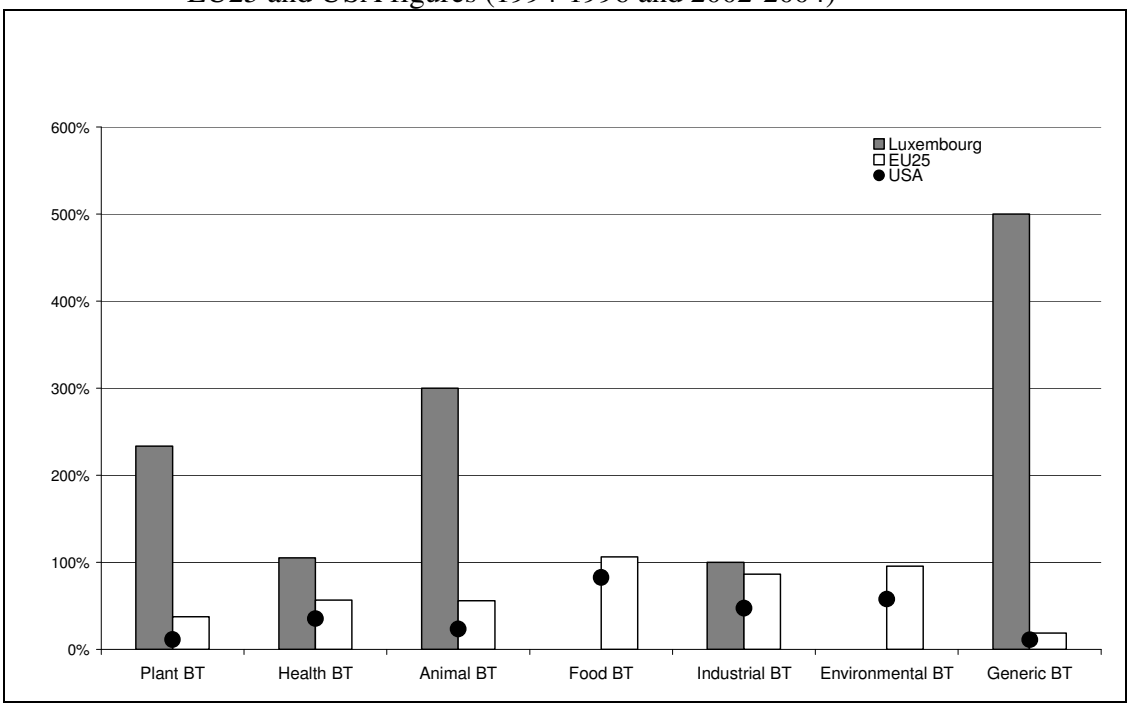


Source: BioPolis Research

Data: Science Citation Index

In the period between 1994-1996 and 2002-2004, the growth rate of biotechnology publications in various subfields was higher in Luxembourg than in both the EU25 and USA, except in the fields of food biotechnology and environment biotechnology where Luxembourg has no activity. This is mainly due to Luxembourg's relatively low starting base. Publications in generic biotechnology grew by 500%, far more than in the USA and EU25 (Chart 3.3). Other growth areas include: animal biotechnology (300%), plant biotechnology (233%), health biotechnology (105%) and industrial biotechnology (100%). The growth rates in the animal and plant subfields are particularly surprising considering that agriculture only contributes 0.73% to Luxembourg's GVA (see section 1.1). They indicate that, despite its late start, biotechnology R&D is being vigorously pursued.

Chart 3.3 Growth rates of biotechnology publications, by subfield: comparison with EU25 and USA figures (1994-1996 and 2002-2004)



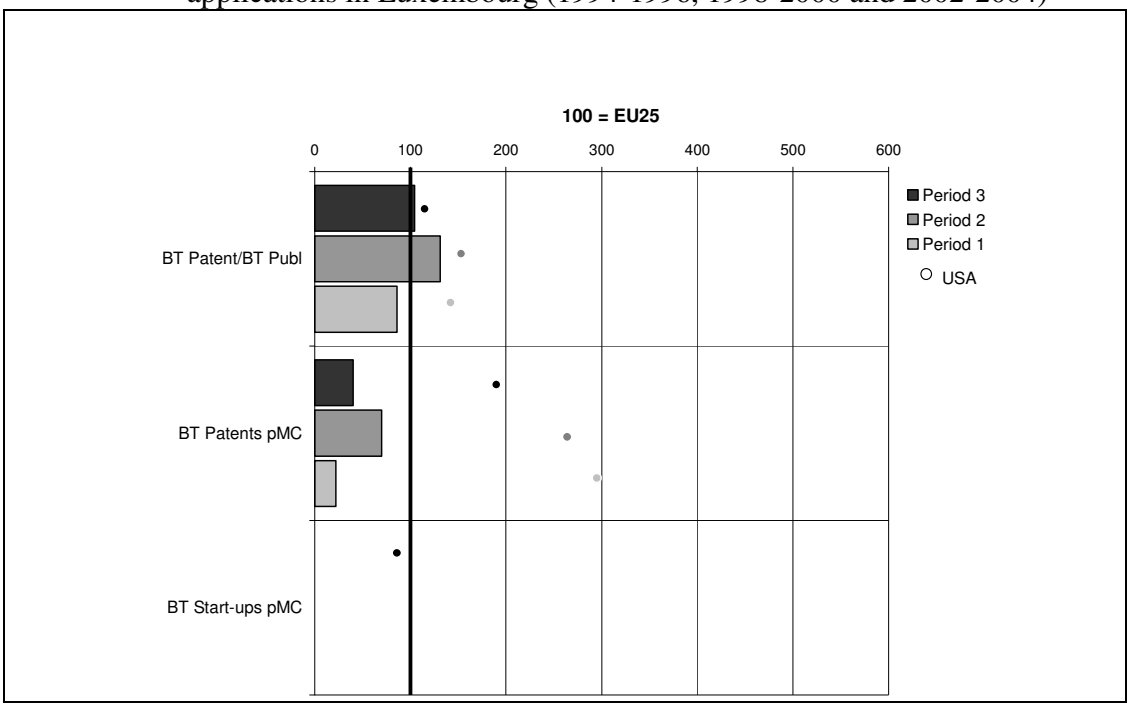
Source: BioPolis Research
Data: Science Citation Index

3.3 Performance in knowledge transmission and application

In terms of biotech patent applications per biotech publication, the output of Luxembourg significantly increased and then decreased over the ten-year time frame (index 86 in 1994-1996; index 131 in 1998-2000; index 105 in 2002-2004). Since the second period, Luxembourg's output is comparable to that of the EU25 but below that of the USA (index 142 to index 115 for the same periods). In terms of biotech patents per million capita, the output of Luxembourg likewise increased and then declined over the ten years (from

index 22 in 1994-1996 to index 53 in 1998-2000 to index 44 in 2002-2004); these figures are far below EU and USA levels for the same periods (index 295 to index 190). As far as biotechnology start-ups are concerned, there is no data for Luxembourg. The relatively low performance in Luxembourg's knowledge transmission and application reflects the country's young R&D sector, which is still in the process of establishing its knowledge base.

Chart 3.4. Performance indicators for biotechnology knowledge transmission and applications in Luxembourg (1994-1996, 1998-2000 and 2002-2004)



Source: BioPolis Research
Data: Science Citation Index

3.4 Industrial development

To date, indicators for industrial development (measured by the number of biotechnology companies pMC, biotech Initial Public Offerings pMC and Venture Capital invested in biotechnology companies EUR pC) do not record any achievements for Luxembourg. The three indicators are not yet applicable to Luxembourg as its biotechnology sector is still very young.

3.5 Market conditions

To date, indicators for market conditions (measured by the number of field trials and approved biomedicines) are absent for Luxembourg. In the period covered by this study,

there were no approved biomedicines in Luxembourg, nor did any field trials take place in the country.

4. Conclusions

4.1 Introduction

This concluding chapter presents a summary of Luxembourg's funding of biotechnology, Details about policy goals promoted, research applications areas funded and activities stimulated through the four FNR programmes are presented in Chapter 2.

4.2 Public funding of biotechnology through non-directed policy instruments

In Luxembourg, public funding of biotechnology research is, according to the definition we use, only available through non-policy-directed funding. Based on available data, Table 4.1 summarises the funds available for biotechnology research through non-directed policy instruments.

Table 4.1 Public funding of biotechnology in Luxembourg, through non-directed instruments, in the period 2002-2005 (in M EUR)

	2002	2003	2004	2005	Total
RESEARCH					
EAU	0.12	0.12	0.12	0.12	0.48
NANO	0.3	0.3	0.3	0.3	1.2
SECAL	N.A.	0.4	0.4	0.4	1.2
BIOSAN/PROVIE	0.95	0.95	0.95	0.95	3.8
Total	1.37	1.77	1.77	1.77	6.68
COMMERCIALISATION					
Biotechnology Institute	n.a.	n.a.	n.a.	n.a.	n.a.
GRAND TOTALS	1.37	1.77	1.77	1.77	6.68

n.a.: not available
Source: BioPolis Research

5. Future developments

Government departments are debating whether or not it is desirable for the national government to promote Luxembourg as an optimum location for biotechnology. Should the government decide to further pursue biotechnology, the Minister of Economic Affairs and Foreign Trade has already made clear that this would require substantial government investments. Moreover, the Minister has reiterated the need to improve social acceptance of biotechnology; facilitate access of biotech companies, particularly SMEs, to venture capital; and strengthen the biotech sector by attracting new companies that are either leaders or potential leaders in industrial development (Krecké, 2006). According to a representative from the Ministry of Economic Affairs and Foreign Trade, if the government decides to stimulate biotechnologies, it is likely to focus on health biotechnology. Immune therapies, diagnostics and research into vaccine development are already prominent in Luxembourg. Therefore, these research activities are likely to be supported in the long term.

Annex 1 List of tables

Annex 2 List of figures and charts

Annex 3 List of contact persons

Mario Grotz and Tom Theves
Ministry of Economic Affairs and Foreign Trade

Robert Kerger
Ministry of Culture, Higher Education and Research

Frank Glod
Fonds National de la Recherche

Robert Kanz
CRP-Health

Paul Schosseler
CRP- Henri Tudor

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Annex 5 Performance raw data

Introduction

This Annex includes the data that was used to develop the indicators discussed in Chapter 3. Chapter 3 describes four sets of indicators used to measure the performance of the national biotechnology system of innovation, in terms of:

1. Creating a knowledge base and supporting the availability of human resources: Charts 3.1, 3.2.1, 3.2.2 and 3.3
2. Knowledge transmission and application: Chart 3.4
3. Industrial development: Chart 3.5
4. Market conditions: Chart 3.6

The indicators aim to capture trends in performance and compare the national situation with that of a reference region. To present trends in performance, most indicators are provided for three or two different time periods, depending on data availability. To avoid capturing erratic trends, each time period includes several years, again depending on data availability. Information on which years have been captured for each period and comments concerning the index used can be found in the last two columns of Table A5.1.

Table A5.1. Performance indicators, charts, comments and time periods

	Indicator	Chart	Comments	Time periods
Ind. 1	Biotech publications per million capita (pMC)	3.1	Index: Reference Region EU25 =100 and US data for comparison	(1) 1994-1996, (2) 1998-2000, (3) 2002-2004
Ind. 2	Biotech publications per BT public R&D expenditure	3.1	Only for those countries included in the inventory Index: Reference Region EU25 =100	BT Pub. 2002-2004 / Total Pub. Expenditure 1994-1998 M Ecu
Ind. 3	BT patents / BT publications	3.4	Index: Reference Region EU25 =100 and US data for comparison	(1) 1994-1996 (2) 1998-2000 (3) 2001-2003
Ind. 4	BT publications / Total pub.	3.1	Index: Reference Region EU25 =100 and US data for comparison	(1) 1994-1996 (2) 1998-2000 (3) 2002-2004
Ind. 5	Citations to BT publications	3.1	Index: Reference Region EU25 =100 and US data for comparison Small country effect	(1) 1994-1998 (3) 2000-2004

	Indicator	Chart	Comments	Time periods
Ind. 6	Graduates in life sciences pMC	3.1	Index: Reference Region EU17 =100 and US data for comparison	(2) 1998 (3) 2002
Ind. 7	BT publications in subfields, as % of total BT publications	3.2.1	Data in % EU25 and US data for comparison	1994-1996
		3.2.2		2002-2004
Ind. 8	Growth rate of BT publications in subfields	3.3	EU25 and US data for comparison Small field effect	Growth rate between 1994-96 (period 1) and 2002-04 (period 3)
Ind. 9	Biotech patent applications pMC	3.4	EU25 and US data for comparison	(1) 1994-1996 (2) 1998-2000 (3) 2001-2003
Ind. 10	Number of biotechnology companies pMC	3.5	European (data available) and US data for comparison	(2) 2001 (3) 2004
Ind. 11	Number of biotech start-ups pMC	3.4	European (data available) and US data for comparison	(3) 2001-2003 (only one period)
Ind. 12	Number of biotech IPOs pMC	3.5	European (data available) and US data for comparison	(3) 2002-2005
Ind. 13	Venture capital in € pC	3.5	European (data available) and US data for comparison	(2) 2002 (3) 2004
Ind. 14	BT acceptance index	No Chart - Discussed in text of chapter 3	Source: BT Policy Benchmarking 2005. The biotechnology acceptance index is a composite index and draws on questions Q.12, Q.13.1 and Q14.01 and Q14.09 of the Eurobarometer 58.0	2002
Ind. 15	Eurobarometer 225	No Chart - discussed in text of chapter 3	See section 3.3 and sections 3.4.1, 3.4.2, and 3.4.3 of the Special Eurobarometer 225[1]	2005
Ind. 16	Biomedicines	3.6	Source: BT Policy Benchmarking 2005 Index: Reference Region EU15 =100 US data for	1995-2002

[1] http://europa.eu.int/comm/public_opinion/archives/ebs/ebs_225_report_en.pdf

	Indicator	Chart	Comments	Time periods
			comparison	
Ind. 17	Field trials	3.6	Source: Biotechnology Innovation Scoreboard 2002 Index: Reference Region EU15 =100 US data for comparison	1996-2001

The following methodological issues are related to some of the indicators:

- Indicator 3 (Patent BT / Publications BT) replaces the indicator *BT publications basic research/ BT publications applied research*. Results of the EPOHITE project have shown that the original indicator does not differ significantly in the case of old EU member states. This might be the result of methodological problems associated with the indicator, since the definition of basic and applied research is based on a journal classification made by SCI. The explanatory power of this indicator is therefore questionable.
- To calculate the citation rate first the publications for the period 1994-1996 (set 1) were searched and all the publications in 1994-1998 that cited any publications in set 1 (set 2). Citation rate has been calculated by (number of publications in set 2) / (number of publications in set 1). However, many of the articles in set 2 cited not only one article in set 1 and these duplicated citations are not taken into account in our calculation. For example, if there are 2 articles in set 1 and they each has one citation but cited by the same article, there is only 1 article in set 2. The citation rate for the 2 articles in set 1 is 0.5 instead of 1. This depreciation is more obvious in countries with more publications such as USA and EU25 since the possibility to cite multiple articles in set 1 is large. Accordingly the citation rates of USA and EU25 are a bit underestimated.
- The indicator 'Citations to BT publications' seems to have a 'small country effect' bias. Small countries show a relatively large citation rate. A possible explanation might be that, as far as number of publications is concerned, larger countries usually have a larger 'middle quality' share of research results (in terms of impact) while smaller countries usually have a 'low in number but good in quality' publications impact. This can be explained by the concentration of resources allocated to selected research groups in small countries. Small countries may concentrate resources in outstanding research units. Accordingly, fewer publications may have greater impact.
- The EU25=100 index is applicable in the indicator 'Graduates in life sciences pMC' since data was only available for 17 member states.
- For those countries starting from zero in period 1 (1994/1996), the growth rate of BT publications in subfields was set to 100% if the number of publications in period 3 (2002-2004) was larger than zero. On the other hand, if the country reduced the number of publications to zero in the period 2002-2004, the growth rate was -100%.Given that a relative growth rate was used, small fields tended to

have relatively larger growth rates.

- To benchmark each country we chose EU25 (or EU15 if data was not fully available) as the reference region. In those cases where data for EU25 or EU15 were not available, the reference corresponds to the sum of national data available. Moreover, to ease the presentation of indicators with different scales in a given chart, an index value was used.

Raw data for Charts in chapter 3

Raw data for Chart 3.1. BT publications per million capita (pMC): absolute and indexed values

	BT publications			Population (million)		
	94-96	**98-00**	**02-04**	**1996**	**2000**	**2004**
EU25	97521	128716	145646	447	451	457
Luxembourg	23	66	64	0	0	0
USA	119802	135508	154402	264	276	292
	BT publications/pMC			**Index EU25=100**		
	94-96	**98-00**	**02-04**	**94-96**	**98-00**	**02-04**
EU25	218	285	319	100	100	100
Luxembourg	56	152	142	26	53	44
USA	454	492	529	208	172	166

Source: BioPolis Research
Publications: SCI
Population: EUROSTAT and OECD

Raw data for Chart 3.1. BT publications per BT public R&D expenditure

	BT Publi-cations	**Non-policy-directed funding**	**Policy-directed funding**		**Total public spending on BT (Mecu)**	**BT Publications/ Mecu BT public expenditure**	**Index**
			Biotech specific	**Generic**			
	2002-2004	**1994-1998**	**1994-1998**	**1994-1998**	**1994-1998**	**2002-2004/ 1994-1998**	
EU25	145646				n.a.		
Luxembourg	64				n.a.		n.a.
USA	154402				n.a.		n.a.

Source: BioPolis Research
Publications: SCI
BT public expenditures in research: Inventory Project, Table 3.4 Executive Summary

Raw data for Chart 3.1. BT publications, as share of total publications: absolute and indexed values

	BT publications			Total publications		
	94-96	**98-00**	**02-04**	**94-96**	**98-00**	**02-04**
EU25	97521	128716	145646	860652	1024327	1117392
Luxembourg	23	66	64	198	308	461
USA	119802	135508	154402	889506	941191	1045894
	Share of BT publication			**Index EU25=100**		
	94-96	**98-00**	**02-04**	**94-96**	**98-00**	**02-04**
EU25	11%	13%	13%	100	100	100
Luxembourg	12%	21%	14%	103	171	107
USA	13%	14%	15%	119	115	113

Source: BioPolis Research
Publications: SCI

Raw data for Chart 3.1. Citations to BT publications: absolute and indexed values

	Citations to BT publications		Index EU25=100	
	94-98	**00-04**	**94-98**	**00-04**
EU25	6.14	7.38	100	100
Luxembourg	3.87	5.89	63	81
USA	6.39	8.54	104	117

Source: BioPolis Researcg
Data source Citations: SCI

Raw data for Chart 3.1. Graduates in life sciences pMC: absolute and indexed values

	Graduates in Life Sciences		Population (million)	
	1998 / 1999	**2002**	**1998 / 1999**	**2002**
EU17	46859**	81316	552**	431
Luxembourg	n.a.	n.a.	0*	0
USA	75253*	70950	276*	288
	Graduates pMC		**Index EU17=100**	
	1998 / 1999	**2002**	**1998 / 1999**	**2002**
EU17	91**	189	100	100
Luxembourg	n.a.	n.a.	n.a.	n.a.
USA	273*	246	321	131

Index EU17=100 for 1998 is EU-16, because for Portugal no data availiable
* data for 1998; ** data for 1999
Source: BioPolis Research
Population source for US OECD
OECD Education Database

Raw data for Chart 3.2.1. BT publications in subfields, as share of total number of BT publications for the period 1994-1996

	1994-1996							
	Total	**Plant**	**Health**	**Animal**	**Food**	**Indus-trial**	**Environ-mental**	**Generic**
EU25	100%	8%	53%	5%	3%	1%	1%	30%
Luxembourg	100%	12%	76%	4%	0%	0%	0%	8%
USA	100%	6%	56%	5%	2%	0%	0%	30%

Source: BioPolis Research
Publications: SCI

Raw data for Chart 3.2.2. BT publications in subfields, as share of total number of BT publications for the period 2002-2004

	2002-2004							
	Total	**Plant**	**Health**	**Animal**	**Food**	**Indus-trial**	**Environ-mental**	**Generic**
EU25	100%	7%	58%	5%	4%	1%	1%	25%
Luxembourg	100%	15%	59%	6%	0%	2%	0%	18%
USA	100%	6%	59%	5%	3%	0%	1%	26%

Source: BioPolis Research
Publications: SCI

Raw data for Chart 3.2.1 BT publications in subfields for the period 1994-1996

	1994-1996							
	Total	**Plant**	**Health**	**Animal**	**Food**	**Indus-trial**	**Environ-mental**	**Generic**
EU25	97217	7629	51944	4375	2434	624	576	29635
Luxembourg	25	3	19	1	0	0	0	2
USA	111686	7118	62274	5580	2230	296	459	33729

Source: BioPolis Research
Publications: SCI

Raw data for Chart 3.2.2 BT publications in subfields for the period 2002-2004

	2002-2004							
	Total	**Plant**	**Health**	**Animal**	**Food**	**Indus-trial**	**Environ-mental**	**Generic**
EU25	140984	10494	81220	6821	5017	1162	1126	35144
Luxembourg	66	10	39	4	0	1	0	12
USA	141680	7910	84234	6872	4070	436	724	37434

Source: BioPolis Research
Publications: SCI

Raw data for Chart 3.3. Growth rate of BT publications in subfields between 1994-96 and 2002-04

	1994-1996/2002-2004						
	Plant	**Health**	**Animal**	**Food**	**Industrial**	**Environ-mental**	**Generic**
EU25	38%	56%	56%	106%	86%	95%	19%
Luxembourg	233%	105%	300%	0%	100%	0%	500%
USA	11%	35%	23%	83%	47%	58%	11%

Note: For those countries starting from 0 in period 94/96, the growth rate was set to 100% no matter how large the number in period 2002/2004 is. On the other hand, if the country reduces the number of publications to 0 in period 2002/2004, the growth rate is -100%.
Source: BioPolis Research
Publications: SCI

Raw data for Chart 3.4. BT Patents pMC: absolute and indexed values

	BT patents			**Population (million)**		
	94-96	**98-00**	**01-03**	**1996**	**2000**	**2003**
EU25	4924	8921	10119	447	451	455
Luxembourg	1	6	4	0	0	0
USA	8590	14396	12348	264	276	292*
	BT patents/pMC			**Index**		
	94-96	**98-00**	**01-03**	**94-96**	**98-00**	**01-03**
EU25	11	20	22	100	100	100
Luxembourg	2	14	9	22	70	40
USA	33	52	42	295	264	190

Source: BioPolis Research
Publications: SCI
Patents: Questel Orbit

Raw data for Chart 3.4. BT Patents per BT publications: absolute and indexed values

	BT patents			**BT publications**		
	94-96	**98-00**	**01-03**	**94-96**	**98-00**	**01-03**
EU25	4924	8921	10119	97521	128716	140219
Luxembourg	1	6	4	23	66	53
USA	8590	14396	12348	119802	135508	148853
	BT patents/ BT publications			**Index EU25=100**		
	94-96	**98-00**	**01-03**	**94-96**	**98-00**	**01-03**
EU25	0.05	0.07	0.07	100	100	100
Luxembourg	0.04	0.09	0.08	86	131	105
USA	0.07	0.11	0.08	142	153	115

Source: BioPolis Research
Publications SCI
Patents Questel Orbit

Raw data for Chart 3.5. Number of BT companies pMC for the period 2001-2004: absolute and indexed value

	BT companies				Population in T			
	2001	**2002**	**2003**	**2004**	**2001**	**2002**	**2003**	**2004**
Europe	1879	1878	1861	1815	452016	452641	454580	456863
EU Available	1643	1650	1782	1605	319337	319484	408602	322210
Luxembourg	n.a.	n.a.	n.a.	n.a.				
USA	1457	1472	1473	1444	285102	287941	290789	291685
	BT companies pMC				**Index**			
	2001	**2002**	**2003**	**2004**	**2001**	**2002**	**2003**	**2004**
Europe								
EU Available	5	5	4	5	100	100	100	100
Luxembourg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
USA	5.11	5.11	5.07	4.95	99	99	116	99

Note: EU Available is the result of the sum of available EU member states
Source: BioPolis Research
Biotech companies: E&Y Beyond Borders 2002, 2003, 2004, 2005, EuropaBio

Raw data for Chart 3.5. BT start-ups pMC for period 2001-2003 and year 2003: absolute and indexed values

	BT start-ups		Population in T	
	2001-2003	**2003**	**2003**	
Europe (EU 15 - Cyprus - Greece + Norway + Switzerland)	523	132	367051	
Luxembourg	n.a.	n.a.		
USA	355	83	290789	
	Biotech start-up/pMC	**Index**	**Biotech start-up/pMC**	**Index**
	2001-2003	**2001-2003**	**2003**	**2003**
Europe (EU 15 - Cyprus - Greece + Norway + Switzerland)	1.4	100	0,36	100
Luxembourg	n.a.	n.a.	n.a.	n.a.
USA	1.2	86	0.29	79

Source: BioPolis Research
Start-ups: EuropaBio

Raw data for Chart 3.5. Number of BT IPO's pMC: absolute and indexed values

	BT IPO	Population T				
	2002-2005	2002	2003	2004	2005	2002-2005
EU Availiable	29	452927	454869	457154	461593	456636
Luxembourg	0	444	448	452	455	450
USA	52	287941	290789	291685		290138

	IPO /pMC	Index
	2002-2005	2002-2005
EU Availiable	0.00	100
Luxembourg	0.00	0
USA	0.00	282

Note: EU Available is the result of the sum of available EU member states
Source: BioPolis Research
IPO data: E&Y 2002-2005, London Stock Exchange, Frankfurt Stock Exchange, Euronext, Nasdaq, Burril & Company

Raw data for Chart 3.5. Venture capital pC: absolute and indexed values

	Venture capital in biotechnology companies M€			Population in T		
	2002	2002	2002	2002	2003	2004
Europe	1100	920	2800			
EU Availiable	890	883	1111	315584	319663	325131
Luxembourg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
USA	2288	2498	2855	287941	290789	291685
	Venture capital in €/pC			Index		
	2002	2003	2004	2002	2003	2004
Europe						
EU Availiable	2.8	2.8	3.4	100	100	100
Luxembourg	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
USA	8	9	10	282	311	286

Source: BioPolis Research
VC data: E&Y Beyond Borders 2002, 2003, 2004, 2005

Raw data for Chart 3.6. Number of Biomedicines pMC

	Biomedicines	Population (Million)	Biomedicines / pMC	Index
	1995-2002	2002		1995-2002
EU15	39	378	0.10	100
Luxembourg	0	0	0.00	0
USA	115	289	0.40	387

Note: EU 15 is the result of the sum of the 15 old EU member states
Source: BioPolis Research
Number of medicines: Benchmarking of public biotechnology policy 2005

Raw data for Chart 3.6. Number of field trials pMC

	Field trials	Population in M	Field trials pMC	Index
	1996-2001	2001	1996-2001	1996-2001
EU15	1334	379	4	100
Luxembourg	n.a.	0	n.a.	n.a.
USA	6745	278	24	688

Note: EU 15 is the result of the sum of the 15 old EU member states
Source: BioPolis Research
Field trials: Biotechnology Innovation Scoreboard 2002

Raw data for biotechnology acceptance. Data are mentioned in the text of Chapter 3.

BT acceptance index 2002		
	Index average	N (sample size)
EU - 15*	100.29	16828
Luxemburg	101.58	599

*Weighted Average according to the weight "W13" of the Eurobarometer 58.2, which considers population differences among countries and corrects for inconsistencies in the national samples
Source: BioPolis Research
BT acceptance index: Benchmarking of public biotechnology policy 2005

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EUROSTAT: http://epp.eurostat.cec.eu.int/

OECD Education Database: http://www.oecd.org/

OECD Statistics: http://www.oecd.org/

STN International: http://www.stn-international.de/

Questel Orbit: http://www.questel.orbit.com/index.htm

Annex 6 Abbreviations

BIOSAN Programme	Biotechnology and Health
CD PME	Société Luxembourgeoise de Capital-Développement pour les PME SA
CNE	National Advisory Commission of Ethics for Health and Life Sciences
CR Santec	Resource Centre for Health Care Technologies
CREBS	Unit for Research on the Environment and Biotechnology
CRP	Public Research Institutes
EAU Programme	Sustainable management of water resources
EUREFI	Cross-Border Development Fund
FEDIL	Federation of Luxembourg Industrialists
FNR	National Fund for Research
LBMAGM	Laboratory of Molecular Biology, Genetics and Modelling
LNS	National Health Laboratory
Luxinnovation	National Agency for the Promotion of Innovation and Research
MAVD	Ministry of Agriculture, Viniculture and Rural Development
NANO Programme	New materials and nanotechnology
PROVIE Programme	Medical Aspects of Ageing
RCMS	Research into Cancer and Blood Diseases
SLIAPMB	StraLux Laboratory of Immunogenetics, Allergology and Plant Molecular Biology
SNCI	Société Nationale de Crédit et d'Investissement