FNR Foresight Final report

National Priorities for Public Research

and Other Findings

June 2007

Readers Guide to the Foresight Report

Predicting the future is a risky business and foresight is not a crystal ball permitting a definitive look into future. The objective of foresight is to compile relevant hints and existing knowledge about the state-of-the-art of scientific and technological development. This knowledge minimizes deficits in awareness and perception and offers a long-term orientation on basis of a systematic approach. The significance of its results is not at all reduced to an illustration of the present development status of research and technology areas, which are seen as relevant. Foresight aims to embed these developments into the broader perspective of societal and global changes. At the same time the results of a foresight-process reflect converging as well as diverging interests, perspectives and assessments of the actors of the national innovation system. Therefore Foresight is one answer to the needs of decision makers in a world becoming more and more dynamic and complex.

The Foresight report presents the results of the discourses and analysis conducted in the frame of the exercise by a large number of national and international research experts and stakeholders of public research in Luxembourg.

The report is structured as shown in the following table:

Chapter	**Description**
Executive Summary	Summarises the process and the main findings
Introduction	Presents the context, scope and rational of the Foresight exercise
Presentation of Process	Describes the outline of the process
Role of Science	Portrays the current view in the literature on the role of the various aspects of research and science in society and the innovation process
Challenges Stakeholder meeting	Presents the main challenges facing Luxembourg in the next decade which can in part be addressed by public research
General SWOT	Presents the general strengths, weaknesses, opportunities, and threats of public research in Luxembourg as seen by the stakeholders of public research
National Research Priorities	Describes National Research Priority candidates, including relevant research issues for Luxembourg and specific topics concerning the implementation of the domains in Luxembourg
Assessment of National Research Priorities	Presents the assessment of the National Research Priorities along a set of specific criteria, preparing the ground for the national priority setting by the government and the further prioritization of these research domains.
Conclusion	Summarises the findings of the FNR Foresight exercise
Annexes	- Annex 1 presents general definitions of the research domains - Annex 2 describes specific Technology Platforms required for the implementation of some research priorities and the building of an attractive research environment - Annex 3 describes the Priorities in short form (“Fiches”) - Annex 4 presents international trends in R&D - Annex 5 lists the participants involved in the FNR Foresight.

The report serves as a basis for the advice of the Board of Administrators and the Scientific Council of the FNR to the Ministry of Culture, Higher Education, and Research of Luxembourg concerning the selection of national research priorities. The report was presented to the Ministry on the 18th of June 2007.

Next steps:

The intentions of the Ministry of Culture, Higher Education, and Research is to use the FNR advice as a basis for its decisions on the funding for the future research directions and the governance of the research centres (through performance contracts etc). The Ministry will accompany the decision making process with consultation of various other Ministries.

Final Report of the FNR Foresight Exercise Phase II

Luxembourg, June 2007

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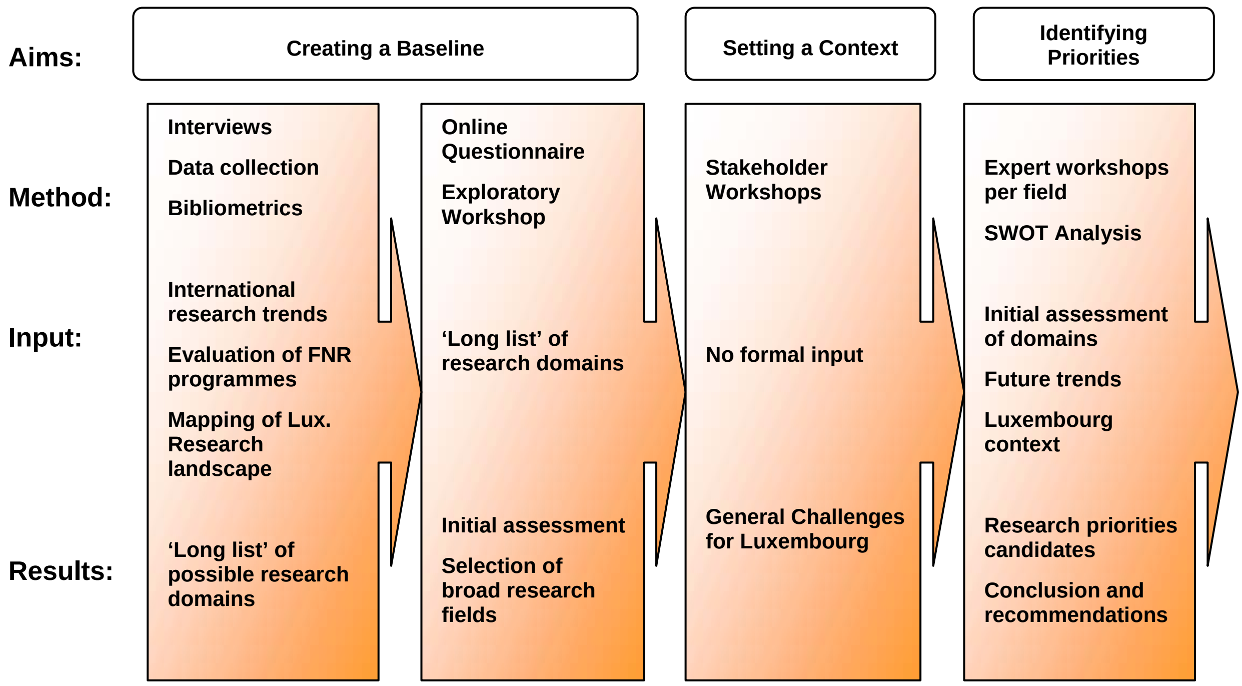
Executive Summary

Luxembourg public research has undergone major shifts in recent years and is facing a period of important transformations in the near future. Key developments are the creation of the University of Luxembourg in 2003, the partial relocation of the public research institutions to the City of Sciences[1], planned for 2011, and the reform of the governance of STI, in response to the OECD analysis of the Luxembourg innovation system. Remarkable has also been the evolution in government spending on public R&D in the last decade (approximately a 4.5 fold increase to 110 M€ in 2006). This trend is set to continue as the government is showing strong commitment to doubling public spending by 2009 in view of the Lisbon targets.

Despite major investments a small country like Luxembourg will only have very limited resources for research when compared to the global spend and it is therefore imperative to focus the budget increases on a limited number of promising research areas. Additionally a strategic approach in priority setting is vital for the development and implementation of public R&D policy.

The FNR launched a foresight exercise in December 2005 with the objective to mobilise a wide range of stakeholders to define and assess the most relevant research priorities for Luxembourg. To this end the exercise engaged with more than 300 researchers, company representatives and public administrators in a range of activities and events designed to identify long term trends in research.

The foresight approach is set out in the diagram below:



[1] Referred to as the « Cité des Sciences, de l'Innovation et de la Recherche ».

Models of Science Production and Exploitation

Discussions in the workshops often revolved around whether basic research should be undertaken in Luxembourg and whether it would not be more effective to focus on implementing ideas generated abroad ('free-riding strategy'). This vision is based on a linear view of the scientific process, in which codified results are freely available and can easily be exploited in the free-riding strategy. As the science, technology and innovation system is nowadays viewed as a complex and constantly changing network of researchers, organisations and activities, the linear model is taken as inaccurate. Appropriate capacities and skills are required to form part of these networks and a national capability to understand the latest research and its importance is needed for the exploitation of science and for influencing the overall directions of research.

General challenges of Luxembourg

The participants of the stakeholder workshop identified a set of major challenges facing Luxembourg society and economy in the next 10 years. As some of these challenges may be addressed by public sector research, these have been considered in the experts' discussions and the selection of the research priorities.

Societal Changes:

- The educational system needs to better respond to the societal and economic needs of the complex Luxembourg multi-lingual and multi-cultural society.
- With an immigrant population of 39% and a large share of cross-border workers, Luxembourg is facing the threat of the development of "parallel societies" and has to tackle the issue of the social and political participation of immigrants.
- The changing social and demographic fabric will have consequences on the social (protection) system, cross-border interrelations of the social systems, public households, the labour market and intergenerational relations.
- Chronic diseases are on the rise due to an ageing population, "unhealthy" nutritional habits and environmental problems. Health costs are rising, impacting on the social system and the economy.

Competitiveness and sustainable economic growth:

- In order to achieve sustained economic growth, Luxembourg has to develop new competence niches in emerging fields such as biotechnologies and services (e.g. logistics), next to the existing growth sectors finances, and manufacturing industry.
- Ecological issues can be exploited as sources for economic growth and can be seen as business opportunities (e.g. energy efficiency schemes).
- Luxembourg has to build scientific excellence, develop, attract and retain highly skilled domestic and foreign human resources in order to achieve competitiveness in research and development.

- Additional stumbling blocks for economic growth are: Land prices and scarcity of real estate, bottlenecks in the transportation infrastructure, and an external political context increasingly beyond immediate influence of the Luxembourg government (e.g. EU directives).

Environmental challenges:

- Luxembourg is facing the challenge to reduce energy consumption and to diversify its energy sources. Both have tremendous impacts on transport, on production and on pollution. Increasing energy efficiency is vital since "home-grown" energy sources will not enable Luxembourg to be self-sufficient.
- Luxembourg faces scarcity of clean water with the rise of water demand due to economic growth and an increasing population. Another important potential threat is the increasing risk of floods mainly due to urbanisation and the effects of climate change on the availability of water resources, on weather hazards and increasing temperatures.
- The political reality of the Kyoto penalties already has a major impact on public finances.
- An important topic is the "risk of unintended consequences" associated with policy decisions, given the fact that our basic scientific understanding of ecological dynamics in Luxembourg is limited.

General SWOT of Luxembourg public research environment

By drawing upon the comments of the participants, several strengths, weaknesses, opportunities and threats of the Luxembourg public research environment in general have been identified. Addressing the issues mentioned below is a prerequisite to develop a favourable environment for Luxembourg public research and contribute to the success of public R&D policy.

Strengths:

- Government commitment and increase of investment in R&D in the next years, with the aim to strengthen and develop the public research base.
- Existing research competences with strong international networks.
- Openness and central geographical position of Luxembourg in Europe, providing a unique environment for students and researchers as well as for companies and research institutions.
- Neutral place for R&D investments for foreign companies since these are neither attracted by strong private research clusters nor repelled by too much competition in R&D - due to the low number of local R&D actors in the private sector

Weaknesses:

- Lack of an academic and research tradition resulting in an unattractive environment for researchers and the associated lack of public awareness of the impact of research.
- Deficient strategic orientation and coordination of funding instruments.

- Ill-adapted regulatory framework in human resource sector and uncertain career development for researchers.
- Insufficiently developed networking between stakeholders in research.
- Limited resources despite large public spending increase: need to focus on a limited number of research fields in order to reach critical mass, international visibility and/or socio-economic impact.
- Inefficient valorisation of research results and contribution to the development to the national innovation system.

Opportunities:

- Major development in the public research sector (creation of the 'City of Sciences') and availability of substantial funding.
- Incentives to develop human resources in public research by building on the existing grant allocation system and the FNR ATTRACT programme.
- Stakeholders support for the recommendations from the *OECD Review of Luxembourg's Innovation Policy.*
- Attractive framework for companies: establishment of a strong public research environment besides the already existing assets, e.g. tax legislation, etc.
- Short decision paths enabling rapid and flexible reactions of decision makers to upcoming problems.
- Small number of actors enables close interaction of all stakeholders (public and private research sector, ministries, administrations, research users and foreign experts) in the implementation R&D policy and the establishment of Public-Private Partnerships.
- Role of Luxembourg as a testbed in the Greater Region by integrating tools and methodologies from neighbouring countries.
- Establishment of a strong network with the large community of Luxembourg born researchers living and working abroad.
- Participation in the 7th Framework Programme allowing public research institutions to gain international visibility and integrate into European networks of highest quality.
- Institutionalisation of a foresight culture and formation of networks amongst actors of research.
- Public research may contribute to the objectives of the government's cooperation policy.

Threats:

- Strong international competition for the brightest researchers.
- Challenge for Luxembourg public research to gain visibility and critical mass against strong international competition.

National research priorities

The research priorities presented below are the result of an intense deliberation process of various actors of Luxembourg research, research users and international experts. Future priorities for future public research in Luxembourg were identified based on data on the Luxembourg context, the expertise on the subject matter of the researchers and stakeholders involved in the FNR Foresight process, as well as the consideration of research and technology trends on the international level.

The order of presentation does not constitute a ranking.

Innovation in Services

As the service sector is Luxembourg's most important economic sector, research in the domain Innovation in Services is a national research priority in order to consolidate and improve Luxembourg's international competitiveness.

In particular, in view of the financial sector's predominant role in the economy, public research focusing not only on the macro-economic financial system but also on all kinds of financial subsystems is of high importance for Luxembourg. Future research projects should focus on specific aspects of *developing and improving performance*, with the aim to optimise all kinds of financial sub-systems within the finance industry, and therefore increase or consolidate the attractiveness and competitiveness of Luxembourg as a business-friendly environment in general and of Luxembourg's financial sector in particular.

Furthermore, in order to minimize the risks associated with Luxembourg's specialization in financial services and to ensure the long-term sustainability of the Luxembourg economy, it is necessary that public research helps diversifying the economy and improving Luxembourg's innovation capacity. Public research should determine the right balance between European harmonisation and intergovernmental competition (esp. regarding investment fund law, contract law, company and commercial laws) in order to consolidate Luxembourg's existing legislative advantages, address existing legal constraints or create new sovereignty niches supporting economic development.

Future research should also contribute to facilitating the development and improvement of new, innovative and high added-value (e-)services by addressing aspects like business model innovation, business process efficiency (and flexibility) and business service regulation compliance. Progress in information security and trust management, contributing to consolidating Luxembourg's reputation as a safe harbour for information will further push the development of new services. Research areas like identity and risk management, as well as privacy - areas that should benefit the banking industry - have top priority; but research related to digital rights management is also important as it will benefit Luxembourg's broadcasting industries.

In order to support the development of more convenient personalised services, research aiming at developing and improving the ICT infrastructures for the aggregation and distribution of content - including multimedia applications - is of high importance. An advanced ICT architecture could also lead to improved crisis and disaster management, as well as to intelligent, wireless and mobile integrated ICT applications. Research in this domain will help the private telecommunications sector to become more competitive. The Luxembourg context offers furthermore a particularly promising opportunity to develop multilingual multimedia applications for semantic or lifelong learning tools.

Sustainable Resource Management in Luxembourg

In order to promote a sustainable Luxembourg society and in particular to support the sustainable management of resources, it is of importance to consider the correlations between the different constituents of the environment and to attain an integrative and holistic understanding of the energy and material flows in Luxembourg. The environmental situation has to be analysed and broken down into territorial levels, at which solutions and optimisation strategies can be implemented. This requires comprehensive monitoring and analysis tools for e.g. the water and soil quality, air pollution, etc. Research on territorial development has also to explore the conceptual construction, organisation and practical use of space including geographical, demographic, social, psychological, political, economical, ecological as well as technological aspects, in order to foster sustainable territorial development in urban as well as rural areas. The aim of this innovative approach is to facilitate an informed decision-making and to find long-lasting solutions with the vision of making Luxembourg a showcase for regional sustainability.

Research on biodiversity and ecosystem functions is of great importance due to the social/environmental benefits associated: recent research reveals that loss of biodiversity can impact the functioning of both natural and managed ecosystems and thus reduce their capacity to deliver ecological goods and ecosystem services which are essential to human well-being. Luxembourg should aim at a comprehensive evaluation and monitoring of biodiversity, a better understanding of the impacts of climate change and other anthropogenic influences on ecosystems.

The need for an efficient and sustainable management of water resources in Luxembourg is obvious in the light of the potential threats arising from water pollution, water scarcity, risk of floods and other hazards. Making intelligent and innovative technologies available and finding more efficient solutions in this field in light of the changing environmental parameters - i.e. climate change, new agricultural practices, etc. - will have a direct impact on the quality of water resources and thus an economic payback for Luxembourg.

Providing the country with sufficient energy is seen as one of the most important tasks for Luxembourg in the future. Considering Luxembourg's economic dependencies on energy imports but also the impacts of climate change and the generally limited availability of fossil energies, it is of high importance for Luxembourg to increase energy efficiency as well as the share of regenerative and renewable energy sources and to develop competencies in these fields. Public research should concentrate on energy efficiency technologies related to innovative construction concepts for buildings and co-generation and process optimisation in the industrial sector. Energy from biomass could be a focus in the field of renewable energy sources.

Luxembourg could become a model system for sustainable food production, consumption and resource use through a holistic and integrative approach based on interdisciplinary research efforts. The need for research in this domain has to be seen in the context of the adaptation of Luxembourg's agricultural sector to expected climate changes and to EU regulations. However, positive effects of a healthier nutrition on human well-being and the health care system in Luxembourg should also be considered.

New Functional and Intelligent Materials and Surfaces, and New Sensing Applications

Developing novel knowledge-based materials and surfaces with tailored properties and functions in various applications is seen as a field of extremely high future importance offering a wide range of technological, scientific, and economic opportunities. Luxembourg's research activities in this domain should be application-oriented and should be built on intense collaborations of the public and private research sectors. Synthesis, analysis and processing technologies for high performance and multifunctional or intelligent materials and surfaces on the basis of polymers, semiconductors, composites, ceramics, metals and nano-structured materials are in the focus of this field.

Research on New Sensing Applications based on new sensing effects is very promising for Luxembourg as there is a high market potential for new low-cost sensors. Application fields are seen mainly in the automotive sector but also in the health, environmental and biotechnology sectors. Contributions from the field of nanotechnology, but also from microelectronics, optics, etc. are of very high importance in this domain.

Biomedical Sciences

Biomedical Sciences is a research field of utmost importance for individual and public health issues and for improving quality of life.

Future research in Biomedical Sciences in Luxembourg should aim at improving public health and health care delivery in order to cope with the health challenges Luxembourg is facing in the next 10 years. These challenges arise from the need to adapt the health care system and the increasing health costs due to the rise of chronic and age-related diseases. Research addressing health information and promotion (especially addressing life style diseases and mental health issues), environmental health aspects, as well as the assessment and improvement of the healthcare system is of high socio-economic importance for Luxembourg. Such research will provide information to policy makers and help translate research results into policy-making with the overall objective of contributing to guarantee high quality health services and reducing the burden on the social security system, as well as improving the quality of life.

On the other hand, highest priority should be given to research activities on age-related diseases in a select number of major pathologies like cancer, cardiovascular diseases and neurodegeneration, with high medical need and where significant progress is expected in the next decade. In particular, research on regenerative medicine and tissue engineering is a promising new area of research expected to significantly improve the therapeutic arsenal of so far untreated severe diseases and therefore to help contribute to reduce the additional health care costs due to an ageing population. Tissue engineering in combination with the development of novel materials for bio-devices may furthermore foster the development of a flourishing biomedical industry in Luxembourg.

Last but not least, it is necessary to establish translational biomedical research programs consisting of multidisciplinary teams which foster the collaboration between scientists, engineers and clinicians and hence accelerate the translation of basic research concepts into clinical application.

Overall the national research priority "Biomedical Sciences" should aim at developing a critical mass of researchers and rendering Luxembourg research in the life sciences internationally competitive as well as stimulating the establishment of a biomedical industry in Luxembourg over the next 5-10years.

Labour Market, Educational requirements and Social Protection

Studies on labour market and social security issues are an established field in Luxembourg, but long-term, sustained lines of research on more fundamental questions are lacking, e. g. about the functioning of labour supply and demand, new work models or educational issues and social protection issues related to the labour market. Apart from statutory or contracted studies, researchers should be in the position to go beyond only adapting foreign methodologies and to consider longer time horizons.

Identities, Diversity and Integration

Research on identity, ethnic, cultural, and language diversity and integration addresses characteristics which distinguish Luxembourg from its neighbours making it a test bed of European integration – and of social studies. Concepts like "identity", "diversity", and "integration" seen in the context of a multicultural and multilingual society with strong immigration are both concrete enough to allow for interesting and productive research and flexible enough to foster interdisciplinary synergies. A research priority in this field with long-term basic funding could stimulate a broad range of activities in the social sciences and humanities.

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Technology Platforms

Although the subject of technological platforms was not explicitly addressed in the workshops, certain platform requirements were highlighted in the Foresight exercise as necessary conditions for specific research priorities. Technology platforms allow for the cost-efficient and expert use of expensive equipment and infrastructure.

The following platforms were deemed necessary:

Modelling and Simulation

A particular need for high performance scientific computing and powerful computation infrastructure was expressed by the experts in material sciences. The platform should operate as an 'intelligent service provider' to public research and the private sector and thus act as a dialogue platform between the two sectors. Additional domains than can draw on this expertise are found in environmental sciences (e.g. modelling in climate change and resource management) and the life sciences (e.g. bioinformatics).

Information Infrastructure

The requirement for a central infrastructure acquiring and managing scientific information (scientific literature, publication licences, searchable databases) housed at the National Library was expressed in the exercise. This infrastructure ought to be a repository of (printed) scientific material produced at a national level and facilitate access to existing material through digitisation and meta-data association.

Tissue Bank

The availability of human material is often a limiting factor for biomedical research. A systematic collection of human samples of tissue, cells or body fluids based on state-of-the-art protocols for collecting, conditioning and storing biological material, and guarantying its traceability through association of anonymous donor data would be an invaluable asset to biomedical research in Luxembourg and an important factor contributing to the activeness of Luxembourg as a location for the biotechnology industry.

Other Technology Platforms like Proteomics, Genomics, etc.

Further steps towards national priority setting by the government

All the priorities listed above are deemed of high importance for Luxembourg. Nevertheless there are distinctions in their impacts on the economy, society, the environment, in their budgetary requirements, etc. If further prioritisation is thought to be necessary, this report aims to prepare the ground for an objective and transparent national priority setting by the government by presenting the assessment of these priorities along a set of specific criteria. This should allow for taking into account the scientific potential of the research domains (state-of-the art in Luxembourg, possibility for Luxembourg research to become internationally competitive within the next ten years, etc.) as well as socio-economic and ecological interests and the potential for the research domains to meet these demands.

The methodology used for assessing the priorities and the 11 criteria used is presented in chapter 2.4. Chapter 7 presents the results of the assessment of each priority along the 11 criteria defined in table form, as well as overall comparison tables.

This criteria table does not constitute an absolute assessment ranking the priorities, but provides together with the detailed analysis of the priorities a sound and an (as far as possible) objective basis for further prioritization by policy-making.

Conclusions

In addition to the research priorities presented above, the Foresight exercise has started building the scaffolds of networks between the various actors of research in Luxembourg (researchers, administrators, NGOs, expatriates, etc.) and thus provides the platforms for future dialogue on the subject of implementing the Foresight findings. With the innovation process being distributed and network-based (replacing the previous 'linear model'), the wiring-up of the actors in research forms the basis for an efficient dissemination and valorisation of public research results. The networks between the researchers forged through the process are vital for setting up the interdisciplinary research seen as central to many of the research priorities.

The Foresight exercise has found large acceptance with the participants of the exercise and a foresight culture has been seeded. The momentum and networks built should be exploited in the implementation phases of the Foresight results and foresight approaches should be drawn upon when developing science policy and when revisiting research priorities in the future. Careful attention has now to be given to the implementation of the foresight results in order to make public R&D policy a success.

1. Introduction

1.1 The Luxembourg context

It is fair to say that the Luxembourg research system and its evolution in recent years are unique in Europe. Before the 1980s, Luxembourg lacked a science, technology and innovation policy in the public sector. As for industrial R&D, policy was for a long time dominated by the steel industry. A key feature of the Luxembourg research landscape is the important role played by the private sector with a gross expenditure on R&D of 1.58% of GDP in 2003[2] primarily concentrated in a small number of R&D centres of large companies such as Goodyear and Delphi.

A first step in relation to innovation policy was the establishment in 1984 of Luxinnovation, an agency for supporting innovation, in particular in the SME sector. However, a more fully-fledged science, technology and innovation (STI) policy began with the enactment of the Framework Law on public sector research in 1987, leading to the establishment of several public research centres (CRPs). The missions of these centres have been particularly oriented towards close cooperation with the private sector in fields with high socio-economic impact potential.[3] It was only in the year 2003, after many years of discussion, that the University of Luxembourg was founded, constituting the latest aspect in the development of an institutional research framework and representing a change of paradigms in Luxembourg's higher education system, with students now being able to undertake their studies in the country.

With the increased recognition of the role of research and innovation in contributing towards the future development of the country, the Luxembourg government decided in 1999 to increase the level of publicly funded research. From there, the government went on to develop a focused STI policy by creating relevant public sector institutions. Thus, the Ministry of Culture, Higher Education and Research (MCHER) was established in 1999 as the key policy centre with respect to Luxembourg research. In addition the National Research Fund (FNR) was created to distribute prioritised funding for multi-annual research programmes[4]. As a response to the low intensity of public research (0.08% of GDP in 1999), the Government increased spending on public R&D to 0.3% during the period from 1999 to 2004. Figure 1 outlines the increase in public funding for public R&D in millions of euros. It also demonstrates the growing level of funding allocated to the FNR since its establishment in 1999.

In autumn 2005 the Luxembourg government published the "National Plan for Innovation and Full Employment 2005-2008" which reiterated the government's strong commitment to the Lisbon strategy and the Barcelona targets, creating the basis for policy making and priority setting in the next years. In view of this renewed commitment, the government intends to increase public spending to approximately 220M€ in 2009. These unprecedented budget increases possibly place Luxembourg in a unique position amongst its partners in Europe.

[2] Private R&D expenditure amounts thus to 88% of the national R&D expenditure and represents around 1200 researchers FTE (Full Time Employment).

[3] The centers employ a total of 450 FTE researchers with an annual budget of 30.8 M€ (2004).

[4] The annual budget of the FNR is approximately 15 M€ (2006).

In addition to this, major investments in institutional infrastructures are taking place, namely the relocation of public research centres and part of the newly established University of Luxembourg to create the so-called City of Sciences[5] in the year 2011. This investment amounts to approximately 650 M€.

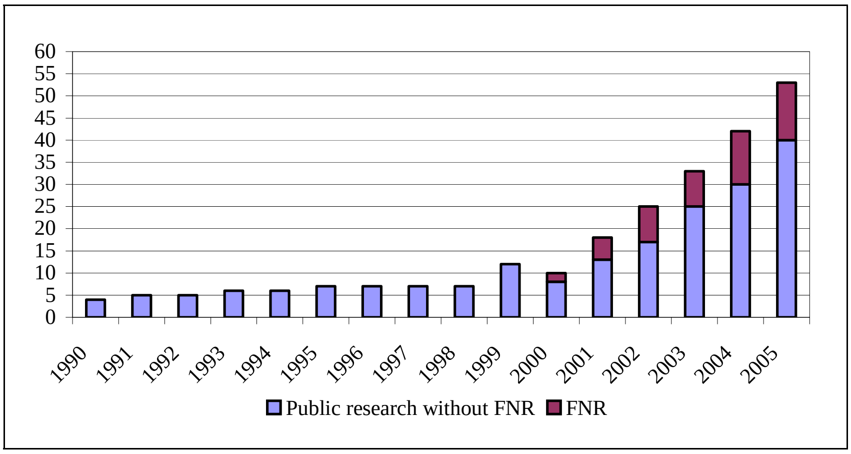

Fig. 1: Public Funds to Public R&D, 1990-2005, million Euro[6]

It is clear, that the Luxembourg research landscape is becoming increasingly complex, characterised by a full range of institutions, a number of funding streams and ministry involvement. As a result of this growing complexity, the MCHER commissioned in 2006 the OECD to perform a review of Luxembourg's innovation policy. The subsequent report observed a high potential for future development with good framework conditions for innovation, strong building blocks with the already established institutions, but also a number of structural weaknesses and inadequacies in research governance.

1.2 Rationale and Scope of the Foresight exercise

It is within this context that in 2005 Luxembourg began to embark upon a national technology foresight exercise, primarily with the aim of identifying new research domains for the FNR to support from 2007 onwards. The foresight exercise was given an extended remit by the Ministry of Culture, Higher Education and Research, which was supportive of the approach and requested the Fund to broaden the scope of the analysis from the mere definition of new FNR programmes to the identification of nationwide research priorities.

As with other small countries, Luxembourg has limited public resources devoted to research and, as highlighted above, it has a small (and young) public research base. However, it is also rather distinctive in that it has enacted sizeable increases in spending on R&D over the last decade and is set to double the budget again over the next three years. Thus, the challenge for Luxembourg does not lie in distributing limited funds among its existing science community.

[5] Referred to as the « Cité des Sciences, de l'Innovation et de la Recherche »

[6] Source: R. Kerger, Luxembourg's Research Landscape, Paper presented at the CREST meeting. Mondorf-les- Bains, 23 May 2005. Extracted from the OECD Luxembourg Review, 2006

Rather, it is looking to identify new areas in which to invest much of the spending increases with a view to developing future national champions.

The FNR in collaboration with the MCHER aims at determining a limited number of national research priorities in the public sector and intends to implement a financing on the basis of clearly stated strategic and operational objectives. As a consequence the specialization of CRP facilities into centres with a limited number of specific areas of expertise, in line with appropriate governmental funding, should be aimed at. It should also provide complete preparatory work for the development of Science, Research and Innovation parks at the City of Sciences on the industrial wasteland of Belval West, consolidating some infrastructure of the University of Luxembourg as well as that of various CRPs, with the goal of creating a genuine technological campus to promote public-private partnerships.

When briefly reviewing STI policy making in small countries, it appears that the challenges for achieving the above objective are great. Firstly, there is a tendency for research priorities to be heavily influenced by external players, such as large countries with whom collaborative links may have been formed, or the European Commission, and/or foreign direct investment (FDI) by transnational corporations (TNCs). In the case of Luxembourg, the latter two players play a particularly important role, especially the research activities of foreign companies, which account for a sizeable proportion of private sector R&D spending in the country.

Secondly, and perhaps contrary to popular belief, it would seem to be even more difficult to coordinate research systems in small countries than in large ones due to the disproportionate influence of a few powerful actors, and the danger that the bigger picture is obscured by parochial concerns and biases. Taking Iceland as a case study, Thorsteinsdottir[7] makes the following observation:

> "To coordinate actions of even small science communities requires extra effort and, to avoid heavy influences from more powerful groups within the PSR system, this mechanism has to be formal and accountable. The reason why lack of co-ordination can be a problem even in small PSR systems is that the disproportionate influences of powerful groups are often overlooked and the need to set up a formal and accountable mechanism is not articulated and carried out. Some formal mechanism, such as technology foresight, can be set up to address this problem and to increase the dialogue, consensus and commitment in the PSR systems. With formal mechanisms in place, small countries are likely to benefit even more than larger ones from such exercises, as their small size should make them easier to carry out."

The Technology Foresight approach adopted by the FNR was used as a tool intending to mobilise industry, academia, and policy-makers to better anticipate future opportunities and threats with a view to adopting more favourable development positions. The exercise aimed to inform the identification of R&D spending priorities through a more forward-looking and participative process than was formerly used in informing policy making. The approach is described in further detail in the next chapter.

With its knowledge sharing aspects and future-orientation, technology foresight also enjoys much congruence with narratives on the "Knowledge Society", the "Learning Society", and the "Network Society". Moreover, recent conceptualisations of the innovation process as being

[7] Thorsteinsdottir H (2000) "Public sector research in small countries: does size matter? *Science and Public Policy*, volume 27, number 6, December 2000, pages 433–442

distributed and network-based (replacing the previous 'linear model') favour the use of tools like technology foresight for 'wiring-up innovation systems'.[8]

This, we feel, is a particularly important aspect for Luxembourg. The challenges faced by STI policy makers in micro-countries such as Luxembourg are rather different from those faced by counterparts in larger countries. Small countries often lack the critical mass needed in domestic R&D, particularly in basic research. Where investments are made in R&D, these will represent only a tiny fraction of the global spend, meaning that small countries are unlikely to achieve dominance in the chosen area. Moreover, domestically generated knowledge spillovers are unlikely to be confined to domestic markets on account of the country's small size. This encourages small countries to focus upon adoption and adaptation of existing technologies developed elsewhere, which often leads to a strategy that emphasises close-to-market R&D.[9]

In recent years, however, it has come to be recognised that even technology transfer, if it is to be a successful strategy, requires some investment in a home-grown research base. This is because of the need to upgrade absorptive capacities to receive and utilise new knowledge (which is often science-intensive) generated elsewhere. In order to inform the reader about the current understandings about the role of science and research in society and the functioning of the innovation system a brief literature review on the topic is presented in chapter 3.

The networking aspect of 'Foresight' is seen as of particular importance and the 'wiring-up' of the various actors of the innovation system is essential in order for the Foresight exercise to bear fruit. These types of exercises however can only lay the corner stones of such networks. The implementation (even institutionalisation) networks and the role of the various actors and funders will need to be discussed in the follow-up phases of this exercise. In our view and the view of many Foresight practitioners[10] it is essential to accompany the results of this exercise with a discussion on the appropriate tools and instruments to implement the results presented in this report.

At this time of strong financial commitment to public research and reforms of the governance of STI - and in response to proposals made by the OECD - it is promising and rewarding to see the results of the Foresight exercise directly inform the policy making of the government.

The candidates for the national research priorities are presented in chapter 6 of the present report. They are the result of the interactive dialogue conducted in the expert workshops which were based on stakeholder views, collected in interviews and questionnaires, bibliometric data and other supportive elements (such as international trends). The approach was designed to be participative and future oriented; current thinking was challenged by new ideas and future trends in research were accounted for.

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[8] Martin B and Johnston R (1999), "Technology Foresight for Wiring Up the National Innovation System: Experiences in Britain, Australia and New Zealand", Technological Forecasting and Social Change, vol. 60, pages .37-54

[9] Berghall E, Heikkila T, Hjerppe R, Kiander J, Kilponen J, Lavrac V, and Stanovnik P (2002), *The role of science and technology policy in small economies*, Helsinki, VATT, Valtion taloudellinen tutkimuskeskus, Government Institute for Economic Research, (B, ISSN 0788-5008, No 91)

[10] M. Keenan, *An Evaluation of the Implementation of the UK Technology Foresight Programme,* PhD thesis, PREST, 2000

2. Description of the FNR Foresight exercise

2.1 Overall Approach and Prioritization Philosophy

The FNR Foresight Exercise aimed to identify research priorities in the public sector with short-term and/or long-term socio-economic interest for Luxembourg society. In a coordinated approach with other elements[11] of public policy, it provides part of the basis for:

- assisting the development of outstanding centres of science and technology excellence in Luxembourg,
- ensuring the specialization of public research centre (CRP) facilities into centres with a limited number of specific areas of high level expertise,
- determining appropriate investment levels through support instruments such as the FNR programmes.

The design of the foresight exercise follows these goals. It comprises the close involvement of stakeholders from the Luxembourg research community as well as from Luxembourg society and business and international experts. To achieve a balance of specific stakeholder interests, more than 360 individual participants (excluding survey respondents) were involved during the different steps of the process. As it is typical for research foresight processes, the time horizon was set to be about ten years – a time frame which in fact is needed to build up important research capacities and to create a sustained impact on the research landscape.

Prerequisite for establishing a clear view on most promising research topics is a segmentation of the thematic fields[12]. Within the process, candidates for research priorities were based on research domains and characterised by research issues (interesting questions / lines of research). Following a demand driven approach, their rationale was anchored in societal issues. The foresight exercise was not constructed around a "winner takes all" competition between research domains – all research domains currently investigated in Luxembourg will obtain at least the present level of financial support.

Prioritization, however, is in a small country with its very restricted personal and financial resources even more necessary than in large countries (where prioritization is done nevertheless[13]). Only through prioritization, can resources be sufficiently focused to enable internationally competitive cutting edge research.

A national research priority (NRP), by definition, should address the challenges of the Luxembourg society, economy, and environment through research. It is widely recognised that research serves as a motor for innovation particularly in the European knowledge-based economies. Excellent research in focused areas should lay the foundation for new innovative

[11] Other elements include: review analysis by the OECD on Luxembourg's public research apparatus, multi-annual development programs of the CRP and the University of Luxembourg, economic development priorities in the various sectors of the economy.

[12] In line with international uses, four levels of granularity were distinguished: thematic field (e. g. environmental sciences), research area (e. g. global change and ecosystems), research domain (e. g. water management), and research axis/issue (e. g. drinking water).

[13] See e. g. the EU project Platform Foresight 2003-01-3 "Emerging science and technology priorities in public research policies of the European countries, the US and Japan" (Final Report as of October 2005).

products and processes, but also contribute in creating an environment and an international visibility making Luxembourg an attractive location for companies to establish themselves and to remain for years to come.

In addition, research has the obligation to inform the public administration and decision making on environmental and societal issues.

In all cases however, a NRP should account for emerging trends on the international level, and should thus ensure that public research in Luxembourg finds overlap with international research activities and allow for sustained development of this line of research in Luxembourg. A NRP should thus permit researchers in Luxembourg to undertake interesting research, to be competitive on an international level and to distinguish themselves in their particular field. As the Lisbon strategy highlights the shortage of researchers in Europe, and Luxembourg stands in competition with other European countries for research personnel, a NRP needs to allow therefore for attracting excellent researchers to Luxembourg, in order to equip the country with the best brains to tackle the relevant objectives.

The feasibility of a NRP to take root in Luxembourg and to address the issues above depends largely on existing assets given in Luxembourg at the time of embarking in the particular direction. The implementation period for the NRP is – in line with the time horizon of the foresight exercise – 10 years and hence the research in the NRP needs to be able to reach critical mass within this timeframe. An existing scientific base (researchers in public and private sector) and an economic base (companies' interest in the research domain, serving also as regional partners for immediate collaboration and recruitment of research personnel) form these assets.

From the point of view of sustaining attractiveness and continuity in future program definitions, a NRP should be neither to narrow (specific) not to broad (unspecific) in scope. At one hand a NRP should have a clear focus, so that a critical mass of research can be built up and attractiveness in term of visibility and competitiveness can be guaranteed. But at the other hand this focus should have sufficient scope for interdisciplinary cooperation, and it should allow sufficient liberty to follow new emerging research questions and reduce the risk of sticking to dead ends or jumping from one narrow niche to the other.

Taking all these aspects into account, research priorities were assessed according to the following set of criteria:

- Attractiveness
    - Social impact / relevance
    - Economic impact/ relevance
    - Environmental impact/ relevance

      Sustainable development
    - Scientific attractiveness (emerging trend, intriguing)
- Feasibility
    - Critical mass can be reached within 10 years
    - International competitiveness can be reached within 10 years
- Focus (Granularity)

- o Sufficient focus, but not too restrictive

The FNR Foresight Exercise has been designed as a two-phase process where the first phase conducted from January till September 2006 consisted largely in defining the current situation of the Luxembourg research landscape, analysing international trends in research priorities, and identifying possible priority domains or areas for research. The second phase of the Foresight Exercise, carried out between October 2006 and March 2007, focused upon a set of broad themes with the aim of identifying national priorities for research funding and providing a clear rationale for them.

Close and continuing feedback with all relevant actors is an indispensable factor of success in a foresight exercise. The Luxembourg research and stakeholder communities as well as international experts, were closely involved at all steps of the process – through workshops, an internet forum, online questionnaires and feedback rounds for all documents produced.

2.2 Phase 1: Generating a Baseline

During the first phase of the foresight exercise, possible research domains were analyzed using complementary resources (expert interviews, questionnaire within the research community, international research trends, and expert meetings/workshop). The initial diagnostic step focused upon the Luxembourg research environment and its context, and consisted of the following elements:

- Evaluation of the first generation of FNR programmes with respect to FNR's operational and management effectiveness against initial objectives, quantitative and qualitative programme outputs and outcomes, recommendations for future FNR programmes.
- A mapping of Luxembourg research landscape (public research actors, R&D indicators like current levels of expenditure, policy instruments for public and private sector research, strategies and research topics pursued by the research actors).
- An analysis of international research trends with respect to major developments in 13 countries[14] and the potential degree of 'competition' that Luxembourg might face when supporting particular research domains.

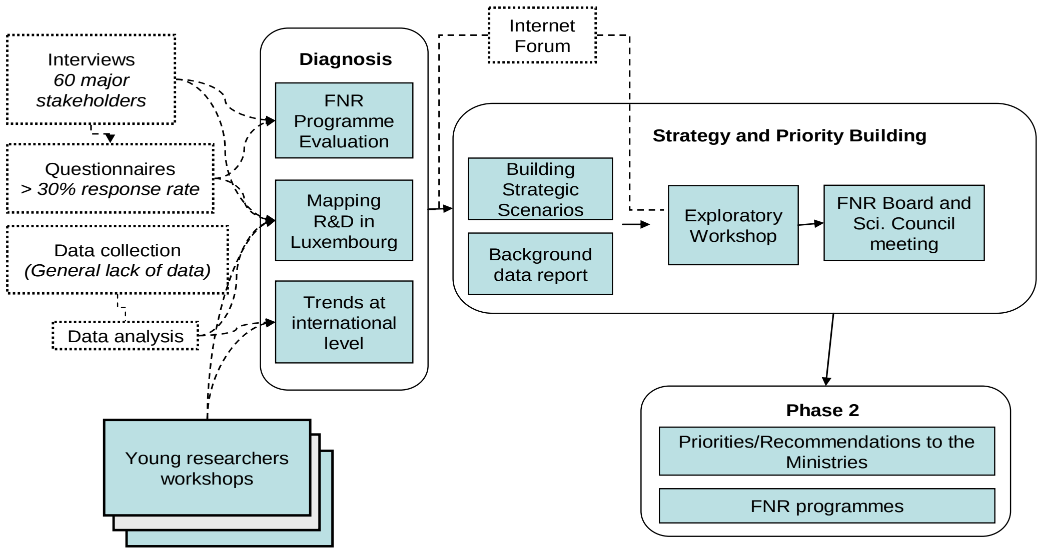
The data collected was complemented by a series of face-to-face stakeholder interviews with senior researchers, company managers and public administrators (59 in total). A small number of international experts, who were familiar with the Luxembourg system, were also interviewed as to counter-balance local views that could be potentially parochial or biased.

In order to avoid discussion on research topics from scratch, the foreign thematic research priorities identified were put together in a "long-list" of 56 possible research areas for Luxembourg with about 250 issues which set a well structured basis for the discussion with the researchers in the next steps of the exercise. This was done through a series of workshops and an online survey.

[14] Finland, France, Germany, Ireland, Netherlands, United Kingdom, Denmark, Switzerland, Austria, Belgium, Japan, Malta, and the United States – The countries were selected taking into account several aspects: existing collaboration between researchers from Luxembourg and the foreign country; the foreign country represents to some extent best practice in STI policy; the foreign country is a major stakeholder in global STI policy.

To test and develop the emerging list of research domains further, five junior researcher workshops were held in March 2006. These covered five thematic fields (environmental sciences, bio-medical sciences, information and communication technologies, physical sciences and engineering, social sciences and humanities). These sessions presented an initial version of the "long list" and asked junior researchers to update the domain list according to attractiveness and feasibility.

Phase 1: Generating a Baseline



In the next step, the "long list" was assessed according to the criteria of attractiveness and feasibility to Luxembourg in the medium to long term through an online questionnaire survey. This online survey was publicised widely (approximately 800 representatives from stakeholders were directly contacted), and received responses from some 298 researchers, companies and administrators in Luxembourg and foreign researchers. All respondents were asked to identify and assess up to ten research domains "of short- and/or medium term socio-economic benefit to Luxembourg society" according to seven criteria of attractiveness and feasibility. The research domains were ranked according to number of times a domain was assessed.

This tentative ranking was presented to participants of an Exploratory Workshop (EWS) in May 2006 where researchers and research users, in total about 120 participants, were brought together for the first time to discuss and validate the emerging analysis and ranking of the research domains in five thematic workshops. In addition the participants were asked in a separate session to debate which specific strategy would be most opportune for Luxembourg's public research to follow. As a result of the EWS, the thematic field of social sciences and humanities was split into one under the same heading and a new one "Law, Economy and Finance".

Following the EWS, a report depicting the work and results achieved during the first phase was discussed with the members of the scientific council (*conseil scientifique*, CS) and board of administrators (*conseil d'administration*, CA) of the FNR. This so-called 'Baseline Report' also contained a proposition by the FNR secretariat for the second phase of the exercise.

2.3 Phase 2: Identification of Priorities

The second phase of the FNR Foresight Exercise was devoted to establishing possible priorities for public research in Luxembourg on the basis of clearly stated strategic objectives and existing expertise in research. For this aim 13 workshops – one Stakeholder Workshop and two series of expert workshops to the six thematic fields – were conducted. They were combined with an online questionnaire survey which broadened the basis for argumentation. As in the first phase, a large number of researchers and other stakeholders (approximately 170) contributed their expertise representing all relevant Luxembourg research institutions, several private companies, business associations, public administrations and last but not least non-governmental organizations.

Thematic Fields of Phase 2

Information and Communication Technologies

Physical Sciences and Engineering

Law, Economy and Finance

Environmental Sciences

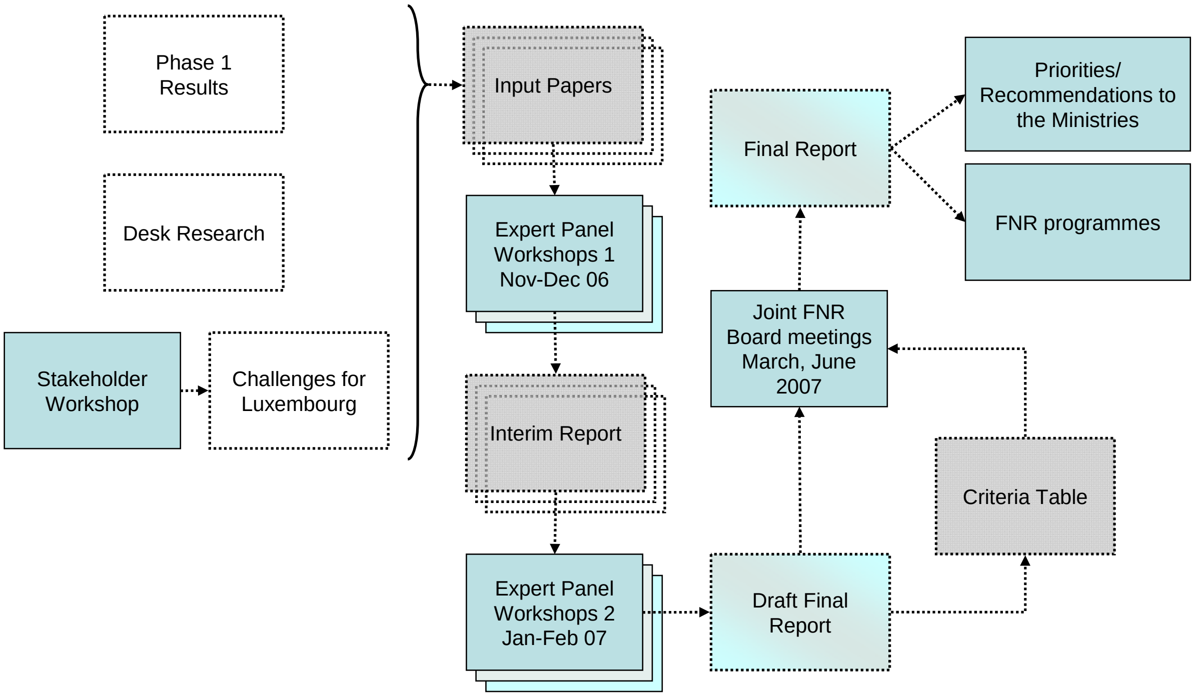
Life Sciences

Social Sciences and Humanities

As a starting point for assessing research domains, representatives from Luxembourg society, business and research were invited to the Stakeholder Workshop aimed at identifying the main challenges, which Luxembourg is facing within the next decade. It was understood that research in general could – hopefully – contribute to answer these challenges and that more specifically public research should be prioritized in view of possible answers to these challenges (criterion of attractiveness in social, economic, environmental terms) – without gearing it too restrictively to unrealistic "quick fix solutions" within the next years.

During a breakout session five working groups discussed the main challenges in the sectors of society, technology, economy, ecology and politics and broke them down into specific aspects, by answering the following questions: What are the implications for Luxembourg? Who is affected by the challenge? And who can address this challenge? Each working group ranked key aspects according to importance, level of interest and research relevance. They provided a sound basis for assessing the attractiveness of tentative research priorities in the subsequent steps of the process.

Phase 2: Identification of Priorities



The first series of thematic field workshops (conducted in November and December 2006) was based on the results of the Stakeholder Workshop and of the first phase, both presented in an input paper. The aim of these workshops was to (re-)define or review[15] the research domains that had resulted from the first phase and the related research issues, to discuss how the R&D environment might evolve within the given time frame and to "build a case" for prioritization. Breakout sessions provided a draft SWOT analysis for the research domains / tentative research priorities. This analysis included the following elements:

- **Strengths**: What is well done? What resources can be drawn on (in terms of expertise, cooperation, networking, support…) within Luxembourg?
- **Weaknesses**: What are main bottlenecks? What is lacking (in terms of expertise, cooperation, networking, support…) within Luxembourg?
- **Opportunities**: Which challenges or societal and economic demands can be answered by research and pose therefore an opportunity for research? What general trends support the research domain? Can strengths (or even weaknesses) be transformed into opportunities?
- **Threats**: What could endanger the success of efforts in public research in this domain? What weaknesses could grow to threats?

[15] Since the thematic fields had been analysed and structured in different depth during the first phase, the workshops had unequal starting points and their methodology had to be adapted to the progress so far.

Naturally, a number of SWOT topics were identified that are peculiarities not of a specific thematic field but of the Luxembourg research landscape in general (see chapter 5). The more specific points form the building block for assessing whether a certain research domain is suited as a research priority or not (rationale or *argumentaire*).

As the workshop approached – and parallel to it – an online questionnaire survey collected the views of a larger number of researches and other stakeholders on possible priorities and the prospects of Luxembourg research. The responses – in some cases very rich analyses of research domains – were fed into the workshop minutes and an Interim Report with draft proposals of national research priorities and additional highly important research topics.

The purpose of the second series of workshop (conducted in February 2007) was to frame the tentative research priorities into concrete terms in order to:

- review their selection
- finalize their definitions,
- review the underpinnings for their objectives and rationales and
- identify important implementation issues.

On the basis of the Interim Report the participants critically assessed and validated the proposed research priorities in the light of the criteria given above. Work continued in breakout groups where the participants discussed:

- Objectives within a ten-year time frame
- Rationale to chose this research priority from a point of view of various actors
- Feasibility to reach a critical mass and international competitiveness within a decade
- Implementation issues, i.e. prerequisites for successful and internationally competitive research, like possible funding instruments, size of research groups, necessary collaborations with foreign teams or the private sector, educational measures etc.

As a result, all research domains obtained a lot of underpinnings and clarifications, some of them were to a certain extend redefined. The "orphan domain" of agriculture and food, which was addressed in three workshops but insufficiently treated, was elaborated after the workshops in a small break-out working-group.

2.4 Joint FNR Board meetings

The concluding phase of the foresight exercise (in April and May 2007) aimed at a final assessment of the proposed research priorities on the basis of certain criteria. A clear result of the steps detailed above is that all of these proposed priorities are of high importance for Luxembourg. Nevertheless there are distinctions in their impacts on the economy, society, the environment, their budgetary requirements, etc. The objective of the concluding phase of the Foresight was therefore, at the request of the FNR administrative and scientific boards, to prepare the ground for the national priority setting by the government and the further prioritization of these research domains.

In order to be as objective and transparent as possible, the further prioritization by policy-makers of the research priorities has to be carried out on the basis of clear criteria. These criteria allow for taking into account the scientific potential of the research domains (state-of-the art in Luxembourg, possibility for Luxembourg research to become internationally competitive within the next ten years, etc.) as well as socio-economic and ecological interests and the potential for the research domains to meet these demands.

In collaboration with the MCESR and the FNR Foresight team, the following set of 11 criteria was developed[16]:

Socio-economic criteria

Socio-economic contribution or expected impact of research in a given priority domain on:

- **C1. Environment**
  For instance: Is public research in this domain expected to contribute to a more environmentally-friendly society and economy, e.g. reduction of air / water pollution, etc.?
- **C2. Economy**
  For instance: Is public research in this domain expected to consolidate the competitiveness of Luxembourg, to support the diversification of the economy, to promote the creation of new firms, to attract new companies to Luxembourg, etc.?
- **C3. Society**
  For instance: Is public research in this domain expected to increase social cohesion, societal participation, political participation, to improve the population's quality of life, to improve living or working conditions, to improve education, to promote a typical Luxembourg identity, etc.?

These three criteria are quantitative: the research domains can be assessed to have no impact on environment / economy / society or a low, medium or high impact.

It should be noted that, in order to ensure a greater differentiation of the priorities, the assessments of these three criteria are mainly based on the *direct* impact the potential research priorities may have on the environment, the economy or on society. Indirect impacts (for instance on society when a specific priority may further the creation of new jobs or contribute to diversifying the economy) - though not negligible - came secondary.

Political criterion

C4. Accordance with the political agenda in Luxembourg

For instance: Is research in the domain expected to contribute to reaching the goals set by ministries, defined in the National Plan for Innovation and Full Employment, in the National Plan for Sustainable Development, etc.? Is there a need for research results in this domain in the public sector, e.g. administrations, ministries, etc.

This criterion is quantitative: the research domains can be assessed to be not in accordance with the political agenda in Luxembourg or to be in little / medium / high accordance with the political agenda.

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[16] In line with and starting from the overall prioritization criteria explained on page 19.

Feasibility Criteria

- **C5. Overall framework: Public acceptance and accordance with legal framework**
  For instance: Is research in this domain publicly acceptable and are there legal hurdles or ethical concerns hindering research in the domain, etc.?
  This criterion is quantitative: the overall framework can be expected to be unfavourable, neutral, mixed, or favourable.

- **C6. Existence of private sector activities in the domain**
  The presence of private sector activities in a specific research domain reflects two aspects:
  1. Are there private R&D activities in this domain and therefore opportunities for Public Private Partnerships (potential for valorisation of research through cooperation with the private sector)?
  2. Are there enterprises, which can be direct "consumers" of research results and implement the results of research in products and innovations, and the other way around, can industry provide the motivation for (new) research activities? This aspect reflects the fact that efficient R&D policy should aim at the successful transfer of industrially or economically relevant research results to practice.
  This criterion is quantitative: there can be no, few, medium or high private sector activities in the domain.

- **C7. Public research capacity in Luxembourg**
  Are there already research activities in this domain or in closely related research areas?
  This criterion is quantitative: there can be no, few, medium or high public R&D activities in the domain .
  If the level of public R&D activities in a given domain or in a neighbouring domain is high, it will be easier for Luxembourg researchers to become internationally competitive quickly. If not, selective policy measures can help to stimulate research.

- **C8. Infrastructure / Critical mass**
  This criteria provides a *qualitative* assessment concerning the critical mass of researchers (e.g. whether critical mass for research can realistically be achieved in a 10-years timeframe), the infrastructure needed (for instance Technology Platforms requirements), etc. to leverage research in a given domain. Estimations whether critical mass for research can be reached soon, and estimations related to what can be understood as critical mass in this domain (in terms of human resources, or input or output indicators) are based on the indications of the experts involved in the FNR Foresight exercise, but build also on comparisons with research units in European countries. They also take into account the absorption capacity of the Luxembourg research system.

Further criteria

C9. International research context

This criterion provides a *qualitative* assessment of the international research context addressing the following issues: How is the research domain embedded in the European 7th Framework Programme? Are there similar research activities carried out or planned for instance in France, Germany, Belgium, the Netherlands or Switzerland? Is there potential for research cooperation within the Greater Region? Is the domain internationally considered as a new emerging topic? Strong international public research activities in this domain can be a double-edged sword: on the one hand, it might be easier for Luxembourg to engage in collaboration with foreign researchers and research institutions. On the other hand, in a highly competitive international research area, it might be difficult for Luxembourg researchers to become visible internationally. It should be noted that, given the timeframe of preparation phase for the joint FNR board meetings, the gathering of information could not be exhaustive and that only a rough picture could be drawn. A more detailed picture of the international competition situation would require a more in-depth analysis.

C10. Contribution to national competences, scientific excellence and international reputation
Contribution of the domain to the overall capacity building in public research in Luxembourg (e.g. possible contribution to research and curriculum of the University of Luxembourg, to the development of Luxembourg as research place); Contribution to the generation of national competences and uniquely Luxembourgish scientific excellence; Potential for Luxembourg to reach internationally recognised scientific excellence and visibility in this domain? For instance, Luxembourg's potential to achieve visibility might be quite low if other countries already have reached a high and recognized level of expertise in the domain.
This criterion is quantitative: the potential for the priority XY to contribute to overall capacity building in Luxembourg can be assessed as low, medium or high; the priority XY might also have no impact on the overall capacity building.

C11. Cross-linkages with other priorities (check marked in the table).
This criterion is a *qualitative* one, highlighting the existing cross-linkages between the priorities identified in the FNR Foresight exercise. Such cross-linkages can push research in the domain as funding efforts can be coordinated to leverage research in several domains.
Also Technology Platform requirements for specific research priorities are highlighted.

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The research domains identified in the FNR Foresight exercise have been assessed along these criteria, using the insights gained from the process e.g. from the involvement of experts in the different fields. However, the assessment of some criteria required additional background information (desk research). It can be estimated that about 70% of the information needed for the assessment of the research priorities was collected during the 2nd Phase of the FNR Foresight process and that the other 30% required further desk research.

These 11 criteria allow for a systematic assessment of the research priorities identified in the FNR Foresight process. Chapter 7 presents the results of the assessment of each priority along the 11 criteria defined in table form, as well as overall comparison tables.

It should be noted that, in order to achieve a higher differentiation in the prioritization process, the criteria listed above could be weighted, reflecting their difference in importance. As an example, feasibility criteria could be weighted stronger than those concerning the socio-economic impact. However it has been agreed on not using any weighting factors for the criteria, as weighting of the criteria includes strategic political decisions which is beyond the mission of the Fund.

The result of this follow-up phase, does not constitute an absolute assessment, totally independent of perceptions and values, of the research priorities identified in the FNR Foresight process. However, together with the detailed analysis of the priorities, this criteria table provides a sound and as objective as possible basis for further prioritization by policy-making.

3. Models of Science Production and Exploitation

Introduction

The public research system in Luxembourg is relatively young, and in some respects, remains under-developed. The creation of new institutions, such as the University of Luxembourg, and new infrastructures, such as the City of Science, illustrate the rapid changes facing the research landscape. Moreover, the significant R&D budget increases planned for the coming five years also present a challenge that will inevitably lead to major changes in the national research system.

All of these changes, whilst creating a certain degree of uncertainty, have been universally welcomed. They demonstrate a strong commitment by the Luxembourg Government to the building of a strong national research base that can play a full and fruitful role in the future socio-economic development of Luxembourg. However, there is less consensus on the focus of research in Luxembourg. Some argue that Luxembourg should conduct leading-edge basic research, which will in the long-run have socio-economic benefits for the country. By contrast, others claim that Luxembourg is too small to gain the necessary critical mass in any scientific area and should instead try to position itself to 'retrieve' scientific results from elsewhere – what might be termed a 'free-rider' strategy. Whilst there are undoubtedly merits in both arguments, this chapter will take a closer look at the assumptions underpinning each.

The chapter begins by critically examining perhaps the most enduring and widespread account of the relation between science, society and the economy, the so-called 'linear model'. Following on from this, the market failure rationales for the public funding of science are discussed, and the concept of 'free-riding' introduced. More contemporary accounts of science are then presented, including the ´new production of knowledge' thesis and the idea of science as a network activity. Finally, a set of conclusion are drawn that dispel many of the traditional arguments used to justify a free-rider strategy, whilst acknowledging that in small countries such as Luxembourg, priorities need to be set for scientific efforts to be appropriately focused.

The Linear Model

Science is an international endeavour involving contributions from scientists in most countries, and the results of research are widely published and available from scientific journals, books, conference proceedings, etc. The dissemination of scientific results is not restricted by national borders. The contribution to global scientific output which can be made by a small country is necessarily limited, and the loss of such a contribution would probably be small as a proportion of global scientific output. Therefore the question to be considered is whether a small, economically developed country can have a conscious strategy of free-riding on the outputs of others.

To consider this, we must have a model of science production and exploitation, including such issues as the justification for public intervention in support of research. The most common model is usually referred to as 'the linear model'. This model tends to be implicitly referred to, rather than explicitly, on the grounds that it is 'common-sense', in particular for practising scientists. The central assumption is that basic science produces results which can later be applied to specific uses such as the solution of problems. The next stage is to take the applied work and carry out development work which results in commercially marketable products. The essential feature of the model is that it is 'chronologically sequential': basic research feeds into later applied research, which feeds into development, and finally is commercially exploitable.

The model is deceptively simple and has many advantages. It appeals to common sense, in particular that of scientists and politicians, and results in apparently straightforward policy decisions. If we wish to increase economic output / value added, or other desirable economic performance measures, we simply increase the funding for basic science which will, after some time, feed through to economic advantage. Moreover, the categories of research (basic and applied) and development can be defined (though exact definitions vary) and statistics collected on a national and global base, which enables comparisons to be made. The standard definitions contained in the OECD's Frascati Manual derive from this framework.[17] Policy discussions are suffused with appeals to increase funding until it reaches some international average, or in the case of Europe, the Barcelona 3 per cent target.

Market failure rationales for public research

If we assume that the linear model holds, then the question is still left as to who should conduct what research, and perhaps more significantly, who should fund it? The linear model seems to define the respective roles of the various actors in the production and use of scientific results. For example, due to problems of appropriability of scientific results, it is assumed that companies will not fund much of the required basic research. This is due to the phenomenon of knowledge 'spillovers', whereby scientific results 'leak-out' of companies. There is little scope for the legal protection of such scientific results, leading commercial funders of research to undertake less research than would otherwise be the case with full appropriability. In economists' terms, the decision would be made to undertake a less than optimal quantity of research.

These considerations have lead to the most frequently cited argument for the public funding of basic research: that of 'market failure'. The function of public policy must be to correct such market failures and to support research in order to achieve a level of research activity closer to that which would be considered optimal.[18] With the public funding of basic research, economists have come to regard scientific results as a 'public good'. This provides at the same time the rationale for public funding of basic research and also the mission for publicly–funded research organisations, such as universities. They receive public support and disseminate the results of research as widely as they can, if possible, free to the user.

These organisations must be clearly distinguished from those carrying out research further down the linear chain that aim to exploit for direct commercial returns. Such research and development may be considered more appropriable. For example many uses of results will be

[17] OECD (2002) *Frascati Manual*, Paris: OECD

[18] The difficulty is in trying to define what is 'optimal': often this is why the comparisons of international statistics are used, in the hope that foreign countries have somehow got a more accurate notion of optimality.

protectable by intellectual property rights, such as patents, so that more optimal decisions are taken and there is no need for public intervention. As the results will produce benefits for the owners, this work must therefore be funded from private sources, and the results need not be disclosed for the use of others.

So, overall the linear model has a strong appeal. It describes the scientific process of production and use of results, the roles and functions of the research organisations and those of funding bodies, it produces definable categories to enable statistics to be collected on a comparable basis, and also seems common-sense to scientists, policy-makers, and the general public. Free-riding would be a policy of deliberately not funding the earlier stages of the chain, and relying on obtaining results from other countries in order to exploit them for commercial advantage. The question is whether this is possible. We return to this point later on after discussing alternatives to the linear model.

The Death of the Linear Model?

Despite its widespread appeal, several decades of science policy research has knocked away the foundations of the linear model. The first criticisms focused upon the direction of causation: the original linear view came to be called 'science-push' or 'technology-push', but evidence in the 1960s showed that in some cases, things worked in the reverse direction. Demand from the commercial side caused researchers (and funders) to concentrate their efforts on particularly promising areas. Clearly, pharmaceuticals R&D is an example of what came to be known as 'demand-pull'.

Controversy raged between supporters of these two views, but was eventually superseded by a synthesis contained in the so-called 'interactive model'. This recognised the importance of feedbacks at all stages of the process: research councils looked at potential contributions to public welfare from promising areas of research, while recognising their role in supporting the best research. In an era in which science and technology started to be viewed as a mainspring of economic progress, companies were anxious to strengthen links with universities and gain access to results as well as influence priorities.

This view coincided with the emergence of science and technology policy as an increasingly important area for policy-makers. Where previously science funding had been viewed as a responsibility to further the limits of human knowledge, it has now become an instrument of economic and competitive performance. Moreover, the funding is now often classed as part of 'innovation policy'. Research councils have as part of their role a requirement to encourage links between commercial enterprises and research performing organisations, to improve dissemination of results, and to support collaborative research.

Mode 1 and Mode 2 Research

Another model of note was proposed in the 1990s that characterised the long established science system as "Mode 1", in which the various actors in the science system performed as in the linear model outlined above.[19] By contrast, in a changing world, the new production of knowledge, known as "Mode 2", depended upon a different system of problem-centred research groups, each brought together for a specific purpose, but dissolving after the original purpose had been achieved. Summarising the distinction between Mode 1 and Mode 2:

"Mode 1 is discipline-based and carries a distinction between what is fundamental and what is applied; this implies an operational distinction between a theoretical core and other areas of knowledge such as the engineering sciences, where the theoretical insights are translated into applications. By contrast, Mode 2 knowledge production is trans-disciplinary. It is characterised by a constant flow back and forth between the fundamental and the applied, between the theoretical and the practical. Typically, discovery occurs in contexts where knowledge is developed or put to use, while results - which would have been traditionally characterised as applied - fuel further theoretical advances."[20]

Under Mode 2, 'science' is now more than what was called 'basic science' in the linear model. It involves the production of knowledge from research conducted by a wide variety of sources, some of which are outside the traditional science system. The results are increasingly important in economic impacts, in particular in promoting innovation. Priorities are set for economic and social reasons as well as for scientific excellence.

The two modes of knowledge production co-exist today: the traditional Mode 1 operating mainly in universities, but Mode 2 growing rapidly, encouraged by the trend towards international formal and informal collaborations, often publicly supported. In some newer fields, such as nanotechnology, bioengineering and optoelectronics, such trans-disciplinary work may be the norm.

What would a Free-Rider Policy look like?

The relevance of the above to the original question posed should by now be clear. With a simple linear view of the science process, is it possible to conceive that a small country could consume the outputs of the global system of science without the expense of having to make a contribution to the resources producing them? Using the more recent perspectives, we can see that the system is not simple with a clear flow of results into exploitation. The subjects being studied at the forefront of research are determined not just by scientific excellence, but by a system including policy-makers, evaluators, taxpayers, commercial enterprises, etc.

In this context it is interesting to examine what exactly a free-rider would look like. If we consider that scientific results are all contained in the peer-reviewed scientific journals and periodicals, could we replace our research institutions with a comprehensive library and information retrieval system? Clearly not, since we would have to retain some level of expertise that would be skilled enough in the 'state-of-the-art' to appreciate the relevance and importance of the most recent results. Whilst information can be codified in books and papers, knowledge resides in the brains of individuals.

[19] Gibbons et al (1994), *The New Production of Knowledge*, London: Sage
[20] Gibbons et al, p 19

This brings us to another perspective which concerns itself with the 'absorptive capacity' of the system. In order to exploit science and research results we must have the available expertise to appreciate and understand its significance.[21] Looked at in another way, the outputs of the science system are not just 'results'. They are also trained scientists and researchers who create the absorptive community which can effectively use the latest science. In other words, knowledge is not freely available off the library shelf: investments must be made in order to be able to exploit it. Paradoxically, this view is counter to the public good argument which assumes a low (or zero) cost of individual consumption. Scientific research is not a public good, because of the investment required to understand it. Scientific knowledge is not freely available to all, but only to those who have the right educational background and to members of scientific and technological networks.[22] In this regard, it is perhaps no accident that the foremost universities are teaching and research institutions since there is recognition that only those who are familiar with current research can understand the significance and transfer this to others.

Science as a Network Activity

Another theoretical perspective that has recently gained in popularity comes from research on social networks. Academic science is a collective activity involving a variety of networks, including formal networks (institutions, professional organisations, journals, funded collaborations…), and informal networks (peer review, unfunded collaborative research projects…). Members of the science network may have a variety of links with other researchers ranging from collaborations to reading papers in journals.

The enormous growth in funded collaborative research in recent years gives an example of one of the more important type of networks. European projects may include universities and other public research organisations, commercial enterprises, charities, etc. The creation of such (Mode 2) groups involves a negotiation and production of a collaboration (or consortium) agreement which defines in a legal document the rights and responsibilities of each participant. The membership of one participant is a result of the contribution which that participant is planning to make to the groups' overall mission. Membership depends upon past invested capital. No participant is considered who does not have a record of past performance. Past work is the 'membership fee' for the next project, and present participation and performance is the membership fee for future collaborations. It can be difficult for competent research performers to break into a sequence of collaborations: for a free rider it would be near impossible.

Membership of these projects is for organisations, so the analogy cannot be drawn for countries' membership of the international science community. However, if a country does not support research groups, then there can be no membership of large collaborative research programmes.

[21] Metcalfe, J.S., 1995, "The equilibrium foundations of technology policy", in P. Stoneman (ed.), *Handbook of Industrial Innovation*, London: Blackwell

[22] Callon, M., 1994, "Is Science a Public Good?", *Science, Technology and Human Values* vol. 19, 345-424

Conclusions

Drawing together the discussions above, some tentative conclusions can be reached. Firstly, the simple idea of free riding results without contributing to costs relies upon a crude and inaccurate linear view of the scientific process, in which codified results are freely available off-the-shelf. By contrast, the science, technology and innovation system is currently viewed as a complex and constantly changing network of researchers, organisations and activities, each of which is producing and consuming research results and performing other activities of use to the whole. It is difficult to envisage an effective exploitation strategy which plans only to identify and use some results coming from this kaleidoscopic ferment of activity. Only by becoming a member of the community can there be any influence upon activities and decisions such as priority setting. Free-riding accepts that there can be no influence on priorities.

But more critically, even if it were possible to implement a free-rider policy, it would still be necessary to carry out several activities. First, national priorities for areas of exploitation would have to be set, so there must be a national capability to understand the latest research and its importance. Second, there is a need to implement the exploitation of science. Both of these require an 'absorptive capacity', that is a set of researchers who are familiar with forefront research and on how to use it.

It could be observed that no single country can be at the forefront of progress in all areas of science, therefore most countries must be free-riders in some, if not most, scientific areas. But to be able to exploit science in the most important areas for a particular country, and to be able to influence decisions and affect the overall directions for research, there must be a residing level of expertise, capable of recognising and understanding the significance of progress in those areas. The policy questions this poses therefore become the generic ones faced by all countries, free-riders or not: (1) in which areas should Governments concentrate public funding for science? And (2) how much funding should be devoted to science? The first of these questions is the main focus of FNR Foresight.

4. Challenges identified in Stakeholder Meeting

As a starting point for the 2nd phase of the FNR Foresight Exercise important stakeholders from Luxembourg society, business and research were invited to contribute their views on the main challenges Luxembourg is facing during the next decade. Subsequently participants discussed to what extent public research could address these challenges. All challenges were collected and systematized along the so called STEEP sectors (Society, Technology/Science, Economy, Ecology, Politics). The following main challenges were identified:

Society	Technology	Economy	Ecology	Politics
- Education - Migration, cultural diversity and integration - Demographic change - Health issues	- Critical mass and competitiveness in research and development - Emerging technologies - Transportation and logistics	- Sustaining economic growth - New competence niches - Attractiveness - Competitiveness - Land reform	- Ecology and economic growth - Energy issues - Water issues - Impacts of climate change	- Governance - External political context - Social systems

Society

- *Education:* Education is crucial for success in a knowledge economy, this from an individual and a societal point of view. According to the 2003 PISA study, Luxembourg student achievement is below the OECD average, with a gap in achievement between native students and immigrant students, mostly from EU-member countries in which Romanic languages are spoken. A factor that makes learning especially challenging for children from immigrant and/or lower socio-economic backgrounds is Luxembourg's trilingual education system. Taken into account, that about one third of the pupils have a foreign nationality[23], the educational system should provide early integration of immigrant children through an improved school and pre-school system. In general, education should better respond to the societal and economic needs of the complex Luxembourg multi-lingual and multi-cultural society and take these as an advantage. Life long learning, involving people of all ages and social groups, is another important point in case.
- *Migration, cultural diversity and languages:* With an immigrant population of 39% and a large share of cross-border workers[24], Luxembourg is facing the threat of the development of "parallel societies" as discussed e. g. in Germany and France. Models and pilot projects for improved social, economic, political and cultural participation of the immigrant population should be developed. Languages play a crucial role in this. But on a deeper layer, the question about the Luxembourg identity is raised. What does identity mean in a multi-ethnic, multi-cultural, multi-linguistic society?
- *Demographic change:* In contrast to its neighbours, Luxembourg is in the specific situation that it has still a growing population – due to immigration. Migration also alleviates to a certain

[23] In 2002, around 36% of the pupils had a foreign nationality. Among them, Portuguese represent an important share (51.3%), followed by Ex-Yugoslavian (11.5%), Italians (8.3%) and French (7.0%).

[24] In 2005, there were about 177.400 immigrant inhabitants as compared to 230.300 native Luxembourgers – see Statec: "Luxemburg in Zahlen 2005".

degree the impact of demographic ageing. Nevertheless Luxembourg has – as most industrial countries – to cope with an ageing population. People aged 65 and above have increased in number from 42.800 in 1970 to 61.000 in 2000 (+42.8 %) and will continue to do so. In 2005 their number reached 65.000 – 14.3% of the total population.[25] Ageing will have consequences for social security, public households, and the labour market; to mention only some: life-long learning, multi-generational work teams, transition between an active professional life and retirement, taking advantage of the expertise of elderly employees. Ageing has impacts on family structures and intergenerational relations (solidarity, the willingness to support others, and the transfer of goods). Last but not least, health issues are important, in particular in view of an increasing share of persons older than 80 years: e. g. age-related diseases, autonomy and dependence in age, measures in order to prevent age-related physical and psychological impairments, availability and quality of care for the elderly.

- *Health issues:* In international comparison, Luxembourg has a high quality health system. Nevertheless, there are multiple concerns. There is an increase in chronic diseases, partly due to ageing. As a consequence of "unhealthy" nutritional habits (depending much on socio-economic and cultural background), obesity is becoming more frequent and severe. Chronic diseases such as allergies caused by environmental problems are likewise spreading. Health costs are rising – with impacts on the social system and the economy. One of the main answers to this situation is to engage more in health education and prevention; another is to monitor, to assess and to increase the efficiency of the health system.

Technology and science

- *Critical mass and competitiveness[26]:* With its young and expanding public science and technology infrastructure, Luxembourg has to face the challenges to build scientific excellence and critical mass and to achieve competitiveness in research and development. This includes creating an environment to attract high level professionals, an excellent quality of education and the availability of high-tech equipment. Public and private sector have to address these challenges in true partnership. It is important to develop a common vision of excellence between all stakeholders. A continuous benchmarking of R&D activities is necessary to stay at the top.
- *Emerging Technologies:* Luxembourg hosts a number of companies performing research and development in high-tech fields like Arcelor, Goodyear, SES ASTRA, to mention only a few. Emerging technologies could, however, pose a threat: Most of Luxembourg's high-tech companies are engaged in the fields of ICT or physical/ material sciences. Emerging fields like life sciences / biotechnologies or neuro sciences or (within ICT) service sciences are not sufficiently covered. Luxembourg's industry has to keep pace with international developments and to find promising niches of competence.

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[25] http://www.portrait.public.lu/en/economic_structures/population/populatio/index.html, and Statec: "Luxemburg in Zahlen 2005".
[26] For a detailed description of the challenges for research in Luxembourg see chapter on SWOT

- *Transportation and logistics:* Luxembourg has become an important European hub in particular for freight traffic. Apart from road traffic, the Luxembourg airport has recently attracted skyrocketing turnovers.[27] Despite investments in transportation infrastructure, bottlenecks are severe and will aggravate with increasing traffic.[28] Taxes on motor vehicle fuel are set so as to maximise tax revenue, and more than half of all motor fuel is sold to non-residents. This “gasoline tourism” has adverse environmental effects. The objective of the strategy “mobilitéit.lu” promoted by the Ministry of Transportation “is to guarantee and manage mobility for all, by limiting the environmental effects of road transport, without affecting economic growth”. This implies an improvement of the modal split (share of traffic by public transportation with respect to private transportation).[29] Improving railroad transportation is an important point in case. It is also one of the pioneering countries in ERTMS (European Rail Traffic Management System).

Economy

- *Sustaining economic growth*: The economy of Luxembourg is synonymous with a high standard of living and wealth. From 1980 to 1995, the economy grew by an average of over 5%. From 1995 to 2000, the country experienced an economic expansion that exceeded international economic trends. Similar positive trends have been evident for other economic indicators such as productivity, where Luxembourg ranks only second to Norway. The expansion of the financial sector has been one of the pillars of the economy and is responsible for one third of Luxembourg’s GDP. The steel industry, which historically acted as the engine of the Luxembourg economy, has declined in its relative contribution. Indeed, other industrial sectors are growing at a faster rate (the energy industry, the production of electrical and electronic equipment, paper and cardboard/edition and printing, for example)[30]. However, the strong specialisation of the economy has also increased Luxembourg’s vulnerability to economic fluctuations. As a result, the stock market decline of the early part of the current decade impacted on Luxembourg’s economy, resulting in a slow-down of economic growth over the last few years. Recent forecasts though foresee a sustained growth of the Luxembourg economy. However, as a small export-oriented economy closely knit into European networks, the Luxembourg economy depends increasingly on external factors. This leads to a higher degree of volatility. Sustaining economic growth remains therefore a central challenge. The other challenges identified during the Stakeholder Workshop have to be regarded as affiliate challenges (“sub-challenges”).

- *New competence niches*: In order to curb dependence on a small number of industries, in peculiar on the finance industry, Luxembourg has to develop new niches – in terms of the

[27] Air cargo at Luxembourg airport rose from about 300.000 tons in 1995 to 500.000 in 2000 and 730.000 in 2004. - Statec: “Luxemburg in Zahlen 2005”.

[28] European road and rail freight traffic is forecast to increase till 2020 by about 75%.

[29] According to the Traffic Model Unit, this proportion should rise from about 12% at present to 25% in 2020. Comp. also Frank Vansteenkiste: “Potentiale und Grenzen der Gestaltung einer sanfteren Mobilität. Eine Analyse der Verkehrsmittelwahl im Berufs- und Ausbildungsverkehr Luxemburgs“, Innsbruck 2006, http://www.mobiliteit.lu/pdf/DiversPDF/TransPub.pdf.

[30] Source: Fedil

OECD[31] "competence niches" based on expertise and efficiency as distinguished from former "sovereignty niches" based on regulatory advantages. It seems to make sense to identify niches next to the existing growth sectors – finances, manufacturing (steel industry…), ICT, communications, logistics, but business itself has to find these niches and migrate to them. Some formulas of success of the financial sector may be transferred to these niches. The government can foster this process through public research relevant for the new niches.

- *Attractiveness* of living and working in Luxembourg: The key to future economic growth lies in developing and keeping domestic and attracting foreign human resources. In order to raise the level of skills, education is of crucial importance. Innovation studies have demonstrated that "high potentials", - i. e. the "creative class"[32], need an inspiring, multi-facetted environment, a global atmosphere with a culturally rich lifestyle. Improving and promoting[33] the image of Luxembourg – as with the present European Capital of Culture – is one point in case.

- *Competitiveness* in global context: It goes without saying, that due to its open and export-oriented economy, Luxembourg is subject to all aspects of global competition. Maintaining a high level of salaries (which sometimes are regarded as not really competitive) is only possible on the basis of excellent expertise and very high value added. Regulatory framework conditions remain crucial for competitiveness, even taking into account that Luxembourg is less depending on "sovereignty niches". Research has to inform policy making on possible impacts of (planned) regulation, in particular the European context.

- *Land reform*: Land prices and scarcity of real estate are hampering development and economic growth. The participants of the Stakeholder Workshop felt that a completely new approach is needed, without giving details. One requirement would be to develop a sound data basis for further analyses.

A bottom line of the economic challenges consists in the fact that due to its small size Luxembourg has a number of peculiarities which are not addressed by international economic studies. Research on small economies and their specific problems (dependence on external influences, problems with statistics etc.) should be promoted.

Ecology / Environment

- *Ecology and economic growth:* Traditionally the relation between ecology and economy is defined as an antagonism between economic benefits and environmental costs, a position which can not be supported anymore today. On one hand, environmental damages impair also the economy, as it is now discussed with climate change. On the other hand, increasing knowledge on ecology can also generate economic growth. Ecological issues should therefore be seen as business opportunities. Luxembourg has at the same time to protect its natural environment in particular against pollution from

[31] OECD Economic Survey on Luxembourg (Vol. 2006/9, July 2006) and OECD Review of Luxembourg's Innovation Policy (2006).

[32] See: Richard Florida: The Rise of the Creative Class and How It's Transforming Work, Leisure and Everyday Life, 2002, and: The Flight of the Creative Class. The New Global Competition for Talent, 2005.

[33] This could be done by a specific promotional agency like IDA Ireland (Industrial Development Agency).

industry, agriculture and traffic, and to take advantage of economic benefits from environmental protection and more specific from environmental technologies[34]. Points in case are "green" ecologically sound / environmental friendly products or energy efficiency schemes (e. g. thermal insulation in buildings) where saving energy saves money too and creates opportunities for the construction industry and others. In general, water, energy, biodiversity, and climate issues can be regarded as affiliate challenges of "ecology and economic growth".

- *Energy issues:* Since the Iraq War, since the Stern Review[35] and even more since the IPCC report[36] energy ranks high on the political agenda. Increasing energy prices are a major economic concern, CO_2 emissions from fuel combustion are the main driver of climate change. As other countries, Luxembourg is facing the challenge to reduce energy consumption and to diversify its energy sources. Both have tremendous impacts on transport, on production and pollution. "Home-grown" energy sources such as wind power, hydro-electricity, biomass or coal can be seen as potentially valuable energy sources in a "diversification" effort. But even in optimistic scenarios they will not enable Luxembourg to be self-sufficient. Increasing energy efficiency – "doing more with less" – is the most important "energy source". Luxembourg has likewise to anticipate the trends of alternative energies, and to address the economic realities of the Kyoto protocol (CO_2 trading, penalties) and energy-related EU directives.
- *Water issues:* With economic growth, an increasing population and a more efficient agriculture, water demand will rise in the next decade. Luxembourg faces already a water scarcity problem in peculiar due to polluted ground water bodies which can no longer be used for drinking water supply.[37] In total, Luxembourg has to invest around 1 billion € into new waste water technologies, infrastructures for drinking water and in the renewal of water treatment plants. Water recycling (purification) and conservation are of rising importance. Both quality and quantity of water supply and cross-border relations need to be considered. EU directives[38], measures taken by the government and water suppliers have immediate impacts on water prices and in the long run on construction constraints. Another important potential threat is the increasing risk of floods mainly due to urbanisation.
- *Impacts of Climate change:* Despite all international research, large modelling and forecasting efforts, the extent and the impacts of global warming are still not understood in detail. Nevertheless, it can be taken for granted, that climate change will have

[34] It should be noted that environmental technologies in the broader sense are not uncontroversial. GMOs in agriculture are used in order to diminish the use of pesticides and fertilisers, but they pose new environmental hazards in themselves (gene transfer to wild forms).

[35] Stern Review on the Economics of Climate Change. – http://www.hm-treasury.gov.uk/independent_reviews/stern_review_ economics_climate_change/stern_review_report.cfm (as of Nov. 2006); comp. also International Energy Association: World Energy Outlook 2006. Paris 2006.

[36] "The Physical Science Basis of Climate Change", 1st volume of the fourth IPCC (Intergovernmental Panel on Climate Change) assessment report, 2007, www.ipcc.ch

[37] On water quality in Luxembourg see L'environnement en Chiffres 2002-2003, edited by the Ministry of the Environment (www.environnement.public.lu).

[38] EU Water Directive, see e.g. La directive-cadre sur l'eau. Tirez-en parti! (Brussels 2002), available on the website of the Administration de la Gestion de l'Eau www.eau.etat.lu.

tremendous impacts on Luxembourg through more weather hazards, increasing temperatures, changes in precipitation and the availability of water resources.[39] Most probably, agriculture will be hit most and has to adapt by plant culture changes. Kyoto penalties are already a political reality for Luxembourg and will have a major impact on public finances (e. g. since fuel sale strongly contributes to Luxembourg GDP). The example of climate change demonstrates that fundamental research is necessary in the field of environment / ecology: In Luxembourg as elsewhere, research should not be limited to projects economically profitable in the short run. An important topic is the "risk of unintended consequences" associated with policy decisions, given the fact that our understanding of ecological dynamics is limited.

Politics

- *Governance:* Good governance is a guiding principle for government today. It includes openness (transparency), accountability, effectiveness, coherence, and last but not least participation. In practice, these principles are not easy to pursue. In a consensus-oriented society, accountability is rather naturally diluted between all public actors – ministries, administrations and public establishments. Participation, or inclusiveness, is another challenge: voting for immigrants, language issues, citizens implication in decision processes etc. In fact, there is a divide between the native workforce (often occupying government positions) and the foreign workforce in the private sector (often doing low wage jobs).[40] This leads to a segregation of foreign people and the development of parallel societies. There is also a gulf between the political and economic system. Business is lead on a global level whereas politics is still done at a local level. This corresponds to a "class difference" between government and private sectors.
- *External political context:* With the enlarged EU-27, Luxembourg's impact on European institutions has generally weakened. At a closer look, the picture becomes more complicated. On the one hand, Luxembourg has gained influence – as a point in case – with the creation of the European Central Bank; on the other hand, deregulation e. g. in the communication sector cuts off some sovereignty. There are estimates that about 70% of all legislation is made or influenced by Brussels through directives which have to be transformed into national law. Likewise in business: decision centres are moving through mergers (i.e. Arcelor-Mittal). There is a need for research on this changing context.
- *Social Systems:* Unemployment in Luxembourg has risen in recent years, growing from 2.6% in 2001, to 4.2% by 2004. This is still much below the unemployment rates in

[39] Recently (Feb. 2007), shocking results of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) have been published (see www.ipcc.ch) and triggered strong media reactions.

[40] Participants of the Stakeholder Workshop called this "Kuwaitisation", because the situation in Luxembourg is somewhat like the situation in Kuwait where low wage jobs are done by foreign workers from Pakistan. Foreigners make up over 50% of the total workforce, with the main countries of origin being: France, Germany, Belgium and Portugal.

neighbouring countries, but nevertheless a clear cut warning sign.[41] At the same time, the burden of ageing on the pension system is growing. Another issue are cross-border interrelations of the social systems: Complementary pension systems may be difficult to adapt for a small country like Luxembourg. The problems of the social (protection) system are aggravated by a changing social fabric. There exists an increasing gap between rules and social realities: The legislative framework in Luxembourg is not yet adapted to social change, e. g. laws are still based on a traditional family concept, whereas divorces are rising and less and less people live in traditional families – which leads among others to an erosion of traditional models of mutual support.

[41] It should be noted that Luxembourg is in the comfortable situation to be able to "export" to certain degree unemployment due to the high level of cross-border workers (about 30% of workforce). – Data from Statec: "Luxemburg in Zahlen 2005".

5. General SWOT for the Luxembourg research environment

During the foresight exercise, a list of strengths, weaknesses, opportunities and threats[42] for the Luxembourg public research sector[43] has been developed by drawing upon comments from national and international experts, stakeholders from the private and public sector as well as research users:

The main strengths of the Luxembourg public research sector

- *Government dedication.* Since 1999 the Luxembourg government is successfully following its decision to strengthen and develop the public research base as a springboard for more innovation-led growth. Public expenditure has grown by a substantial margin in recent years and the government is strongly committed to additional investment in R&D in the next years, reducing the gap in the ratio of R&D expenditure to GDP with other western economies. The creation of the National Research Fund, the University of Luxembourg and the "Cité des Sciences, de l'Innovation et de la Recherche" in Esch/Belval with the physical regrouping of the premises of the University of Luxembourg and of the CRPs on one site can be considered as the lighthouse projects in this endeavor.
- *Existing strong research groups.* Over the last years a small number of strong and internationally visible research groups have been established in Luxembourg in various domains. It is of outmost importance to further strengthen these groups.
- *Openness of Luxembourg.* Luxembourg has always been a melting pot of different cultures and nationalities, providing a unique environment for students and researchers as well as for companies and research institutions. International collaboration within research projects has always been a strong asset for public sector research. Additionally the central geographical position in Europe and the strong ties to the European Union are competitive advantages over other regions.
- *Neutral place for R&D investment.* Due to the low number of local R&D actors in the private sector, Luxembourg could play the role of a neutral place to attract foreign companies provided a strong public research environment is created.

In regard to these strengths, the objectives of the Luxembourg government to develop a more innovation-led economy are ambitious but realistic if the following weaknesses of the system are addressed resolutely:

The main weaknesses of the Luxembourg public research sector

- *Lack of a research tradition.* Although research in the private sector is comparatively strong, the country lacks an academic and thus research tradition, which makes it difficult for public sector research to gain visibility on a European and international level as well as on a national level. In the future Luxembourg should not only be known abroad as a financial

[42] Some of the key issues have already been addressed in the "OECD review of Luxembourg's Innovation Policy", 2006.

[43] This means that an "internal" positive characteristic of the public research sector is considered as strength whereas a positive characteristic from an "external" perspective is considered as opportunity, meaning that the SWOT is carried out in relation to what is internal and external for the public research sector. The same holds true for weaknesses and threats.

centre or home of the largest steel producer but also as an innovation-led economy. Furthermore, some aspects of a favorable research environment need to be addressed in the near future, e.g. access to databases and scientific libraries, legal frameworks, etc.

- *Applied research myopia.* Public sector research tends to suffer from a widespread "applied research myopia" resulting in recurring discussions on the effectiveness of basic research in Luxembourg (see chapter 3).
- *Science, Technology and Innovation Policy.* As the research community itself is very young, the same holds true for the science, technology and innovation policy. There is a clear lack of strategic orientation and coordination of funding instruments. These mechanisms do not transparently and flexibly support research activities from basic research to the development of products or technology transfer to the user. The current funding instruments tend to produce a high administrative burden on researchers and management thus reducing efficiency and international competitiveness. Additionally the lack of coordination between the strategies of the different actors has led to some redundancies in research activities. At the same time the coordination between decision makers beyond the mere funding instruments needs to be improved.
- *Human resource policy.* Developing national human resources as well as attracting researchers from abroad is the key element in a successful government policy beyond the creation and improvement of isolated funding instruments, like ATTRACT or the research grant system. The regulatory framework needs to be improved to provide an attractive research environment in Luxembourg. Further progress in the human resources sector is needed especially concerning the career development for researchers, the transposition of the directive on a specific procedure of admitting third-country nationals for the purposes of scientific research,… The recommendations of the "European Charter for Researchers" and of the "Code of Conduct for the Recruitment of Researchers" should be followed at all levels, from funding instruments at the funding agencies to job offers at the research organisations, to achieve a successful human resources policy.
- *Networking.* Even though Luxembourg is a small country, networking between stakeholders in research can be improved, in particular in view of promoting partnerships between research performers and research users and thus the transfer of knowledge from the public to the private sector.
- *Scale of Luxembourg.* For the government's policy to be effective, it is crucial not to spread the very limited resources on a large number of research fields which would make it difficult to reach critical mass, international visibility or socio-economic impact in none of the fields. On the other hand, prioritization needs to provide public sector research with enough freedom to investigate upcoming questions and explore promising research topics. Research priorities should ensure to keep a maximum number of options open for the future.
- *Valorisation.* For public research institutions to efficiently contribute to the development to the national innovation system, it is of outmost importance to promote the valorisation of research results at all levels (publications, IPR generation, creation of spin-offs, technology transfer to the private sector, mobility of trained people to industry, etc.). The instruments

supporting the different steps from basic research to development need to be evaluated in detail and adapted to an integrated vision of the innovation chain.

- *Scientific awareness.* With an academic and research tradition missing in Luxembourg and the low media coverage of research activities in Luxembourg, the public awareness of the impact of research on everyday live as well as the economy is low compared to other countries, thus jeopardizing the successful implementation of the government's policy. Additionally science education in schools needs to gain further importance to counter the shortage of researchers and scientists.

The main opportunities for the Luxembourg public research sector

- *Dynamic situation.* The development of a fully-fledged public research sector basically from scratch has been and still will be for some years an exciting endeavour. Substantial funding is available and every person involved in this process may contribute to shape the environment and the institutions at a level which has no equal in other developed countries. The creation of the "Cité des Sciences, de l'Innovation et de la Recherche" is a huge opportunity to gather people from very different research backgrounds in a central location to perform multi- and/or interdisciplinary research activities. As a precondition to this, it is of outmost importance to foster the excellence in the disciplines covered by the research institutions. Additionally decreasing or stagnating public R&D investments in other countries contribute to make Luxembourg attractive for highly-qualified researchers.
- *Incentives to attract researchers.* Human resources (training of young researchers and attracting foreign researchers to Luxembourg) play a crucial role in the implementation of the government's policy. The improvement of the grant allocation system is a major step in providing efficient support mechanisms to young researchers. The FNR programme ATTRACT, which aim it is to attract excellent young researchers to Luxembourg, will increase the international visibility of Luxembourg public sector research as well as its scientific excellence. Last but not least the high level of wages is an attractive incentive for researchers to come to Luxembourg.
- *Youth of the research system.* The fact that the public research system is relatively young entails a certain openness and readiness for structural changes, where needed.
- *OECD Review of Luxembourg's Innovation Policy.* The research system has undergone a recent review which gives a detailed overview of the structural deficiencies of the Luxembourg innovation system. In general, stakeholders support the recommendations formulated in this review, which the Government intends to pursue determinedly and to implement rapidly, first steps having already been taken (strategic audits of the CRPs, creation of a High Level Committee assisting the Government in defining the national research policy, ..).
- *Attractive framework for companies.* The establishment of a strong public research environment is a further step in the development of Luxembourg as an attractive business environment on top of the already existing assets, e.g. tax legislation, strategic geographical location, etc.

- *Short decision paths.* Due to the size of the country and the low number of stakeholders, the decision paths are short and decision makers can react rapidly and flexibly to upcoming problems.
- *Testbed.* Luxembourg could play the role of a testbed in the Greater Region by integrating tools and methodologies from neighbouring countries, by developing new solutions for a multilingual environment and by playing a neutral mediator between strong interests of larger countries. Additionally strong links with the universities of high standard in the Greater Region will contribute to increase the critical mass and visibility of Luxembourg research.
- *Expatriates.* There is large community of Luxembourg born researchers living and working abroad. Public and private sector research will benefit from a strong network of expatriates and by attracting some of them to the country by providing a favourable environment for research. In general, international collaboration should be promoted at all levels.
- *7th Framework Programme.* Participation in the 7th Framework Programme of the European Union allows public research institutions to gain international visibility and integrate into European networks of highest quality.
- *Foresight culture.* In the future, the thematic prioritization of public R&D policy should be established in close collaboration with all stakeholders, including actors from the public and private research sector, ministries, administrations, research users and foreign experts. Recurring foresight exercises, possibly focussed on one thematic field at a time, seem to be the adequate tool to be implemented.
- *Public-Private Partnerships*. PPPs are an essential instrument to guarantee an optimal contribution of the public research institutions to the development of the national innovation system. The specific instruments supporting these collaborations at different levels, from networks to common research projects, need to be further developed to increase their effectiveness. PPPs foster the mobility of trained people and the transfer of knowledge from the public sector to industry.
- *Cooperation*. Luxembourg is one of the leading countries in the world for its financial aid and the commitment towards the development in the South and poverty reduction and sustainable development are the two major objectives of the policy of cooperation. Public sector research could complete and reinforce these activities by providing skilled expertise, by developing innovative solutions and by training researchers from developing countries.

The main threats for the Luxembourg's public research sector

- *Recruitment*. At the moment there is strong competition between the developed and some of the developing countries for the brightest researchers. This competition will persist in the future and the basis for the government's policy to be successful is by efficiently and rapidly addressing the issue of human resources.
- *International competition*. In most of the developed countries, research and innovation has a long and fruitful tradition and is one of the backbones of the national economies. It will be

therefore a difficult task for Luxembourg public research to gain visibility and critical mass against this strong competition. Additionally, a number of private decision centres lie outside of Luxembourg, making it difficult for public policy to establish a stable environment.

As a conclusion, for the government's intention to further promote a more innovation-led growth and to diversify the country's economy to be successful, public R&D policy and all concerned stakeholders need to specifically address all the above-mentioned issues in order to provide a favorable environment for Luxembourg public research. Provided the necessary actions will be taken, the participants in the Foresight exercise generally expressed their belief that public sector research will contribute to the sustainable welfare of the country.

6. Six National Research Priorities for Luxembourg

This chapter presents the National Research Priorities for Luxembourg as they emerged from the FNR Foresight exercise. In particular, the following sub-chapters outline the socio-economic as well as environmental relevance of the priorities, the specific research issues to be addressed by future research projects and the steps to be taken to implement the research priorities.

6.1 Innovation in Services

Luxembourg's impressive economic growth since the 1980s[44] - compared to neighbouring countries - has been due to the performance of the service sector which developed at an accelerating pace in the last decade of the 20th century. Today, the service sector is Luxembourg's most important economic sector: by 2001, services as a whole (commerce, financial services, property and business services, other services like public administration, education, and community services) contributed more than 80 % of the total value added[45] and employment in services accounts for about 75 % of total employment in Luxembourg.[46] The service sector is driven by the outstanding performance of the financial services (financial intermediation, insurance and financial auxiliaries) which contributed, between 1996 and 2000, for more than 25% to the total growth of gross value added.[47] The development of financial services has also had favourable repercussions on such sectors as hotels, catering, air transport, business services (consulting, advertising, legal services, cleaning, security) and IT services[48] and the impact on growth of these sectors should not be underestimated.[49] The employment in business services practically quintupled from 1985 to 2002 (from 7000 people to more than 35 000) and represented approximately 13% of total employment in the Luxembourg economy in 2002. The share of business services in total value added grew from 3.1% in 1985 to 6.3% in 2002.[50]

It is of highest importance for Luxembourg to consolidate the competitiveness of its most important economic sector on the one hand, and, on the other, to strengthen the innovation capacity in all sectors in order to diversify the economy and therefore minimize the risks

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[44] Since the 1980s, economic growth has been much higher in Luxembourg than in neighbouring countries: it averaged 5.2% over 1985-2005, turned up sharply during the 1980s, reaching a peak trend rate of around 6% per year in the late 1980s-early 1990s, before gradually declining to 4-4½ per cent during the early 2000s.[44] For 2006 and 2007, economic growth projections have been revised upwards. Real GDP is now forecast to grow by 5.5% in 2006 and then slightly slows down by 4.0% in 2007.[44]
[Sources: OECD Economic Surveys, Volume 2006/9 – July 2006.
National Report Luxembourg, Eurochambres, 2007.]

[45] By 2001, manufacturing industry's share of the sum of values added was only 11%; the electricity, gas and water sectors and the agriculture sector accounted for only 1.2 % and 0.6 % respectively of this sum, and the share of the construction sector stood at 5.9 %. [Source: Statec, Economic and social portrait of Luxembourg, 2003.]

[46] Statec, Economic and social portrait of Luxembourg, 2003.

[47] Employment in this sector, which stood at 11 000 in 1985 (7 % of total employment) reached 33 000 in 2001 (11.9 % of total employment).

[48] http://forum.europa.eu.int/irc/dsis/regportraits/info/data/en/lu_eco.htm

[49] The transport and communications sector contributed for nearly 18% to the total growth from 1996 to 2000. Also the trade sector and the health and social services contributed to growth - albeit to a lesser extent.

[50] http://forum.europa.eu.int/irc/dsis/regportraits/info/data/en/lu_eco.htm

associated with a strong dependency of the economy on one sector (the finance sector) and the current declining trend in growth.[51]

Hence, "Innovation in Services" emerged from the second phase of the FNR Foresight exercise as a public research priority of extremely high socio-economic relevance for Luxembourg. This priority was defined by the experts involved in the workshops as an "umbrella" notion covering the three domains "Business Service Design and Innovation", "Fostering the Economic and Legal Framework for Innovation", and "Performance and Development of Financial Systems". The FNR administrative (CA) and scientific (CS) boards recommended at the beginning of their joint meetings to also include the two research domains "Information security and Trust management" and "Telecommunications and Multimedia" in this umbrella priority, highlighting the fact that progress in these two domains should allow for the improvement of existing services and the development of new ones. Even more, future research projects in "Information security and Trust management" and "Telecommunications and Multimedia" should be explicitly oriented towards applications in the domain of services.

The five research domains covered by the umbrella priority "Innovation in Services" are presented in detail in the following sub-sections.

6.1.1 Business Service Design and Innovation

Luxembourg's economy is largely based on the service sector and this dominance is even expected to rise in the future whereas the manufacturing industry will correspondingly lose its share in the Luxembourg economy. IT activities, comprising consulting in information technology systems, software services production, data processing, database activities, etc., currently constitute the most dynamic sector of the economy in terms of employment and value added.[52] Additionally customers of e-services are not only located in Luxembourg (e.g. finance and broadcasting industry), the market potential and thus the economic impact is enormous in comparison to the size of the country. At a European level, the software and services sector employs more than one million European specialists and is expected to account for 215 B€ in revenues with an expected growth in 2005 around 4,4%. This figure, roughly 2% of the European GDP, represents 65% of the total European IT market value and 31.5% of the total European ICT market value[53].

Hence, it will be important to develop tools that facilitate and aid the development and improvement of services in Luxembourg; the 'new' subject of *Business Service Design and innovation*, which is in line with the new emerging discipline of Services Science, providing the means to do so. The definition of Services Science given in an IEEE Computer journal article reads as follows: "[…] services science, [is] a discipline concerned with finding ways to increase productivity and innovation in services-related industries and tasks by applying scientific means and methods.[…] Services science is a multidisciplinary field that seeks to bring together knowledge from diverse areas to improve the service industry's operations, performance, and

[51] OECD Economic Surveys, Volume 2006/9 – July 2006.

[52] Source: STATEC (2003) Economic and social portrait of Luxembourg.p.123

[53] NESSI Strategic Research Agenda, 2006.

innovation."[54] Services science is based upon an interdisciplinary approach, which guarantees the alignment of technologies, business processes and strategies as well as human skills - as demonstrated in a report by IBM in 2004 and shown in the adjacent picture[55]. Within the Luxembourgish context, it might be also interesting to take care of an additional dimension regarding research related to and needed for the alignment with the regulatory and legal framework.

"Business Service Design and Innovation" covers many different applications and e-services of different levels of granularity: business related e-services (business to-business, administration-to-business services, same processes in e-administration and internal e-solutions of a company…), e-government (including e-voting), e-governance, e-administration, but also services related to e-health, e-learning, etc.

Research in Services Science aims at facilitating the improvement and the more efficient development of ICT-based services together with an associated better quality and SLA (Service Level Agreement) - for applications in the financial sector (like today's example of Web-banking services enabled by internet technologies) but also in other sectors like for example multi-media services in the broadcasting sector and services in the transport and logistics sector.

Since the service sector is likely to continue to be under increasing pressure to innovate – and technology-related innovation is likely to accelerate in many services - , research in Services Science will have a large economic impact. Services Science is of direct interest for Services clients, consultancy firms and "service providers" as most activities are concerned with the development and integration of new business services. Furthermore, research in Business Service Design and Innovation might have a potential for providing support to SMEs and spinning off new companies. "Developing services science is a necessity, an opportunity and a vision for Luxembourg's public and private research actors." Public research in this domain is also of high social relevance as it would foster job creation in the service sector. By helping reducing waste by optimizing processes, research in this domain might also have a positive environmental impact.

Given the structure of Luxembourg's economy, public research in the area of e-services should primarily answer the needs of the business and financial sector. The most promising research issues identified in this FNR Foresight exercise (cf. table below) are mainly concerned with the services science and deal with the three following business/IT alignment situations:

- business model innovation
- business process efficiency (and flexibility)
- business service regulation compliance

[54] Linda Dailey Paulson, Services Science: A New Field for Today's Economy, IEEE Computer, August 2006, p18-21
[55] IBM Research, "Services Science: an new academic discipline?", 2004, http://domino.research.ibm.com/comm/www_fs.nsf/images/fsr/$FILE/summit_report.pdf

List of research issues in the domain of Business Service Design and Innovation
• seamless service architecture • incentive systems • business-IT alignment • service disintegration • enterprise architecture • adaptivity, interoperability • simulation and optimization • service level agreements

Luxembourg should aim for an exceptionally efficient and easy-to-use interface between businesses, financial institutions and government, to further attract businesses to Luxembourg. As Luxembourg is a high cost country and cannot implement products that require a lot of human workforce, the private and public sector research needs to focus on the development of new high-value added products and services for both business and the general public.

Public sector research should achieve a sort of "clearing house" functionality for information exchange in various sectors (e.g. health services for cross-border workers, clearing house between national standards) to make it easy to create, share and use knowledge in business, scientific and societal applications. A platform could be developed to enable interoperability and interconnectivity of information. As larger countries build national information systems that are incompatible with those of other countries, Luxembourg has the natural need to interconnect those systems to serve businesses and individuals from the Greater Region. This need should lead to an opportunity of setting interoperability standards, pushing the image of Luxembourg, and building hubs. In order to establish Luxembourg as a hub for logistics information services, research on information flow and lingual transformation should be in line with other services provided to the logistics industry.

Research in Business Service Design and Innovation may cover a variety of application fields and thus foster specific synergies with some of other priority domains discussed in the FNR Foresight exercise (see criteria table, C11); therefore research in services science will benefit from a multidisciplinary approach which may be easier to put in place in a small and developing research environment like Luxembourg than in larger countries.

As a new trend in IT (started in 2004), part of the new economy and together with its multidisciplinary partner subjects (business, law), services science is a scientifically attractive domain with many intriguing open questions for research[56]. Within the next 10 years, Luxembourg should aim at:

- providing knowledge and direct support to industry for the development of more productive services;
- fostering innovation and creating added value for the banking sector;

[56] Among the ICT-related research priorities, this domain might offer the largest opportunities for more basic research, which should not be neglected, as opposed to the rather application-oriented flavour of the proposed research in the domains Information security and Trust Management and Telecommunications and Multimedia.

- developing a university course/degree on services science and become a hub/reference point for services science in order to increase Luxembourg's scientific reputation in this domain and attract talents.

This research priority is in line with the EU's Seventh Framework Programme (FP7) and priorities set abroad (see criteria table, Criterion C9). However, even if a number of scientific institutions have already started their positioning[57] there are still opportunities in services science for Luxembourg to develop competences and gain critical mass at an international level.[58] Services science may even be one of the very few ICT related fields where the scientific competition at international level is still open.

There are already research activities carried out in the domain in Luxembourg (see criteria table, C7). Nevertheless, efforts are still needed to reach critical mass for research. This can be achieved in building research groups in IT and taking initial steps towards establishing training and collaboration on multidisciplinary level (incl. Public-Private partnerships), a sine qua non for being internationally competitive. As services science is a relatively new field of science, it might be difficult to recruit personnel for research. Therefore, incentives have to be defined to attract top-level researchers to Luxembourg. Collaboration with experts from abroad appears to be very important in order to adapt existing e-service solutions from neighbouring countries. Synergy between research and technology transfer in Luxembourg, mainly at the level of the CRPs, is an opportunity to build upon.

6.1.2 Fostering the Economic and Legal Environment for Innovation

Innovation can refer to the successful exploitation of new ideas in the form of a new or improved product or service but also to the way in which a product or service is delivered. Equally, innovation can be about creatively marketing an existing product, or about changing the business model of a sector. Boosting innovation is at the core of the Lisbon Strategy since it is a key determinant of the ability of an enterprise, sector, region or country to remain competitive.[59]

Despite its good general economic performance, Luxembourg performs less well in innovation. The EIS indicators in 2004 highlighted many areas related to innovation where Luxembourg is below the EU25 average[60]. Nevertheless, in some areas, the figures show that the country is making up for lost time. Luxembourg ranks 14th out of the 33 countries and 10th out of the 25 EU countries. Luxembourg's best performance is in Intellectual Property Rights (IPR), which could be linked to above average performance in business R&D. In terms of innovation drivers and knowledge creation, Luxembourg ranks low and its performance in applications ranges

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[57] It should be noted that there are also important activities in Services Science in the private sector at Accenture, Electronic Data Systems (EDS), Hewlett-Packard, and especially at IBM which has been a leader in promoting services science. [Source: Linda Dailey Paulson, ibid.]

[58] Linda Dailey Paulson, ibid.

[59] European Innovation Progress Report 2006, European Commission, DG Enterprise and Industry

[60] European Trend Chart on Innovation, Annual Innovation Policy Trends and Appraisal Report Luxembourg 2004-2005

from very poor for new-to-market product sales and for employment in medium-high and high tech manufacturing, to far above the EU average for high tech exports.[61]

The fact that Luxembourg is a very prosperous country relying mainly on a very competitive service sector and especially on the high-performing financial sector has led to a neglect of innovation policy: Before 2006, Luxembourg had no formal innovation policy document setting broad objectives and the innovation policy was not a stand-alone policy. There was only a vague understanding of innovation, beside research, as one of the means to maintain and increase Luxembourg's competitiveness and to reach the Barcelona objectives as redefined by the government in the elections 2004.

The following targets were set: to raise investments in R&D to 3% of GDP; to strengthen innovation in SMEs; to foster entrepreneurship; to increase the number of graduates in science and engineering. However, even if innovation policy in Luxembourg is closely linked with research policy - since there is a unique research and innovation policy -, in its "National Plan for Innovation and Full Employment", the government has set up 2 different goals for innovation and research. For research, the goal is to increase and improve R&D investments, in particular in the private sector, in order to establish a European knowledge area; for innovation the goal is to facilitate innovation in all its forms.

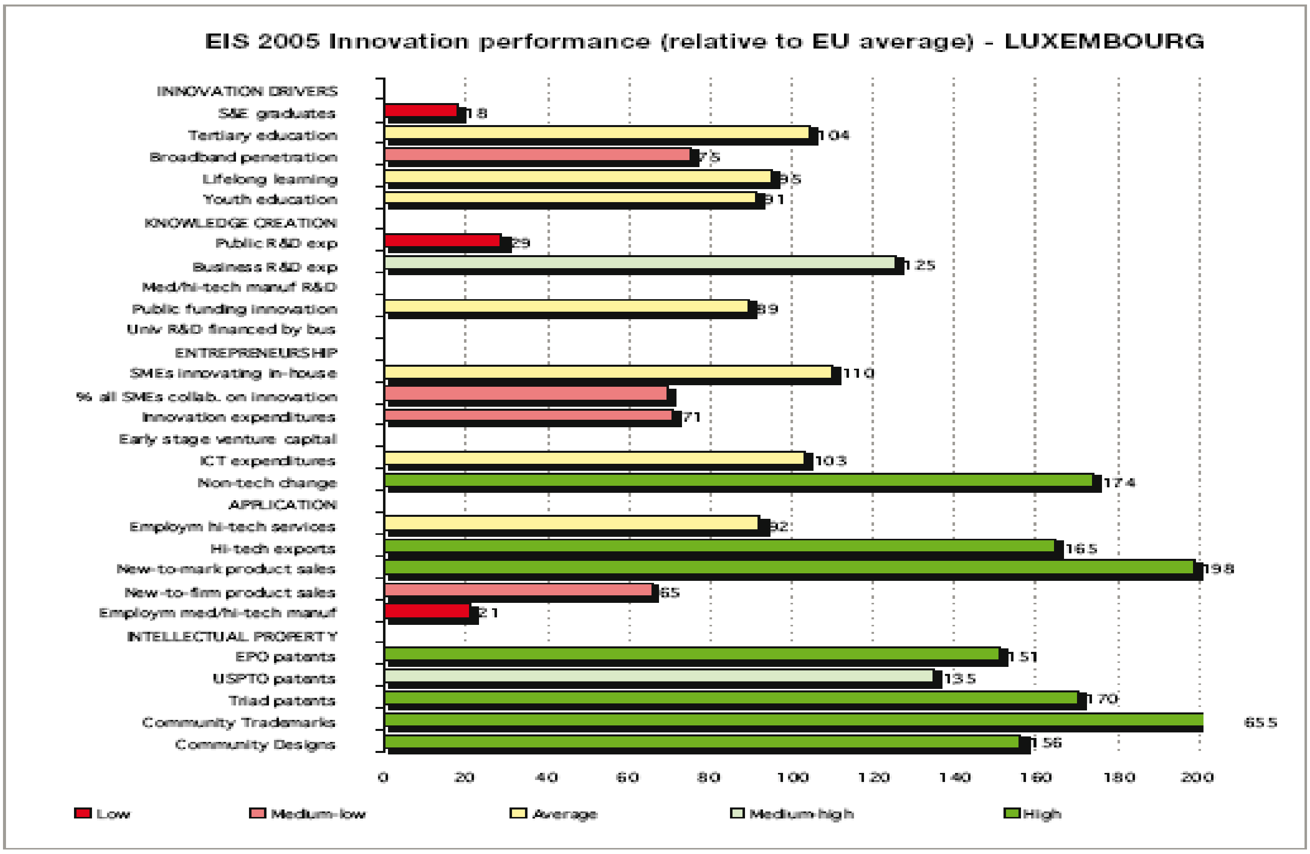
Today, innovation expenditure in Luxembourg is only 68% of the EU average - Luxembourg ranking 20th.[62] However, innovation policy is at a turning point since the adoption of the first national innovation programme in 2006[63]. Increased resources are earmarked and a consensus policy was created. Channelling innovation efforts into carefully selected areas and raising rapidly the share of public research expenditure and innovation expenditure is important.[64]

[61] European Innovation Scoreboard 2005 - Comparative Analysis of Innovation Performance / European Innovation Progress Report 2006, European Commission, DG Enterprise and Industry

[62] European Innovation Progress Report 2006, European Commission, DG Enterprise and Industry

[63] http://www.odc.public.lu/publications/pnr/06_10_27_PNR_Rapport_de_mise_en_oeuvre_EN_VFF.pdf

[64] European Innovation Progress Report 2006, European Commission, DG Enterprise and Industry



Luxembourg's innovation performance relative to EU25[65]

The improvement of Luxembourg's innovation capacity should be one of the priorities of public research in view of increasing Luxembourg's competitiveness, diversifying the economy and minimizing the risks associated with Luxembourg's specialization in financial services[66]. Hence, research aiming at Fostering the Economic and Legal Framework for Innovation - in Small and Medium-sized Enterprises (SMEs) and large companies alike - is highly important in order to ensure the long-term sustainability of the Luxembourg economy (transforming Luxembourg from a financial market to a knowledge economy), attract more companies to Luxembourg and support the creation of new ones. The social component is also relevant as research in this domain contributes to fostering a culture of entrepreneurship and creating jobs[67] - especially important in view of the rising unemployment rate in Luxembourg.

Public research should not reduce itself to being a mere supplier of tools for businesses but should focus on general issues such as e.g. understanding links between regulation and

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[65] Source: European Innovation Progress Report 2006, European Commission, DG Enterprise and Industry. N. B. Concerns about indicator quality: There are several concerns with the data from Luxembourg that are partly due to several unique features, such as a poorly developed tertiary education system, and the fact that it serves as the head office for many EU firms. The former probably explains poor performance on S&E graduates while the latter could explain the excellent performance on all IPR indicators, which conflicts with the low share of employment in medium high and high tech manufacturing. Head office firms could receive the patent assignment for inventions developed outside Luxembourg. The high level of high tech exports could also be due to Luxembourg serving as a stock location for high-value airfreight.

[66] See also priority domain "Performance and Development of Financial Systems".

[67] Luxembourg's National Reform Program (2006) already underlined the link between innovation and full-employment.

innovation as well as the development of appropriate methodologies for evaluating political measures within market economies.

The domain *Fostering the Economic and Legal Framework for Innovation* is per se highly interdisciplinary (see criteria table, C11); future research projects should therefore include law, economic and financial aspects but also consider the impact of e.g. territorial development, education, technological infrastructure and quality, process and knowledge management - to name just a few important areas.

List of research issues in the domain Fostering the Economic and Legal Framework for Innovation
• Analysis of legal framework to improve economic competitiveness and innovation • European harmonisation / EU directives and regulations vs. national statutes • Impact of globalisation, supra-nationalisation and European integration on governance • Regulatory competition between member states (in areas like banking, security, company law, retirement funds) • Business Law • Corporate governance and shareholder protection • Entrepreneurship • Efficient administration – innovation funding mechanisms for SMEs • Intellectual Property Rights • Employment protection legislation / labour market • Tax incentives / Tax law

As innovative regulatory frameworks in Luxembourg have created new opportunities and fostered innovation - especially in the financial sector so far -, it is important to build on this competitive strength. Where and how regulations facilitate innovation and what the best innovative-friendly regulatory framework for Luxembourg's companies in the next 5-10 years should look like - given the context of European harmonisation - should be fields of research. In that regard, the regulatory framework can be seen as an enabler for innovation in the whole services sector. In general, public research should determine the right balance between European harmonisation and intergovernmental competition in order to consolidate the legislative advantages already existing in Luxembourg, to address existing legal constraints or create new sovereignty niches supporting economic development, as well as to modernise Luxembourg's legislation. This would be the basis to maintain the competitiveness of Luxembourg and to ensure European harmonization.

More specifically, research should address the implications of EU harmonisation and legislation on the economy and growth. For instance, the free movement of services faces many regulatory and political challenges which should be addressed by R&D in order to develop solutions supporting successful cross-border commerce of services, especially within the Greater Region. Furthermore, research should address the legal framework for companies and good practice for improved management and focus on issues like the harmonisation of contract law and company law. Luxembourg could for instance become a leader in the area of company law in the EU (and the opportunities that arise due to company law harmonisation). This could be a substitute for the current habit of importing law from neighbouring countries, a practice by which legal constraints are imported as well.

Further promising issues are: the investment fund law (at EU and at national level), the social responsibility of enterprises, the improvement of the social economy legal framework and the improvement of Luxembourg's commercial law, in particular those provisions relating to the governance of its corporations. Beyond the business sector, it appears to be important to improve governance and accountability of the public sector.

SMEs often play an important role in fostering sustainability. Research on the linkage between regional development, SMEs and sustainability could be of particular interest to Luxembourg. This topic is connected to research on bankruptcy laws and their impact on SME development.

The STATEC has already launched studies on entrepreneurship (e.g. a typology on entrepreneurs, proving that a majority are from outside of Luxembourg), but more general knowledge on the issue is required. In order to answer the question, on how Luxembourg can promote an environment, which fosters entrepreneurship within Luxembourg and attract entrepreneurs from other countries, it might be important to analyse existing research in other countries and identify barriers and drivers for entrepreneurship in Luxembourg.

Fostering the Economic and Legal Framework for Innovation is, from a scientific point of view, an attractive domain with the potential of hiring high quality researchers from abroad. Due to the high impact expected on the Luxembourg economy, research projects in this domain should be supported to tackle Luxembourg's specific challenges.

Research competencies in law are limited for the moment - the University is the only important actor in public research on law (see criteria table, C7) - and Luxembourg doesn't yet dispose of a critical mass for internationally recognised research. The University will need to increase its capacities in the future and needs to implement measures to improve its attractiveness and recruit highly qualified researchers from abroad. Despite of the scarce capacities at the moment, the Law Research Unit can build on existing research networks (see criteria table, C9) and the faculty is also involved in the activities of the network of qualified lawyers in the financial sector ("Association luxembourgeoise des juristes de banque" ALJB) and of the "Association européenne de droit bancaire et financier" (AEDBF). Such international research collaborations should be strengthened. Public-Private-Partnerships for research may also be a promising way to increase the innovation capacity of private companies[68]. Possible private partners for public research could be: Luxembourg Bar Association, ABBL, Chambre de Commerce, Managers and Bank Directors.

The fact that Luxembourg is close to EU law and institutions (European Court of Justice, Eurostat, European Investment Bank, European Court of Auditors) should be actively exploited. The small size of Luxembourg might furthermore allow an efficient communication between all actors concerned with research in both law and law implementation.

6.1.3 Performance and Development of Financial Systems

The financial sector, as defined in the Classification of Economic Activities in the European Community NACE 6567, underpinned Luxembourg high economic growth during the period 1985-2005 and can therefore be rightly considered as the *heart of the Luxembourg economy*.[69] The

[68] Austria was named as leading in the field of implementing such PPP, e. g. a competence centre for SME.

[69] From the mid-1980s until 2000, the average real growth rate of the Luxembourg economy reached a level hitherto unknown over such a long period (more than 5.5% p. a.) and exceeded that of the other European countries apart

financial sector, growing by 9.9% p.a. over 1986-94 and 3.4% in 1998-2003, contributed 2.0 percentage points to average annual real economic growth during 1986-94 and 0.8 percentage point p.a. since 1994.[70] The sector's contribution to nominal growth over 1986-2003 was even higher than that to real growth, reflecting a substantial increase in the relative price of financial services.[71] The impact of financial services is strongly apparent in the economic downturn of 2001[72]: the GDP growth rate fell from 9.1% in 2000 to little more than 1% in 2001 due to the decline of gross value added (GVA) at constant prices in financial services (negative growth). The growth rates of GVA in other economic sectors, which remained positive in 2001, were unable to balance the decline of GVA in financial services.[73] Today, the Luxembourg economy is growing by around 4-4.5% p.a. and the financial sector, which has recovered from the bursting of the stock market bubble and benefited from the return of investors' confidence in capital and equity markets, currently accounts for 31% of economic activity.[74]

Research on financial systems should not only focus on the macro-economic financial system but also on all kinds of financial subsystems. Research in this area appears to be a "natural" national research priority. Public research should focus on specific aspects of *development and improving performance*, with the aim to optimise all kinds of financial sub-systems within the finance industry. Thus it would increase or strengthen the attractiveness and competitiveness of Luxembourg as a business-friendly environment in general and of Luxembourg's financial sector in particular - especially in the context of European harmonisation ("switch from sovereignty niches to excellence niches"). In particular, given the situation of Luxembourg being a high-cost country, research should support the development of high-added value products helping to keep the labour factor at high level and provide an added-value to the financial sector as a whole (competencies, opportunities for innovations, academic credibility, international reputation, etc.).

The definition of specific future research priorities within the domain *Performance and Development of Financial Systems* requires a lot of consideration. Given Luxembourg's very young and small research and innovation system, a too strong prioritization of finance research today - at a time when Luxembourg's research capacities are still very scarce (even when exploiting existing collaborations with foreign institutions within the Greater Region) - might be counterproductive and hamper the development of an internationally visible and successful critical mass of researchers. Therefore Luxembourg should rather focus on the *effects* expected

from Ireland (over 6%). The annual average growth rate in the Grand Duchy was even more than 7% in the period 1997-2000. [Source: Economic and Social Portrait of Luxembourg, STATEC, 2003.]

[70] To a lesser extent, also the Transport, Storage and Communications Sector (NACE 6064) underpinned the Luxembourg economic growth, contributing on average 1.4 percentage points to annual growth of the whole economy over this period. [Source: OECD Economic Surveys, Volume 2006/9 – July 2006].

[71] OECD Economic Surveys, Volume 2006/9 – July 2006.

[72] Another indicator of the importance of financial services for the Luxembourg economy relate to the number of persons employed in financial services: it increased from 4 300 in 1970 to 11 200 in 1985 and 33 400 in 2002. As for the number of banks, it went from 37 in 1970 to 223 in 1996. [Source: Economic and Social Portrait of Luxembourg, STATEC, 2003.]

[73] Economic and Social Portrait of Luxembourg, STATEC, 2003.

[74] The sector has also escaped unscathed from the introduction of a withholding tax on interest income, which does not appear to have deterred non-resident customers. [Source: OECD Economic Surveys, Volume 2006/9 – July 2006.]

from public research[75], without depriving the country at an early stage from potentially future interesting research ("keep the doors open for unforeseen interesting topics"[76]).

Examples for such *effects* of public research are the increase of the impact on economy and society and the attraction of new private companies or advanced R&D from private firms to Luxembourg. Public research should focus on research topics which cannot be easily addressed by companies and therefore contribute to leveraging the capacities of companies involved in the field. The set up of Public-Private-Partnerships would allow for a dialogue between the researchers and the main users of research and as such for a quick implementation of the results by all social and economic stakeholders. Still, as it cannot be the objective of public research to directly support some specific private firms, the definition of future research issues should essentially take topics into consideration which are of high importance for the financial sector or the Economy as a whole. It is furthermore important to find the right balance between research that addresses concrete needs of Luxembourg and which no other country will fund and research with international scope but no direct impact on Luxembourg (national agenda vs. international scope).

Broad promising research topics for future public research can be defined starting from the *drivers on the demand and supply side* of the financial systems.[77]

How to define research topics in the domain Performance and Development of Financial Systems?					
		Quantitative Methods	Law and Regulation	ICT	Behavioural Finance
Level 1	Performance and Development of Financial Systems				
Level 2	Supply / Demand Side of financial services				
Level 3	1. Competitiveness of the financial sector 2. Private Banking 3. Fund Industry 4. New Business lines / New high added-value products				

For public research to be relevant for the financial sector, research should focus on the main drivers on the demand and supply side of Luxembourg's most interesting financial areas - in terms of revenue generation and job creation -, namely the Investment fund industry and Private Banking[78]:

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[75] Once the effects expected from the research are clearly stated, the choice of the adequate criteria to obtain these effects will follow (e.g. if one would decide to fund only research projects relevant to economic or social actors, one funding criterion could be that such a relevant actor must be involved in the public research project).

[76] Quotation from the Workshop on Law, Economy and Finance on 12th February 2007, Luxembourg.

[77] For instance, an interesting question on the demand side could be "what brings consumers to buy financial products and services?" including aspects of behavioural finance (psychological issues related to financial systems).

[78] Initially, development in Luxembourg's financial sector was built on private banking. Strict bank secrecy laws, a solid reputation for protecting property rights, sound government policies and a high economic freedom (together with New Zealand, Luxembourg occupies third place in the Index of Economic Freedom, behind Hong Kong and Singapore and ahead of the United States, the United Kingdom.), rising taxation of capital in neighbouring countries and the fact that, until 2004, interest on savings was not taxed at source as well as financial liberalisation all provided a favourable backdrop for the development of Luxembourg as a financial centre. Subsequently, mutual fund administration emerged as a major activity, boosted in 1988, when Luxembourg became the first EU member State to

- the *Investment Fund industry*, where Luxembourg has managed to develop into a global player in administration and cross-border distribution. Luxembourg has a predominant position because of its UCITS-related law. The objective for Luxembourg should be to be the best location to domicile non-US funds. The main challenge is not the administration of funds anymore, but innovation in the distribution of funds, especially considering tomorrow's new markets: Asia, Russia, the Middle East, and Latin America.
- the *traditional Private Banking activity*, with its services offering constantly adjustments to the changes in the regulatory and tax framework and hence the needs of the client.

In particular, research should help to cope with the most important challenges and opportunities faced by the banking market at the moment: the quality of services provided to the client, the development of new products and services and the managing of distribution channels[79]. Also research projects in collaboration with social scientists can help to meet the most important organisational challenges: staff recruitment and retention (in line with the gap between labour supply and demand identified in the scope of the priority Labour Market, Educational Requirements and Social Protection), the monitoring of regulatory compliance and the control of costs. In these last two domains, R&D in Luxembourg could play an important role.
Other possible interesting research areas might be[80]: Portfolio Management, Behavioural Finance, Socially Responsible Investment including Microfinance, Risk Management and forecasting financial risks, Venture Capital, Retirement Planning and Financing, Financial Education, etc.

Retirement planning and Financing is one of the key societal challenges in most western European countries including Luxembourg. Creating or enhancing public awareness could be achieved by public research by an in-depth study of these issues, which would: cover the demographic structure and outlook of different countries, outline the expected financial gap of the total pension requirements of the future population, and study how individuals impact the economy by taking investment decisions. A further topic for research could be to function as a helping hand for the financial industry to develop and to improve retirement solutions provided to and by companies or private individuals – which could have an important potential impact on the Fund Industry, Asset Management companies and Insurance companies.

An increasing number of people are confronted with investment decisions (e.g. selecting a risk profile in a pension plan or selecting the right investment fund). Public research could help to improve the general level of competence of the population with respect to investments, e.g. by developing educational tools made available to the public through internet. Studying how

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transpose the first EU Directive concerning Undertakings for Collective Investments in Transferable Securities (UCITS) into national law. Other factors have boosted Luxembourg's expansion as a financial centre: the effectiveness of its prudential supervision, its skilled, multilingual workforce, convenient geographical location and competitive operating costs, particularly in terms of income tax and national insurance. [Sources: Economic and Social Portrait of Luxembourg, STATEC, 2003. OECD Economic Surveys, Volume 2006/9 – July 2006.]

[79] Luxembourg Banking Market Challenges and Opportunities 2006 – Viewpoints of CEOs on the entity's positioning within their group by Pricewaterhouse Coopers (PwC), 2006.

[80] Some of these research issues, like Portfolio Management, are already addressed by private R&D (banks, etc.) and the role *public* research should play still needs to be clarified.

optimised investment decision-making by individuals will add wealth to the economy as a whole could be also promising.[81]

Performance and Development of Financial Systems is *per se* an interdisciplinary research domain: quantitative methods (Financial Mathematics), Law and Regulation, ICT and Behavioural finance are "transversal enablers" for research addressing the 3 levels of issues listed above (see also criteria table, C11).

Given the fact that Luxembourg's financial sector is a pure export sector[82] with almost no domestic market[83], research related to Performance and Development of Financial Systems is of high importance to maintain the international competitive position of Luxembourg as financial market place.

Furthermore, Luxembourg's specialization in financial services has contributed to making the Luxembourg economy very dependent on the performance of the financial sector. Even if the estimated trend growth rate of the Luxembourg economy remains high by international comparison, it has nevertheless slowed down considerably from the 1980s-90s, reflecting lower contributions from financial services. In the long term, such contributions may weaken further as adjustment to factors such as financial market liberalisation and harmonisation, as well as regulatory and tax advantages that have underpinned rapid development of Luxembourg's financial sector draw to a close, pulling growth trend closer to the European average.[84] Therefore public research aiming at consolidating Luxembourg's most important economic sector is of high economic importance in order to minimize the risks associated with dependency on the financial sector and declining growth.

This is also in line with a strategy of ensuring the long-term sustainability of the whole Luxembourg economy, as the financial sector has an important "multiplier" effect on the rest of the economy[85], obviously nurturing highly skilled professions like lawyers, accountants or engineers but also such sectors as hotels, catering, air transport, business services (consulting, advertising, legal services, cleaning, security), law services, and IT services. The civil engineering and construction sector also benefited enormously from the healthy general economic situation.[86] Today, many jobs, including less-qualified jobs depend on the good performance of the financial sector as one of the main drivers of the Luxembourg economy.

Research in the domain Performance and Development of Financial Systems is, from a scientific point of view, very attractive - as research issues to be addressed are not specific to Luxembourg - and internationally competitive (see criteria table, C9). As Luxembourg's research resources are still very scarce (see criteria table, C7), one of the first objectives should be to build broad capacities by developing research institutions like the Faculty of Law, Economy and Finance

[81] In that respect, public research could build on and collaborate with existing activities in this area in the private sector, for instance at the Banque de Luxembourg.

[82] Financial services represented more than 35% of exports of goods and services on average in the years 1995-2001. [Source: STATEC (2003) Economic and social portrait of Luxembourg.pp. 21-32]

[83] 99% of the financial services "made in Luxembourg" are cross-border services.

[84] OECD Economic Surveys, Volume 2006/9 – July 2006.

[85] This is particularly important in view of the threats on the economy due to the deterioration of public finances, the rising unemployment rate, and the large liabilities which the pension system will incur after 2030. [Source: OECD Economic Surveys, Volume 2006/9 – July 2006]

[86] http://forum.europa.eu.int/irc/dsis/regportraits/info/data/en/lu_eco.htm

with the Luxembourg School of Finance, attracting high quality researchers to Luxembourg[87] - a sine qua non to achieve international competitiveness in a 10 years timeframe -, setting up multidisciplinary groups addressing relevant issues in the domain and building a high quality master and PhD programme around those. In order to achieve critical mass at least in some domains, public research in Luxembourg should not address too many different topics but rather opt for cooperation with international research institutes in domains where Luxembourg is lacking a basis at the moment. In general, as public funding resources for research are limited and research results are expected to help improving the performance of private firms, the private sector should contribute to the research funding through Private-Public-Partnerships (PPP). This would automatically provide the basis for a platform for dialogue on common (future) research needs between research actors and private actors (users)[88]. It should be noted that as a consequence of the dialogue platform provided by this foresight exercise, such a PPP has been set up between the University of Luxembourg and Pricewaterhouse & Coopers. The research activities of the EDHEC Business School in France were mentioned as a very good example for research focused on the needs of the industry and for projects directly connected to the needs of the private sector. In the future, the Luxembourg School of Finance (LSF) will rely on a privileged partnership with the "Luxembourg School of Finance Foundation", a public-private partnership with the financial centre of Luxembourg.

6.1.4 Information Security and Trust Management

IT activities, comprising consulting in information technology systems, software production, data processing, database activities, etc., currently constitute the most dynamic sector of the economy in terms of employment and value added.[89] E-commerce opens doors to the international market as it allows a wider range of potential customers to be reached without taking account of the limitation of space. This advantage is even more beneficial for small- and medium-sized businesses, allowing them thereby to compete with the large companies and to expand distribution of their products to an international market. Furthermore, the development of ICT and especially of research in this domain is high on the political agenda of the Luxembourg government[90].

[87] As for all priority domains, this requires a coherent human resource policy for public research including the development of incentives (salaries, scientific environment, infrastructure, etc.) to attract researchers to Luxembourg and convince them to *stay* there.

[88] According to the stakeholders of the private sector involved in this FNR Foresight exercise, today public research is mostly too academic and not adapted to the needs of business and finance in Luxembourg.

[89] From 300 people in 1985, employment rose to nearly 4800 in 2001. The share of IT activities in the total value added of the Luxembourg economy increased from 0.2 % to 1.3 % over the same period. Source: STATEC (2003) Economic and social portrait of Luxembourg.p.123

[90] To promote the spread and use of ICT in general, the government launched the "e-Luxembourg" programme in 2000 (www.eluxembourg.lu), in answer to the "e-Europe" Community initiative approved in June 2000 at the Feira European Council. Among the challenges for future success in the ICT field identified by Luxinnovation in its annual report 2005: Develop the IT competences and resources (R&D) especially in cryptology, etc. / Further supporting the development of an electronic signature tool (Internet security, definition of a publiy key infrastructure) / Development of eGovernment and other e-Services / Further supporting the eLuxembourg plan; Luxembourg needs to develop innovation in ICT according to the i2010 plan of the EC.

"Information Security and Trust Management" is a "transversal" research domain of central and ever-growing importance not only for the banking industry, but for nearly all other ICT applications and e-services - e.g. health applications and applications in critical infrastructures like water and energy infrastructures (see also criteria table, C11). Information security research in Luxembourg should concentrate on the needs of Luxembourg as a market place. As the financial sector is the heart of Luxembourg's economy, research should contribute to consolidate Luxembourg's reputation as a safe harbour for information. Research areas like identity management and privacy - areas that should benefit the banking industry - have top priority. The public and the private sector are particularly interested in risk management and security issues. Also research related to digital rights management beneficial to the existing broadcasting industries should be supported. Other information security areas might be identified in relation to the needs of the European Union, particularly in security topics where European countries are too dependent on non-EU technology (like patented cryptosystems or proprietary software systems).

It is foreseeable that public research in Information Security will have a very high socio-economic impact. Luxembourg should therefore set the objective of becoming a leader in all aspects of trust and security in order to attract new business to Luxembourg and to further develop the economy based on services and finance. Besides its obvious impact on the financial and the broadcasting sectors, public research in this domain will be also profitable for SMEs, as information security and trust are enablers for other business activities. However it is of importance not to develop security applications on its own, but research should be rather steered towards the development of secure (IT-based) applications considering the interdisciplinary character of growth sectors e.g. customers in telecommunications are increasingly asking for new protocols merging identity management and data protection solutions. This is also of significant relevance for guaranteeing the public acceptance of new ICT applications like, for instance, e-health and e-government applications. New challenges for dynamic identity management are posed by new mobile ICT applications. Additionally secure services should not only be developed for businesses but also for citizens: e-government applications will profit from successful public research in information security.

Developing public research activities in cryptology and cryptographic algorithms - as they are the building blocks of security protocols – is of primordial importance for Luxembourg to become a leader in information security and trust management.

Apart from the technical side, the legislation frameworks sometimes limit the use and implementation of new security solutions. Luxembourg should therefore aim at achieving a clear and appropriate legal framework adapted to security issues[91] as this could be of high relevance for companies and a competitive advantage over other countries. Public research in this domain should therefore be carried out in an interdisciplinary way involving ICT experts, users of security solutions, business law researchers and public decision makers.

Furthermore, the concepts of trust and trust management can not be seen only from a technical side, but there is also a need for research on social and behavioural aspects of security and trust, for instance addressing how to communicate security aspects thus reducing the digital divide in

[91] The legal framework dealing with formal proof is being developed at the moment.

society. Beyond its social impact, research on these aspects may increase public awareness of the threats in e-services and e-applications.

The following list of research issues[92] for "Information Security and Trust Management" has been identified in the Foresight exercise:

List of research issues in the domain Information Security and Trust Management
▪ Trust, Information security and Risk management ▪ Identity and Privacy Management, including Digital Rights Management ▪ Reliability and Resilience ▪ Legal framework for trust ▪ Security protocols and Cryptology o Pseudo-anonymity o Formal proofs / Verification / Validation o Secret key algorithms cryptanalysis and design o Public key algorithms and protocols design o Security of implementation of cryptographic algorithms

"Information security and Trust management" is of high scientific interest and a very competitive research domain (see criteria table, C9)[93]. Luxembourg can indeed build on already existing public research competencies (see criteria table, C7); in order to reach internationally recognized excellence and visibility in public research in information security issues, it is nevertheless necessary to increase the number of researchers active in this field (see criteria table, C8) and to further research collaborations with the private sector on the one hand and with public administrations and European research institutes on the other hand. Furthermore, efforts have to be made to further promote and validate the results of public research, especially towards businesses. However, although collaboration with industry is important, the primary aim of public research should be excellent fundamental research rather than only short term industrial projects. Last but not least, public research in information security issues must be carried out in collaboration with business law experts from the University of Luxembourg as well as experts in the field of multimedia and e-services as information security is a sine qua non for developing new applications in these domains. Notwithstanding all the undisputable positive effects, the socio-economic impact of public research in ICT will depend on good communication between public administrations and researchers on the one hand and decisions-makers and those in charge with the implementation of ICT services and tools in the private sector on the other hand.

[92] The domain "Information Security and Trust Management", as defined in the FNR Foresight process, includes only security issues, but no safety issues (operational safety). The broader issue of critical infrastructure, already addressed by the priority domain "Telecommunications and Multimedia" and focusing on operational safety was excluded here.

[93] The development of information security and trust management tools was also identified in many international foresight exercises (e.g. from Denmark, the UK, Korea, Slovenia) as highly important for the development and use of new pervasive ICT applications.

6.1.5 Telecommunications and Multimedia

The domain "Telecommunications and Multimedia" encompasses the development of technical infrastructures for the distribution of content as well as the development of new multimedia applications.

Telecommunications

The development of technical infrastructures for the distribution of content was seen to be very important for Luxembourg. Research in this area should be media and telecommunication-neutral, addressing therefore satellite as well as terrestrial transmission. Regarding satellite distribution of content, the ESA membership provides new opportunities for collaborations with experts and industries abroad and for influencing the development of new telecommunications standards. Research in this area should focus on the distribution and personalisation of satellite signals (e.g. for households, but also mobile users) and build on the existing competencies in the private sector, especially in the ground segment.

Crisis and disaster management could significantly profit from advanced ICT architecture, regarding monitoring and early warning-systems as well as integrated "alarm" chains. The fundamental research question is the optimization of information flows in crisis situations. The development of crisis response systems and early warning systems for natural disasters (flood, wildfire, earthquake, tsunami, etc.) are important domains for public research with high socio-economic impact. Besides obvious important applications for crisis management bodies and operational units such as emergency services, police, army, etc., such tools also serve as an information tool for the public during a crisis. Research in this domain may also have a positive impact on the economy by providing companies with new secure tools regarding crisis management - for instance, in case of pandemics, plane/train crashes, terrorism induced incidents, power shortages, data losses, etc. - and data security might attract foreign business to Luxembourg. Some solutions to the problems cited above already exist, but there is still a need for research to optimize such systems. Furthermore, as Luxembourg has to provide crisis management resources for a lot of different customers, a technical solution should be developed which copes with many different customers with different needs.

A satellite infrastructure for content-distribution could furthermore support the development of intelligent, wireless and mobile integrated ICT applications. The convergence of devices and content was highlighted as an important ICT trend as well as (the urgent need for) universal plug-and-play. The study of intelligent, self-organised and dynamic networks for improving seamless applications/hand-over has been assessed as very promising for public research, especially because of a lack of a strong international R&D on that issue so far. Public research in this domain could help the private sector become more competitive. Architectures and applications of/for ad-hoc networks, mash-up networks can also be carried out by publicly funded research. The task consists of building a new paradigm that can be used for the convergence of services. There are already competencies at the University of Luxembourg, but there is a need to extend this research.

Public research focusing on Telecommunications / ICT Architecture on the one hand will have a high societal impact as it contributes to increase people's connectivity and to offer more convenient personalised services; on the other hand, the economic impact of research may also be high, given the market size for Pan-European content distribution platforms and the strategic ICT infrastructure needs of modern knowledge societies.

The research domain is also scientifically attractive as its size makes Luxembourg a good test bed for requirements of the ICT infrastructure - as already demonstrated for instance by the current U2010 Project (FP6) carried out, amongst others, at the University of Luxembourg and dealing with establishing an interaction of different national and international critical IT infrastructures[94]. Luxembourg can also be a good testing ground for wireless infrastructure all over the country. The research focus needs to be on services and applications, relying on already existing technology (and partly already used abroad) and not on further, new basic research. Therefore it is very important to develop research collaboration networks with experts abroad. Especially, some research is still needed to adapt existing technologies to Luxembourg's specificities. The importance of seamless connectivity was stressed regarding business and public life as well as schools, for which connectivity and bandwidth is very important. For instance, an available wireless infrastructure could allow an increased use of Internet in schools and teaching methods. Therefore this issue might also be of concern in the context of Social Sciences and Humanities - see for instance the corresponding aspects of the priority "Labour Market, Educational Requirements and Social Protection". Wireless connection technology is also necessary to develop dynamic networks and dynamic tailor-made services.

With the three EC-funded research projects U2010[95], Nartus and ARTUS5, the University of Luxembourg has already acquired some international visibility and competencies in the domain, on which future similar research projects related to "Telecommunications and Multimedia" should build. In particular, as research on the topics described above is mostly already carried out by the private sector (e. g. SES Astra, HP Luxembourg, Luxspace, Satlynx, etc.), especially by large international and competitive solution providers, Public-Private-Partnerships for research should be promoted. Considering the strong international competition in the field (see criteria table, C9), a market-analysis and an in-depth analysis of the competitive environment should be carried out during the implementation phase of this FNR foresight exercise in order to define promising entry points for research projects in Telecommunications and Multimedia.

Multimedia

With the view of developing a Pan-European platform for aggregation, distribution and delivery of content, public research activities related to multimedia applications should be promoted. Multimedia is an important application field with many feasible research issues and opportunities for Luxembourg – from interfaces to content generation. Two trends shaping the behaviour of the consumer of multimedia were identified: 1. Users (in particular the young

[94] U2010 is a consortium of 16 industrial, governmental and scientific partners to address the strategic objective for Environmental Risk Management of the European ICT information and communication technologies) sector. In-line with this objective U2010's research is designed to support GMES in-situ monitoring systems (emerging self-organizing, ad hoc network technologies), public safety communication (alert systems, citizen communication, rapidly deployable emergency telecommunications systems) and convergence (early adoption of common open architectures). (source: http://wiki.uni.lu/csc/Projects.html)

[95] The focus of U-2010 is to provide robust telecommunications capacities for crisis management. It is intended to be technology-neutral by using existing and future telecommunications infrastructures.

generation) not only want to consume content, but also to create and interact with it - Web 2.0 has drastically changed the mediasphere; 2. Users want to have "their" content available whenever, wherever and on whatever mobile device they chose. Mobility is a challenge for future ICT architectures.

Important research issues for the next years concern the management of multimedia content; the convergence of different media contents and of distribution of media content; search engines and cross-format data retrieval; the semantic web (semantic tools); geolocalisation and location-based services. Research in multimedia applications requires the availability of digital libraries and competencies in language engineering and knowledge management and data mining. There is also a need for integrative databases as a necessary knowledge platform for research on multilingual applications, though databases are more an issue of implementation than of research.

Bringing digital media content to the end-user can be highlighted as a very promising field, as satellite technology makes it possible to distribute content to the consumer with high precision and bandwidth. The presence in Luxembourg of a satellite-based communication operator (SES) and a number of content providers seems to offer some opportunities for Luxembourg in positioning new services regarding interactive TV and/or interactive internet content. It was considered that some R&D would be worthwhile in this theme (it could also be reinforced through participation in the ESA programme). In this regard, Luxembourg could build upon existing public research projects in this domain, e. g. in the scope of LIASIT[96] addressing issues like the analysis and design of mobile satellite broadcast systems or the assessment on improved spectral efficiency of multi user satellite networks. Furthermore, Luxembourg hosts some companies that (can) play major roles in the multimedia world and in the development of new multimedia applications, such as Amazon, Skype, RTL, and SES. Funding for research collaborations with these and similar players could be very beneficial to increase their investment in Luxembourg, attract other players, and create innovative spin-offs. Furthermore, when developing new multimedia applications, it should be important to be aware of Intellectual property rights/DRM[97] and the way to cope with them in order to reduce users' restrictions. An interesting research topic would be the development of a legal framework for purchasing multimedia content in a globalized market. It may be an opportunity for Luxembourg to develop or unify standards to overcome country barriers. Public research could help to overcome these barriers, in particular by evaluating where the legal frameworks have to be modified, in order to create business opportunities. Such research will profit from an interdisciplinary approach involving business lawyers as well.

Especially new opportunities for quick and easy intuitive data retrieval and usage enabled by new tools for cross-format (audio, video, visual, language) data retrieval and utilisation of semantic (web-)search engines were deemed as very promising despite a limited economic impact. Such technologies could be used for biometric or other recognition methods in security applications. Further developments could also lead to new tools for lifelong learning and therefore have an important impact in the education and training domain. In this area, public research could build on existing competencies and projects like the "eLearning" project within

[96] http://www.liasit.lu/research/research.shtml
[97] Digital Rights Management

the scope of e-Luxembourg[98]. Also Web 2.0 applications[99] are likely to play an important role for Luxembourg in the future and should be seen as a promising area for R&D.

Another important aspect was seen in multilingual content management, in applications that allow multilingual content generation, data retrieval and platforms/tools that enable „barrier-free"-communication (e.g. for life long learning) by being accessible in multiple languages. Such applications could provide an interesting niche for Luxembourg research and business responding to needs that cannot be addressed by monolingual societies. The interest in multilingual aspects is not new for Europe[100], and the European Commission has already funded a great number of projects in earlier years. It is important to note that the US only recently started to heavily increase its funding of multilingual multimedia research.[101] The development of multilingual data search engines by semantic retrieval could be combined with a strategy of promoting the use of the Luxembourg language in ICT tools. This could contribute to consolidate the visibility of Luxembourg's culture and language on the Web, thus promoting Luxembourg's specific identity. As a multilingual country, Luxembourg may be interested in offering multilingual ICT services to its citizens and residents. Access to Luxembourgish audio in parallel with the residents' native language can be an incentive to learn and practice Luxembourgish; this issue should be addressed together with social scientists in charge of research projects focusing on the priority "Identities, Diversity and Integration". ICT may thus contribute to the health of Luxembourgish as a living language. Automatic processing of both written and spoken Luxembourgish documents produces as a positive side-effect resources for linguistic studies and language-related services (disabled people, language training centers...).[102]

As multilingual ICT development requires large linguistic resources[103], European countries should coordinate their efforts for structuring and developing multilingual resources and research.[104] The role Luxembourg could play in that matter still needs to be explored. For the public sector to contribute to semantic web and multimedia applications, it is essential to create Public Private Partnerships which could offer promising opportunities for Luxembourg, especially regarding Web 2.0 applications.

[98] http://www.eluxembourg.public.lu/eLuxembourg/plan_action_projets/index.html

[99] e.g. user-driven media. e.g. tools and platforms for user-generated content etc.

[100] One can cite for instance the Norvegian Euro-American iAd (Information Access Disruptions) project, headed by the Norvegian *Fast Search* launched in 2006 with a budget of at least 50 million euros. (consortium related to the FP6 PHAROS project) and more recently the Israelo-Euro-American SAPIR project involving *IBM* Haifa, Israel together with a number of European academic and industrial partners. [Source: Communication by M. Adda-Decker, LIMSI-CNRS, France]

[101] The Advanced Research Project Agency (ARPA) of the Department of Defense (DoD) is massively pushing efforts in multilingual ICT for intelligence, security and business reasons. [Source: Communication by M. Adda-Decker, LIMSI-CNRS, France]

[102] [Source: Communication by M. Adda-Decker, LIMSI-CNRS, France]

[103] The LDC (Linguistic Data Consortium) of the University of Pennsylvania is currently the major multilingual language resource agency, collecting and distributing spoken and written corpora, dictionaries, parallel corpora... in a large number of languages. In Europe there is only a smaller equivalent to LDC is the ELRA (European Linguistic Resource Agency) organisation which is based in Paris, France. [Source: Communication by M. Adda-Decker, LIMSI-CNRS, France]

[104] [Source: Communication by M. Adda-Decker, LIMSI-CNRS, France]

However, it should be noted that even if the development of open tools for multilingual applications could be of high interest to reduce the dependency on commercial products, public research on multilingual multimedia applications is, in general, not expected to have a strong economic impact.

List of research issues in the domain Telecommunications and Multimedia
- Aggregation and distribution of content o Distribution/Personalization of content o Location based services, contextual based services (using satellite-based solutions) o IP based, on demand and interactive o Multimedia - Distributed, Mobile, and Self organising networks o Seamless connectivity/interoperability/networking (security, handover, QoS,...) o Sensor networks o Wireless access o Engineering of distributed applications o Network support (testing, operation, management...) o Mobility and Interoperability / Interfacing between systems o Radio frequency systems o Next generation networks o Mobility governance o Pervasiveness o IP-based converged networks - Crisis management o Early warning systems o Data back-up

6.2 Sustainable Resource Management in Luxembourg

Sustainable development means maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend on the other. According to The World Commission on Environment and Development, it is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland report 1987).[105] As Luxembourg's ecological footprint[106] ranks among the highest worldwide, research priorities in Environmental Sciences should be chosen so as to promote a more sustainable use of resources and a sustainable way of life in Luxembourg.

The international importance of sustainability is revealed by a recently published study[107] that compares national foresights and general technology studies of various countries, such as the USA, South Africa, Canada, China, Denmark, South Korea, India, and the United Kingdom. The

[105] The Global Development Research Center (GDRC): http://www.gdrc.org/sustdev/definitions.html

[106] The Ecological Footprint (EF) measures the extent to which humanity is using nature's resources faster than they can regenerate. [Source: Ecological Footprint and Biocapacity, European Commission, 2006, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-AU-06-001/EN/KS-AU-06-001-EN.PDF]

[107] Holtmannspötter, D., Rijkers-Defrasne, S., Glauner, C., Korte, S., Zweck, A.: Aktuelle Technologieprognosen im internationalen Vergleich. Übersichtsstudie. Hrsg: VDI Technologiezentrum GmbH; 2006 (= Zukünftige Technologien Band 58)

thematic field "Sustainability and Environment" was the most frequently covered topic in these multidisciplinary studies.

The umbrella priority "Sustainable Resource Management in Luxembourg" was defined by the experts involved in the FNR Foresight exercise as encompassing all research areas related to environmental sciences that were assessed as important for Luxembourg in this foresight process. Besides the obvious fact that these domains have points of contact where they are interlinked with each other, it is of outmost importance for research to contribute successfully to a sustainable management of resources in Luxembourg to overcome disciplinary hurdles and develop a more holistic approach by combining results from various research activities.

The research fields[108], which will be presented in detail in the following sub-sections, are:

- Managing Sustainable Development,
- Understanding Ecosystems and Biodiversity,
- Sustainable Management of Water Resources,
- Sustainable Uses and Sources of Energy,
- Sustainable Agro-Systems Management,
- Spatial and Urban Development.

6.2.1 Managing Sustainable Development

"Managing sustainable development" could simply be understood as an overarching, interdisciplinary principle to be applied in all sub-domains of the national research priority "Sustainable resource management in Luxembourg". However, there are good reasons for creating a dedicated research priority for the development and implementation of sustainable management tools and methodologies. In order to achieve sustainability for the Luxembourg society, it is of importance to consider the correlations between the different constituents of the environment, e.g. agriculture, energy, waste treatment, water management, etc., and to gain an integrative understanding of the energy and material flows in Luxembourg. Before optimizing resource use (water, energy, raw materials), it is essential to dispose of comprehensive data on the current use of environmental resources. The environmental situation in Luxembourg has to be analysed and broken down to territorial/geographical levels, at which solutions and optimisation strategies should/could be implemented. This requires comprehensive monitoring and analysis tools for e.g. the water and soil quality, air pollution, etc. Such analysis tools do partly exist already but only for certain resources, e.g. water or energy. A comprehensive model for the use and management of all natural resources and their relations, however, is still missing; therefore, the development of such a model is seen as a very promising issue for research.

[108] Practically all of the sub-domains named above are directly related to expected changes of local environmental parameters due to global climate change. Thus, the working groups in the different environmental research fields have to be provided with data on changing climatic variables. This can be done by the envisioned Modelling and Simulation Platform as described in Annex A2.

List of research issues in the domain Managing Sustainable Development
▪ Development and application of tools and methods for the sustainable use of resources ▪ Data collection and scenario development, including the setting up of an information base for decision-makers ▪ Multi-criterial assessment of processes, scenarios, technologies, products… ▪ Analysis and optimization of material and energy flows on a local, regional and national level ▪ Assessment of existing and development of new governmental support systems and financial tools; micro-finance; contracting tools; development of business opportunities for SMEs ▪ Development and analysis of indicators ▪ Integrative approach between the Plan National de Développement Durable, the National Plan for Rural Development and the National Plan for Environmental Protection, as well as the Implementation of the EU Water Directive

This concept is seen as an innovative approach to generate a systematic knowledge on the field and to improve the quality and coordination of research efforts in the various environmental research domains. The approach should also include the integration of economic and ecological goals in the different fields of interest. For instance: Is there a conflict between environmental claims and economic competitiveness? Sustainable production and products play an increasing role not only in the manufacturing industry but also in SMEs. The contribution of public research to help meeting this objective has to be identified together with the industry.

To be able to achieve sustainable development goals (for society, industry or economy) industry and agriculture should choose strategies that focus on ecotechnologies[109], clean technologies, integrating technologies and highly efficient technologies regarding to resources use and pollution. However, the question is not so much to provide and develop ecotechnological solutions "made in Luxembourg" but to have a consistent approach on and implementation of existing and emerging technologies for sustainable resource use. The objective is to constantly monitor and feed an existing action plan in order to facilitate an informed decision-making and to find long-lasting solutions with the vision of making Luxembourg a showcase for regional sustainability. Luxembourg has, due to its size, a unique chance to set up a systematic, transdisciplinary research approach in order to govern upcoming ecological challenges in a proactive manner.

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[109] Ecotechnology, which is sometimes used synonymously with ecological engineering, has been described as "the use of technological means for ecosystem management, based on deep ecological understanding, to minimize the costs of measures and their harm to the environment" (Straskraba, 1993; Straskraba and Gnauck, 1985). Combining ecosystem function with human needs is the emphasis of ecological engineering, defined by Mitsch and Jørgensen (1989b) as "the design of human society with its natural environment for the benefit of both."
Ecological engineering combines basic and applied science for the restoration, design, and construction of aquatic and terrestrial ecosystems. The goals of ecological engineering and ecotechnology are as follows:

- The restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution or land disturbance.
- The development of new sustainable ecosystems that have human and ecological value.

[Sources: W. J. Mitsch. 1996. Ecological Engineering: A new Paradigm for Engineers and Ecologists, in Engineering with Ecological Constraints, Peter Schulze (ed.), National Academy of Engineering. Straskraba, M. 1993. Ecotechnology as a new means for environmental management. Ecological Engineering 2:311-331. Straskraba, M., and A. H. Gnauck. 1985. Freshwater Ecosystems: Modelling and Simulation. Amsterdam: Elsevier.]

An important aspect of the research activities in this area is the collaboration with stakeholders and the involvement of potential users in the public and private sector. The success of the implementation of sustainable technologies might highly depend on the support of the public authority – especially if these sustainable technologies are more cost-intensive than "traditional ones" (at least at first glance). Therefore, consumer information systems and models and strategies taking care of consumer behaviour are needed and should be developed with the aim of enhancing public support of new sustainable production methods. Also information systems for politics (political consulting) were regarded as highly important.

The actual implementation of research activities in this sub-domain could be as follows. A core group of researchers (+/- 10 people) in an interdisciplinary competence centre collects existing data, develops indicators and scenarios, and sets up an information base for decision-makers. At the same time these researchers collaborate with other research teams from the environmental research fields listed above (water management, biodiversity, energy, etc.). Out of this networking new research topics will be generated and specific research projects will be launched if deemed necessary. These projects should then receive substantial funding within the corresponding research field.

This systematic research on a national level is of particular scientific interest as it enables flexibility and interdisciplinary thinking. The concept implies a high potential for Luxembourg to gain international visibility, since such integrative approaches are internationally not yet widely developed (see criteria table, C9) and especially in larger countries much more difficult to implement.

6.2.2 Understanding Ecosystems and Biodiversity

As with every kind of resource, an adequate management plan of natural resources needs to be elaborated, based upon a thorough understanding of the intimate functioning of the ecosystems, i.e. of the so-called ecosystem functions. Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem. Some examples of ecosystem functions are provision of wildlife habitat, carbon cycling, or the trapping of nutrients. Thus, ecosystems, such as wetlands, forests, or estuaries, can be characterized by the processes, or functions, that occur within them.[110]

Research on biodiversity and ecosystem functions is of great importance for Luxembourg due to the social-environmental benefits associated with it. The preservation of biodiversity is, in general, a fundamental component of any sustainable development. According to a study of the Ministry of Environment on the evolution of Luxembourg's biodiversity in the period 1962-1999 several biotopes of high ecological value were lost in the last years.[111] The recent Millennium Ecosystem Assessment (MA)[112] launched by the UN Secretary General found that Europe's ecosystems have suffered more fragmentation induced by human activities than those of any other continent. In numbers, this means that 42% of Europe's native mammals, 43% of birds,

[110] http://www.ecosystemvaluation.org/1-02.htm
[111] http://www.gouvernement.lu/salle_presse/actualite/2006/10/24lux/
[112] http://www.maweb.org

45% of butterflies, 30% of amphibians, 45% of reptiles, and 52% of freshwater fish are threatened with extinction. Recent research reveals that loss of biodiversity can impact the functioning of both natural and managed ecosystems. These results raise concerns about the capacity of impoverished ecosystems to deliver ecological goods and services ("ecosystem services"[113]) which are essential to human well-being. In order to reverse the trend of ongoing loss of biodiversity and to ensure the achievement of long-term sustainability goals, research in this field should be integrated into the concept of sustainable development in Luxembourg in the near future.

In addition to the environmental implications, the economic relevance of biodiversity for Luxembourg should not be neglected. Although there exist many ecosystem services with high socio-economic benefits for present and future generations[114], research activities in this field are often regarded to be of minor economic importance not only by the public but also by policy-makers. One objective of public research in this domain should, therefore, be to tackle this acceptance problem by a systematic assessment of ecosystem services in order to properly ascertain the socio-economic benefit of biodiversity which is practically unvalued so far. The approach to this task should be more in the sense of identifying opportunities for economic benefit by emphasising the potential sources of economic growth through conservation of biodiversity rather than simply ascribing a monetary value to, for example, the conservation of a specific habitat ("ecosystem valuation"[115]).

Luxembourg has also many commitments to the EU which call for research on biodiversity and a better understanding of ecosystem functions. The European Commission has produced an action plan aimed at conserving biodiversity and preventing biodiversity loss within the EU and internationally.[116] Besides several objectives related to safeguarding important habitats and species, the action plan explicitly states the need for improving the knowledge base for conservation and sustainable use of biodiversity, which requires strengthening of the related research areas. Luxembourg should aim at fulfilling the addressed international obligations and contribute to the European efforts in the field (see criteria table, C9).

The international relevance of this domain is also demonstrated in several foresight exercises carried out all over the world. The European Foresight Monitoring Network (EFMN)[117], which analysed 40 international foresight exercises completed in 2004-2005 or still ongoing, identified

[113] Ecosystem services are the beneficial outcomes, for the natural environment or people that result from ecosystem functions. Some examples of ecosystem services are support of the food chain, harvesting of animals or plants, regulation of water, air and climate or the provision of scenic views. In order for an ecosystem to provide services to humans, some interaction with, or at least some appreciation by, humans is required. Thus, functions of ecosystems are value-neutral, while their services have value to society.

[114] For instance, the economic value of biodiversity is exemplified by the increased biomass and energy yield per hectare achieved in Germany.

[115] Ecosystem valuation can be a difficult and controversial task, and economists have often been criticized for trying to put a "price tag" on nature. However, agencies in charge of protecting and managing natural resources must often make difficult spending decisions that involve tradeoffs in allocating resources. These types of decisions are economic decisions, and thus are based, either explicitly or implicitly, on society's values. Therefore, economic valuation can be useful, by providing a way to justify and set priorities for programs, policies, or actions that protect or restore ecosystems and their services (http://www.ecosystemvaluation.org/1-02.htm)

[116] Communication from the Commission (2006): "Halting the loss of biodiversity by 2010 - and beyond. Sustaining ecosystem services for human well-being"; http://europa.eu/scadplus/leg/en/lvb/l28176.htm

[117] http://www.efmn.eu/

"Reduction of Environmental Quality" as the most frequently addressed socio-economic issue. Studies that explicitly deal with biodiversity issues are, for instance, the *Foresight Biodiversity Workshop Report* of the *Foresight Energy and Natural Environment Panel* (UK, 2001)[118] and *Biodiversity Conservation Research: Australia's Priorities* (Australia, 2001)[119] or, more recently, the report on the *"2010- Global Biodiversity Challenge"*-Conference (UK, 2003).

The research issues of interest in this context fall under three general headings: Evaluation of biodiversity and monitoring; understanding ecosystems, including the impact of climate change and other anthropogenic influences; and management and conservation of existing ecosystems in terms of a sustainable resource management. Luxembourg should aim at progressing in all these areas by strengthening available competences and concentrating efforts in a competence centre for biodiversity. Especially, the expertise in the use of bio-indicators for monitoring applications should be further expanded, which is also demanded by EU regulations on monitoring the environment. By strengthening classical biology subjects like e.g. taxonomy, Luxembourg could gain a unique profile and thus international visibility. This should go hand in hand with establishing facilities for training in the scientific disciplines related to the research in this field.[120]

List of research issues in the domain Understanding Ecosystems and Biodiversity

▪ Evaluation of Biodiversity/Monitoring
  o Taxonomy
  o Status evaluation
  o Monitoring
▪ Understanding of System (incl. Population, impact of climate change, human-nature interaction etc.)
  o Population dynamics
  o Invasive and introduced species
  o Human biodiversity interactions
  o Impact of climate change and pollution
  o Dissemination of genes in space and time including habitat corridors
  o Socio-economic evaluation of BD and ESF
  o Climate Change related issues:
    ▪ Climate change and its effects on environment and society in Luxembourg:
    ▪ Climate change cause and effects
    ▪ Analyse Climate Feedbacks and Sensitivity to natural and Human-induced environmental changes
▪ Management and conservation (restoration ecology; sustainable management of resources; management of human biodiversity interactions; public awareness
  o Restoration ecology
  o Sustainable management of natural resources including agriculture, forestry,…
  o Management of human/BD interactions
  o Strategies for public awareness

The research domain Understanding Ecosystems and Biodiversity is strongly interlinked with the other environmental research fields (see criteria table, C11) and, since research on biodiversity is also very dependent on new findings and data related to the global climate

[118] http://www.foresight.gov.uk/
[119] http://www.environment.gov.au/biodiversity/publications/research-priorities/index.html
[120] For example, there is an existing training on specific algae used as bio-indicators for water quality at CRP Gabriel Lippmann. The training is attended by students from several European countries.

change, there should be an intense cooperation between the researchers in this field with the Modelling and Simulation Platform described in Annex A2.

Another important argument for developing research in the domain Understanding Ecosystems and Biodiversity is its high feasibility: there are already several Luxembourg institutes involved in this research area (see criteria table, C7) and the know-how for doing this kind of research is already present. A critical mass for internationally competitive research in Luxembourg can be reached on the basis of these competencies by a moderate increase of staff and the provision of new laboratory facilities (e.g. molecular tools). Research can also profit from good collaborations between the administration and research institutions and from existing international collaborations. All research aspects related to numeric modelling and database processing (e.g. bio-statistical and ecological modelling, databases of organisms, and integration of data of land use by GIS) should be transferred to the envisioned Modelling and Simulation Platform described in Annex A2. In general, the implementation of research projects on biodiversity and ecosystem functions can be expected to be not very cost-intensive, increasing the feasibility of successful research in this field.

6.2.3 Sustainable Management of Water Resources

Water resources management is the integrating concept for a number of water sub-sectors such as hydropower, water supply and sanitation, irrigation and drainage. An integrated water resources perspective ensures that social, economic, environmental and technical dimensions are taken into account in the management and development of water resources.

The further development of the current competences in the water sector with the aim to achieve a sustainable management of water resources is certainly in the national interest of Luxembourg. The fundamental resource water in form of the three water bodies[121] (ground water, surface water and urban water) and the water cycle as an interlinking mechanism is a highly complex system which is very sensitive to climatic changes and other anthropogenic influences. For instance, excessive abstraction of water from ground water and surface water can have a negative impact on the hydraulic regime of Luxembourg's rivers. In Luxembourg the average consumption of drinking water in the households and service buildings is 150 l/capita/day. The need for an efficient and sustainable management of water resources in Luxembourg is obvious in the light of the potential threats arising from water pollution, water scarcity, risk of floods and other hazards.[122] [123]

It is not surprising that water resource management is an important and prominent research topic all over Europe (see criteria table, C9). This is emphasised by a number of recent foresight exercises on water issues, such as *Turning the Water Wheel Inside Out - Foresight Study on*

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[121] The structuring of research issues according to their relevance for the different water bodies is also used in the water framework directive of the EU. In order to achieve a good compatibility with this programme it is recommended to adopt this system for all future activities of Luxembourg in this research domain.

[122] Global data on water-related natural disasters is continuously collected by the UNESCO World Water Assessment Programme, http://www.unesco.org/water/wwap/facts_figures/managing_risks.shtml

[123] Between 1998 and 2004, Europe suffered over 100 major damaging floods. An EU policy on flood risk management is envisaged in the proposed "Directive on the assessment and management of flood risks"; http://ec.europa.eu/environment/water/flood_risk/index.htm

Hydrological Science in The Netherlands (The Netherlands, 2005), *Sustainable Water Management* (United Kingdom, 2003), and *Flows and floods - knowledge and innovation challenges for a watery Netherlands* (The Netherlands, 1999), as well as the identification and discussion of water-related issues as emerging critical issues in more general foresight exercises, such as *Teknologisk Fremsyn / Danish Technology Foresight* (Denmark, 2005).

Luxembourg is already spending large amounts of money in water processing, waste water treatment, etc. Making intelligent and innovative technologies available and finding more efficient solutions in this field will have a direct economic payback for Luxembourg. Research on water resources management also needs to take the territorial aspects of water management into account. Due to the small size of Luxembourg and the short knowledge-policy chain, the implementation of research results can occur quite quickly. The economic relevance of research in this field should also be seen in the light of the possibility to export those technologies that have been developed and successfully implemented in Luxembourg.

Luxembourg should extend research on water in the future and address the research issues given below by focussing on the following objectives.

First, sustainable water management methods based on non-stationarity principles should be developed. It is a fundamental property of the environmental parameters and variables that they are strongly influenced by global climate change and human activities. With predicted changes in agricultural practices (e.g. energy from biomass), altered pollutant fluxes, climate changes, and modified energy balances, there will certainly be changes in the water balance of the surface and sub-surface water bodies. It is seen as an important challenge to develop water management tools to cope with the emerging quantitative, seemingly contradictive, threats of flood risks and droughts on the one hand and the scarcity of high quality water for human consumption on the other hand.[124] [125]

The second objective is to find identification and remediation methods for the emerging threats to the qualitative state of the water bodies. There is a strong need for new technologies for measuring the state of pollution of all water bodies by emerging substances (chemical and microbiological) and also for the removal of identified contaminants. A major goal is the implementation of an online measuring and monitoring system for all water bodies. Besides these technological aspects the development of risk assessment and management tools is demanded in order to prevent water pollution hazards and to reduce the number of water analyses needed to guarantee high water quality standards. In this context the treatment of water is not only understood as a technological processing of drinking water or waste water but also as a means of restoring the natural quality and the pristine state of the water bodies and water cycles.

Third, the socio-economic impacts and conditions of sustainable water resources management should be investigated. A successful water resources management will have a beneficial effect on water pricing. On the other hand, there is also an educational challenge to create more public

[124] Luxembourg is facing a real water scarcity problem in particular due to polluted ground water areas which can no longer be used for drinking water supply. This scarcity problem will have increasingly severe impact on humans, biodiversity, agriculture etc. within the next 20 years.

[125] The theme of the UN-Water's World Water Day on 22 March 2007 is "Coping with water scarcity".

awareness of the high value of quality and availability of the fundamental resource that is water.

List of research issues in the domain Sustainable Management of Water Resources
▪ Water pollution by emerging substances, incl. removal by innovative processes ▪ Water availability/ scarcity ▪ Flood risk ▪ Protection of groundwater and of other water bodies ▪ Hydrological functioning of groundwater, interaction in the hydrological cycle ▪ Chemical and microbiological risk assessment ▪ Biological indicators ▪ Risk assessment and management ▪ Climate change and impact on the water cycle in Luxembourg ▪ Remediation of polluted ground water / risk assessment of accidental pollution scenarios ▪ Demand of irrigation in agriculture in drought phases ▪ Water issues related to biomass farming ▪ Resource management ▪ Online measurement and monitoring

A key instrument to achieve the goals stated above is the formation of a 'water platform' which facilitates the communication and networking between researchers and the pooling of competencies and information (see also Annex A2). A second platform should be implemented for the interaction of research actors and stakeholders, i.e. public and private entities that are involved in water resources management, in order to support partnerships for the technological implementation of research results.

6.2.4 Sustainable Uses and Sources of Energy

Providing Luxembourg with sufficient energy is seen as the most important task for the future, given the country's per capita energy consumption rate, which is one of the highest in Europe, and the existence of a number of energy-intensive industries (e.g. raw materials conversion). In 2004, 98.2% of Luxembourg's gross energy consumption had to be imported[126] leading to an enormous economic dependency of Luxembourg on oil and gas exporting countries, including high uncertainties in pricing and long-term availability. Considering the climatic impacts and the generally limited availability of fossil energies, it is of high importance for Luxembourg to increase energy efficiency as well as the share of regenerative and renewable energy sources and to develop competencies in these fields.

Finding a sustainable energy mix for Luxembourg is of uttermost importance. In 2000, renewable energy represented 3.9 % of final electricity consumption of the national grid, of which 80 % came from hydroelectric stations and 16.5 % came from wind power. It is clear that Luxembourg's future energy mix should be based on the whole scope of renewable energy sources but no final consensus could be reached on whether research efforts should be focused on energy from biomass or whether other energy technologies should also be included. On the one hand, biomass taken alone has not the potential to be a substitute for fossil energy sources.

[126] Source: eurostat, Energy: Yearly Statistics, 2004, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-CN-06-001/EN/KS-CN-06-001-EN.PDF

According to a study of the Ministry of Agriculture only about 5% of Luxembourg's primary energy demand can be provided by biomass. On the other hand, biomass is considered to be of great importance by the government, with a target of 20% of Luxembourg's agriculturally usable surface to be planted by energy crops being under discussion.

Biomass, i.e. all organic plant and animal products used to produce energy, currently accounts for around half of all renewable energy used in the EU and meets around 4% of the EU's energy needs. Energy from biomass encompasses different technologies for various applications, of which heat production, electricity production and transport are identified to be prioritised by the EU[127] (see criteria table, C9).

On the international level the development of new energy technologies is also considered a top priority (see criteria table, C9). In an evaluation of emerging issues 2006 based on 40 international foresight exercises completed in 2004-2005 or still ongoing, the European Foresight Monitoring Network (EFMN)[128] identified the thematic field "New Energy Technologies" as the most interesting by far, followed by "Sustainable Energy Production and Distribution" on second place. Among the foresight studies that refer to these issues are *AGORA 2020 - Transport, Housing, Urbanism and Risk* (France, 2005), *Teknologisk Fremsyn / Danish Technology Foresight* (Denmark, 2005), *Swedish Technology Foresight* (Sweden 2004), and *Futur - The German Research Dialogue* (Germany, 2005). Last but not least research in the energy domain has also to be seen in the light of continuously tightened EU regulations, e.g. with respect to limitations for CO_2 emissions or the European biofuel directive.

However, the motivation for research activities in the energy sector is not only environmental but is strongly influenced by economic issues. In addition to the economic aim of reducing Luxembourg's energy dependency, there is a high potential of exporting energy related technologies developed in Luxembourg. Both applied and basic energy research hold high potential to produce high value added, as the market for energy- and environmental technologies is continuously increasing[129]. Also, the expected effect of creating jobs in this sector, especially in SMEs, should be considered in this context.

The domain Sustainable Uses and Sources of Energy is one of the broadest among the different fields of the research domain "Sustainable resource management in Luxembourg", as the long list of research issues shown below reveals. It is supposed to cover all forms of renewable energy sources, i.e. energy from biomass, wind energy, geothermal energy, hydropower, and photovoltaic technologies, as well as energy efficiency technologies in the industrial, domestic and public sector, and hydrogen technology as a new energy vector. However, during the course of this foresight exercise the main focus was set on energy efficiency technologies and energy from biomass as the most promising research topics for Luxembourg in the energy domain. The discussions related to this sub-domain were very controversial, and it was impossible to reach a final decision on which parts of the energy sector should be prioritized so far. At the end, the energy supply of Luxembourg being one of the fundamental challenges, that

[127] Source: Biomass Action Plan of the EU; http://europa.eu/scadplus/leg/en/lvb/l27014.htm
[128] http://www.efmn.eu/
[129] For Germany a joint study of the Federal Ministry of Environment and Roland Berger Strategy Consultants predicts, that automotive industry will be overtaken by environmental- and energy technology producing industry as the national lead market.

the society faces today, it is of outmost importance that discussions with experts go on to develop a more clear cut structure of public sector energy research.

List of research issues in the domain of Sustainable Uses and Sources of Energy
▪ Energy efficiency o Recovery of waste-energy and co-generation in industrial processes o Energy efficiency in private, commercial and public buildings (including research on construction materials, installed technology, integrated planning) ▪ Bioenergies o Biomass, biogas and biofuel, including biological conversion and thermochemical conversion o Sociological, technical and economical evaluation o Storage and distribution of novel biofuels o Biofuels for aviation o Linocellulosic resources o Wind energy ▪ Hydrogen as energy vector[130] o Embarked storage and security of hydrogen o Transport and distribution of hydrogen

On the subject of energy efficiency, several objectives for public sector research were highlighted:

One main objective should be the reduction of energy consumption in domestic, commercial and public buildings by innovative construction materials, installed technology and integrated planning, thus taking the whole life cycle of buildings into account. This approach should also include the development and application of monitoring techniques for energy consumption and losses.

A second focus should lie on increasing the rate of recovery and co-generation from waste energy in industry. Production processes should be optimized with respect to primary energy demand, and sources of energy loss should be identified.

Considerable energy savings can also be achieved in transportation and logistics. This includes e.g. the development of innovative fuels but also encouraging a different kind of mobility. From 1990 to 2000, the energy demand from transportation (primarily truck transport and private automobile transport) increased over 90% in Luxembourg. In the *Intelligent Energy - Europe Programme* particular attention is paid to the transport sector.

Obviously, energy efficiency as a research field has a fundamental (finding new materials, developing new concepts etc.) and an applied research component (implementation of existing technologies). It should, however, be emphasized that the reduction of energy consumption is not only a technological question but does also have a behavioural and pedagogical aspect. To achieve progress in this regime a joint research project with social sciences may be useful. Concerning renewable energy research topics, the following were mentioned:

[130] Only relevant in combination with bioenergies.

Research in Luxembourg should focus on a deeper understanding of the conversion processes involved (e.g. biomass to liquid, biogas production[131] etc.) in order to decide which of these technologies are relevant and feasible for Luxembourg. As an example, biogas production may be especially interesting because in nearly 70% of the EU member states not enough support is provided for the development of this technology. Other important research topics to be investigated in this field are technologies for the storage of energy or electricity generated from renewable sources and the sustainable production of energy crops.

The agricultural production of biomass for energy generation has very important socio-economic consequences that have to be considered. For farmers this is primarily a completely new and fast growing market. However, it has to be taken care that the biomass production does not displace production of sufficient and affordable foods.[132]

Research focused on the above mentioned topics might build on existing competencies in the public research sector (see criteria table, C7). Starting with a small nucleus, research activities should then be expanded to a larger number of researchers involved. Within 10 years, critical mass and international competitiveness can be achieved in this field, as there seem to be no obstacles from the political or the economic side, and there is practically no major infrastructure to be installed. It is seen most important to establish a close cooperation and an efficient knowledge transfer between public research and private companies and to build a strong business case.

A major concern with research on renewable energy sources in Luxembourg is the lack of regional industrial partners in the country. This can be a massive obstacle for the development and especially the implementation of new technologies in this research field. Funded research can only have an impact when the developed technologies are actually used and their market penetration is feasible. From all renewable energy technologies biomass seems to be, in that respect, the most promising for Luxembourg. For photovoltaic technologies and wind power the international industrial and research competition in particular from Germany or Denmark might be too strong.

[131] Research should build upon existing projects related to biomethanization, like the "Cooperative Biogas Biekerich" exploiting biomethanization for efficient energy production: energy production by biomethanization allows to produce 5 times more energy than consumed and to reduce the CO_2 emissions by 90%. [Source: La Voix, 25.01.2007]

[132] In Mexico, mass demonstrations ("tortilla riots") occurred in the beginning of 2007 as a consequence of an 80% increase of the corn price in 2006 due to the increasing use of corn for biofuel production.

6.2.5 Sustainable Agro-Systems Management

Food production in Luxembourg should be viewed in a context of sustainable use of resources and within sustainable agro-systems. The main objective of research in this domain is to facilitate an informed and evidence-based governance of the Luxembourg agricultural sector since self-governance, following the rules of an open market, does not apply in this area due to the high degree of subsidies and foreign dependences. The need for research in this domain has also to be seen in the context of the adaptation of Luxembourg's agricultural sector to expected climate changes and to EU regulations. The short decision paths in Luxembourg are seen as a unique opportunity to facilitate a fast transfer of knowledge.

The main research issues of this domain (see list below) are related to food production by means of sustainable farming and the implications of agricultural activity for the natural resources, such as soil, water, and ecosystems. The strong linkage to the other domains of the thematic field of sustainable resources management is obvious. Questions concerning the impact of farming on the qualitative and the quantitative state of the water resources or on the biodiversity of ecosystems have to be addressed in a multidisciplinary effort. In order to achieve progress in the domain Sustainable Agro-systems Management it is necessary to bundle the sectoral knowledge and expertise of other domains in joint projects following an integrative approach. This could constitute a change of thinking in Luxembourg and truly help to modernize the agro-industrial sector.

List of research issues in the domain Sustainable Agro-Systems Management

▪ Issues of sustainable farming
  o Food quality and authenticity, food safety, food security, food technology
  o Animal health and sustainable livestock production systems
  o Plant health and pest management
▪ Biodiversity and preservation and development of local genetic resources (livestock, plant species)
▪ Water protection
▪ Soil protection
  o Erosion and compaction
  o Soil quality and fertility
  o Climate relevance of farming and food production systems
  o Monitoring tools
▪ Renewable resources
  o Impact on ecosystems
  o Valorization of by-products
▪ Nutrition and food
▪ Consumer education and behaviour

Research issues related to food production should be seen in the light of sustained development. How much energy does it take to produce the apple on ones plate? How much biodiversity (what was its socio-economic value?) was destroyed in the production of ones food? The assessment of pest damage versus the (economical, environmental) cost of preventive actions is also seen to be important. Here, preventive strategies through cultivation methods and strengthening of self-regulating mechanisms should be further investigated. In the context of animal health, emphasis should be put on system approaches, such as encouraging the natural immunological defense of the animal as well as the selection of appropriate breeds and animal welfare friendly husbandry and feeding systems.

Biotechnologies related to food in view of opening new economic activities should also be considered in this context.[133] [134] Biotechnologies should serve to valorize Luxembourg's agricultural products. Spectroscopic methods and genetic methods to check food quality along the production chain seem interesting.

Biodiversity is seen as important in view of sustainable development of the live stock and plants. Therefore, not just niches and particular habitats need to be studied but the agricultural surface (constituting a major part of the total surface) needs to be part of these studies. A better understanding of the interactions between habitats and crop is necessary to improve functional diversity as a strategy for pest and disease control.

Soil and water should be considered as a resource of the whole ecosystem. In particular, new competences in pedology are needed in the country. Knowledge about soil quality throughout the country is required for optimal territorial planning (cf. chapter 6.2.6). Soil is one of the most important resources since it is where food production occurs and since it acts as a natural filter in the water-cycle. A better understanding of the interaction between the plants and soil life is necessary, e.g. for preventing soil borne diseases and to improve the nutrient uptake from the soil reserves.

Monitoring tools become of increasing importance when studying large areas of land where traditional chemical analysis becomes too laborious. Telemonitoring is seen as a future technology in the surveillance of soil and large areas of land.

Following the indications of a recent study addressing the potential for the increased use of renewable energies in Luxembourg[135] and carried out on behalf of the Ministry of Environment and the Ministry of Economy and Foreign Trade, the government wishes to dedicate 20% of the agricultural land to the production of Biomass by the year 2020 (cf. chapter 6.2.4). The impact of this change, especially the introduction of non-native plants for the production of biomass (e.g. sorghum, elephant grass *Miscanthus sinensis gigantheus)* on the ecosystems in Luxembourg needs to be investigated. In addition, the use of by-products in agriculture (up to 20% of the production) as biomass should be studied. For example 1 ton of by-products in the wine production can give rise to 50 l bio-ethanol.

Interesting research issues related to this domain lie also in the field of social and health sciences. For instance, the question of what type of food people need to eat in order to lead a healthy life is deemed to be of particular interest in view of the drive towards prevention in

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[133] For instance, the culturing of particular yeast strains within Luxembourg Wine making industry (e.g. *Saccharomyces* type Mosel) that produce fewer detrimental side products is of interest and immediate economic benefit. These results could also be translated to the brewing and the Probiotica industry.

[134] Biotechnology in agro-industrial applications is seen as a highly important future domain of research by many foresight studies in other countries. The Teknologisk Fremsyn - Technology Foresight in the Danish Ministry of Science (Denmark, 2003-2006) sees precision agriculture and bio-farming as top issues in the field of sustainability and environment.

[135] „Bestimmung der Potenziale und Ausarbeitung von Strategien zur verstärkten Nutzung von erneuerbaren Energien in Luxemburg" (2007). Fraunhofer Institut für System- und Innovationsforschung (Fh-ISI), Energy Economics Group, TU Wien (EEG), BSR-Sustainability. http://www.eco.public.lu/documentation/etudes/2007/03/Endbericht_RES-Lux_26_03_07_final.pdf

Public Health. Studies on sustainable consumption patterns or a better understanding of consumer perceptions and needs should also be considered. A better understanding of the socio-economic interactions within the whole supply chain is seen as a condition for promoting a more sustainable development for Luxembourg.

In order to achieve a sustainable management of agro-systems, Luxembourg should aim at improving the interrelationships between the scientific knowledge developed in public research centers and the actual implementation on the terrain. Mechanisms need to be put in place for the direct application of the research results in the 'field' through stronger collaborations between farmers, consultants, decision makers and researchers.

On the national level, there is an existing basis in scientific fields related to this domain (see criteria table, C7), although an integrated approach and the needed tools are missing. Integrated approaches and multi-disciplinary projects should be encouraged when it comes to the implementation of research activities in this domain. Additional experimental parcels and farming units as well as laboratory infrastructures are needed. A good coordination and cooperation of all actors and stakeholders in the field is important.

Research in the domain Sustainable Agro-systems Management can make Luxembourg a model system for sustainable food production, consumption and resource use. Results in this domain are also of social relevance, since a more healthy nutrition will have positive effects on human well-being and the health care system. Also the economic relevance should not be neglected, since fostering sustainable food production or energy production from biomass can create new economic activities in Luxembourg.

6.2.6 Spatial and Urban Development

On the European level, territorial development[136] and research on territorial issues have gained crucial relevance in the last decade with the enlargement of the EU, the subsequent reframing of structural funds and the necessary redefinition of regional policy.[137] Already in 1999 the European Spatial Development Perspective (ESDP[138]) has been agreed on as a policy framework with the "triangle of objectives": economic and social cohesion, conservation of natural resources and cultural heritage, and a more balanced competitiveness of European territory[139]. In line with the ESDP, the European Spatial Planning Observation Network (ESPON –

[136] Its roots go back into the reconstruction period after 1945, when nations engaged in urban and territorial planning and institutions like the French DATAR and similar bodies in other countries were founded.

[137] Comp. e. g. Kai Böhme: „Future directions in European spatial policy", in: Susan Brockett and Margareta Dahlström (eds.): Spatial Development Trends, Nordregio R2004:6, Stockholm 2004 and Serge Wachter : « L'agenda de l'aménagement dur territoire entre prospective et rétrospective (1980, 1990, 2000) », in : Repenser le territoire. Un dictionnaire critique, DATAR, Paris 2000.

[138] ESDP European Spatial Development Perspective. Towards Balanced and Sustainable Development of the Territory of the European Union Agreed at an Informal Council of Ministers responsible for Spatial Planning in Potsdam, May 1999; see http://ec.europa.eu/environment/forum/spatreport_en.pdf

[139] The new term of "territorial cohesion" has been introduced to describe a social, economic and environmental balanced development on all regional levels. See e. g. "Territory matters for competitiveness and cohesion. Facts of regional diversity and potentials in Europe. ESPON Synthesis Report III, results by autumn 2006", available form the ESPON website.

www.espon.lu)[140] was set up to support policy development and to build a European scientific community in the field of territorial development. The main aim is to increase the general body of knowledge about territorial structures, trends and policy impacts in an enlarged European Union.

Luxembourg is facing a number of challenges with an important territorial dimension that have to be addressed by spatial planning and development:

1. *Environmental problems*: Urban and rural development has to take the impacts and risks of climate change into account which are affecting the territory of Luxembourg in multiple ways, through weather hazards, changes in precipitation etc., and secondary impacts like adaptation of agriculture, measures for the protection against natural disasters, etc.[141] Moreover it is essential to find new ways of living (manufacturing, housing, mobility) that allow for a sustainable development. Studying these ways of life, behaviours, perceptions and preferences at the disaggregated level includes always a territorial dimension. Furthermore, sustainable land use is becoming a real issue for Luxembourg. The share of the national territory occupied by buildings and transportation routes has increased significantly during the last decade, rising from 7.47% in 1990 to 10% in 1999. The target of the National Plan for Sustainable Development (of 1999) is to reduce its annual consumption by 50 % until 2010.[142]
2. *Economic challenges*: In a context of globalization and competition (also on the regional level), spatial planning could reinforce the attractiveness of a country through living quality, efficiency of the transport system (intra-urban accessibility and metropolitan accessibility within a city network) and a high level infrastructure. As one of the means to influence land use and to curb real estate prices, spatial planning has a direct impact on the conditions of economic growth.
3. *Social issues*: Social exclusion is rather regularly associated with processes of spatial segregation (in particular with respect to housing and mobility). The aim is to implement a model of spatial development that counterbalances urban inequalities.
4. *European integration*: Luxembourg has become a hub of transportation. Situated in the middle of the "blue banana"[143] it profits from increasing commerce (in the North-South direction and in the East-West direction) and from closer integration within the Greater Region. Infrastructure development has to keep pace with growing inter-regional links and increasing traffic. At the same time negative impacts of traffic on the environment and the structure of the territory have to be curbed.

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[140] ESPON, a body of the European Commission, is situated at Esch-sur-Alzette within the CRP Henri Tudor and represents one of the assets of Luxembourg in this field of research.

[141] Comp. Mark Fleischhauer: Klimawandel, Naturgefahren und Raumplanung: Ziel- und Indikatorenkonzept zur Operationalisierung räumlicher Risiken. Dortmund 2004

[142] STATEC (2003) Economic and social portrait of Luxembourg. pp. 175 ff. and Plan National pour un Développement Durable, available from http://www.environnement.public.lu

[143] Geographically, the "blue banana" stretches from Greater London through the Netherland, Belgium and the Rhine Valley via Western Switzerland to Northern Italy. It is the region with the highest economic activities in the EU – and (apart from urban agglomerations) the highest density of traffic.

5. *Urbanisation*: With its increasing population and the transformation from an industrial to a knowledge society, Luxembourg is experiencing processes of urbanisation and redefinition of land use (i.e. Esch-Belval). The geographic challenge consists in promoting a controlled urban development, particularly concerning urban sprawl, density and mixing of land use.

Recently, the economic need of a transition from an industrial society to a knowledge society has given additional boost to territorial research with the concept of "knowledge regions": What are the specific conditions that enable a region to successfully manage this transition? Examples from Finland, Wallonia and other regions demonstrate that regional foresight can play an important role in the empowerment of regional actors.[144] It should be noted that in terms of its size, Luxembourg is comparable to the regions addressed in these studies (as territorial sub-units of the larger EU member states), and methods/instruments developed on the regional level are mostly applicable to Luxembourg.

Despite a strong European research tradition in spatial development, Luxembourg has to engage on its own in this field. Finding answers to the question of how Luxembourg can foster economic development, provide a liveable habitat for its population and protect its natural environment is crucial to the future quality of life within the country – and this "search process" can only be successfully organized within Luxembourg itself in combining research with stakeholder participation.

The main objective of research in spatial or territorial planning and development is to explore the conceptual construction, organisation and practical use of space (geography and land use, e. g. for buildings, transportation and other infrastructures, industry, agriculture, tourism...), in order to foster sustainable territorial development in urban as well as rural areas. It is a highly cross-sectoral and interdisciplinary research domain, which includes geographical, demographic, social, psychological, political, economical, ecological as well as technological aspects.

Research in spatial development in and for Luxembourg will cover a wide set of research issues (see list below) and will have to adapt, improve on or even invent methodologies and tools to investigate, model, and forecast territorial development within the country and the Greater Region. Within this research domain, monitoring and simulation tools have to be employed or to be developed. This includes geographical information systems (GIS) but also empirical surveys and databases on e.g. the mobility and habitat behaviour of people within and around Luxembourg, qualitative studies on their intrinsic motivations and basic research on how processes of metropolization and polarization can be described and explained. Luxembourg has wide-reaching urban effects beyond its national borders: it attracts people and concentrates wealth and material flows from a much larger area (problem of transport and mobility of workers). Managing this development in a sustainable way on a local, regional, national and trans-national (trans-border) level is the task of a large number of different stakeholders.

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[144] Several EU programmes with multiple projects are a point in case: "Blueprints for Foresight Actions in the Regions", see e. g. "Foresight and the Transition to Regional Knowledge-based Economies", EUR 21262 of Oct. 2004; SPIDER Project "Increasing Regional Competitiveness through Futures Research Methods", see e. g. Juha Kaskinen et al.: "Rethinking Regional Performance in the Knowledge Society", Turku 2006. INTERREG III programmes (2000-2006) like "Binding North-West Europe Together" - http://www.nweurope.org/.

List of research issues in the domain of Spatial and Urban Development
• **Integrated spatial and, urban development at different scales** • Processes of urbanization: urban sprawl, urban density • Processes of metropolization: polarization of streams and activities, centralization and concentration of activities, specialization of space • Processes of (spatial) exclusion: social inequalities and segregation, functional specialization • Urban living quality, urban comfort • Infrastructures • **Environmental health and ecological aspects of urban development (pollution, noise …)** • **Transport, mobility, migration and accessibility** • Relation between residential and daily mobility • Labour market daily flows, trans-border working flows • Transport systems and flows • Perception of mobility and behavior • Virtual space and its impact on mobility (telework, e-trade, etc.) • **Evaluation of existing and development of new policy instruments on local, regional, national and transnational levels** • New forms of governance and cooperation with other cities and regions • Citizen participation • Planning policies • **Modeling and simulation of urban growth and spatial development (scenario and prospective approach)**

6.3 New functional and intelligent materials and surfaces, and New Sensing Applications

The focus of the research domain New Functional and Intelligent Materials and Surfaces is on "novel" or "innovative" materials and surfaces. Functional materials or surfaces are based on materials with tailored properties or specific functions in a large number of applications. Intelligent materials can be defined as materials that are capable of changing specific properties and adapting to changing conditions in the environment. They are complex systems containing multifunctional parts that can perform sensing, control, and actuation. Materials and surfaces with novel properties are seen as a field of extremely high future importance offering a wide range of technological, scientific, and economic opportunities. High performance and multifunctional or intelligent materials on the basis of composites, polymers, ceramics, metals and alloys are the focus of this internationally fast growing research field.

On a national basis, there are many R&D activities on materials and surfaces in the industrial sector with existing activities on polymers, on composites and multicomposites, new materials in automotive supplier industry, ceramics, etc. However, these efforts are not equally distributed over the different material classes. In fact, over 90% of private research activities are directed towards polymers.

Luxembourg's research activities in this domain should be application-oriented, i.e. the development of new materials should be guided by the demands of a specific application. This does not only imply the sought function of the material but also other criteria like stability, cost, or ambient conditions.

The main objective of this research domain is to investigate and to develop novel materials with new or improved functions (e.g. surfaces with no corrosion, catalysers, absorbers) and also basic materials for applications in new sensors (as discussed below). Potentially interesting classes of materials are polymers, composites, nano-structured materials, semi-conductors, ceramics, etc. Also the combination of materials (interfaces) and materials that can change their properties are of interest.

In many cases the functionality of a material arises from its surface properties, i.e. from the interaction between the surface and the environment, which is why technologies for surface functionalisation are a major focus of this domain. However, also bulk properties and effects of materials can be exploited in various applications and should not be generally neglected.

List of research issues in the domain of New Functional and Intelligent Materials and Surfaces
▪ Surface and interface engineering ▪ Intelligent materials and materials combination (related to surfaces and bulk) ▪ High added-value materials ▪ Sustainable synthesis and production processes

It should also be considered that the technologies of modification and processing and also of analysis are strongly coupled to a specific material class and are completely different from one material class to another. Process knowledge is a critical factor for developing novel materials. Therefore, studying and optimising such processes, including their modelling and simulation, the synthesis at laboratory scale as well as the scale-up and the production of new materials at industrial scale should be investigated.

An essential part of research on new materials and surfaces lies in the analysis and characterisation of the developed materials. State-of-the-art analytical equipment is based on highly sophisticated technology and is thus expensive. Some analytical equipment has already been bought and installed, e.g. in the TRASU programme, but further funding is needed for progress in this domain.

Research into novel materials and surfaces is to a great extent based on computational models of the studied materials at a molecular level in order to understand (and predict) their properties and interactions with the environment. Therefore, projects in this research domain should be strongly supported by scientific computation activities based on the Modelling and Simulations Platform described in Annex A2.

Publicly funded research in this field plays the role of an enabler for new economic activities (spin-offs, start-ups, licensing). Novel materials for applications in various fields, such as medical applications, have a great potential of generating high value added. The environmental relevance of this research domain should also be considered. In many cases, new materials allow the replacement of toxic materials and thus improve recycling processes or contribute to energy savings due to an improved energy-efficiency in their application. This does also imply social benefits like the generation of new jobs but also the improvement of quality of life through the use of new materials. Major progress and applicable results can only be achieved by intense collaborations between the public and the private research sector and by establishing efficient channels for technology transfer.[145] This philosophy of fostering the collaboration of public and private actors has successfully been realised in Luxembourg's public research programmes related to materials sciences so far (see criteria table, C7) and should find its way into all upcoming research activities in this field. Critical mass can only be reached by attracting excellent researchers and by joint efforts in the public and industrial research sector.

There is yet another interesting - and for Luxembourg industry highly relevant - context for the development of technologies related to new materials: after the implementation of the EU REACH directive, part of the 30.000 existing substances / materials will have to be replaced. This is seen as constituting a unique opportunity for research on materials with novel properties, albeit not only for Luxembourg.

New Sensing Applications

The global market potential for new low cost sensing devices is considered to be very high. When the size and cost of sensing devices will drastically be reduced, domestic and environmental sensors research will experience an explosive growth. Continuous miniaturisation and cost reduction enable the use of networks of sensors for decentralised control, monitoring and tracing applications. Applications can be developed in the following fields:

- Environmental issues and Energy efficiency, i.e. in the automotive sector
- Safety at workplace
- Domestic sensors, i.e. multiple sensors to measure the temperature in the entire household, air circulation quality control in households and buildings, quality and storage conditions of food
- Health; medical diagnostic tools, portable and low-cost sensing devices controlling physiological functions
- Lifecycle control of a product
- Automotive sector
- Traceability (for logistics)

Contributions from the field of nanotechnology are of high interest in this domain. However, research on new sensors should not only be limited to nanotechnologies, as they are just enabling technologies. Most modern sensors are based on microelectro-mechanical system technology and use microelectronics rather than nanoelectronics. Other technologies that are relevant for this domain include ion guides and electrode structures, organic and inorganic semiconductors, e.g. FET structures, optics, light sources and image sensors and acoustic and electromagnetic wave guides. In fact, various scientific disciplines, such as physics, chemistry, nanotechnology or biology, feed into the development of new sensors.

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[145] Technology transfer in material sciences is also a major issue in other countries. For instance, in Germany, the national programmes "WING - Werkstoffinnovationen für Industrie und Gesellschaft" and "StützWerk" aim at fostering collaborations between public and private sector in the field of material applications.

Nanosciences and nanotechnologies as a whole form a new and promising domain that is receiving substantial funding (7th Framework Programme of the EU) and is attracting a large number of researchers on a European and a global scale.[146] This will make it easier on the one hand to engage in international cooperations and to build networks (also with expatriates) working on nanodevices for sensor applications. On the other hand this implies that any activities in this domain in Luxembourg will need a well chosen focus.

The current profile of the domain in Luxembourg features strong private players in the field of sensors[147] plus existing research groups in nanomaterials and nanoanalytics at the CRP Gabriel Lippmann, the CRP Henri Tudor and the University of Luxembourg (see criteria table, C7). The relevance of New Sensing Applications for future applications in many fields is documented in a number of foresight studies performed in other countries. The *Tekologisk Fremsyn - Technology Foresight in the Danish Ministry of Science* (Denmark, 2003-2006) sees nanosensors as a top field in the domain of nano- and microsystem technology, the *Science and Technology Foresight Pilot Project (STFPP)* (Canada, 2003) describes applications of new sensors in the domains sustainability and environment as well as defence and security. [148] The *Sensor Technology Forsight* (Denmark 2001) offers a detailed analysis of future issues related to the different sensor types, technologies, applications, and market sectors.

The main objective of this domain is to exploit various technologies for the development of New Sensing Applications for the various applications listed above. Therefore, the approach of research activities in this domain should be highly application-orientated. Public research on New Sensing Applications has to be done in strong collaboration with the private sector. The implementation of an effective science management structure fostering networking between the public and industrial sector but also between different disciplines in the public research community is of high importance. Structures for an efficient technology transfer, e.g. encouraging spin-offs from the University[149], are also needed in this field. Small teams (e.g. 3-4 groups of 5 researchers) can start to promote this thematic field and serve as a nucleus. The expected rapid growth of the market for New Sensing Applications will provide additional sources of funding and thus facilitate the growth of the research capacities in this domain.

List of research issues in the domain of New Sensing Applications
Nanoelectronics, nanooptics, nanomagnetism
Microelectronics
Nanobiosciences
Nanostructural surfaces, nanocoating

The attractiveness of research in this domain lies in the high impact on the social, economic and also environmental sectors given by the immediate relation to products and applications. The obvious market potential of this field offers opportunities for new economic activities in Luxembourg promising the generation of high value added. Research outcomes can directly be transformed into patents, applications or products. The development and application of New

[146] http://cordis.europa.eu./nanotechnology
[147] IEE; International Electronics & Engineering, www.iee.lu.
[148] Holtmannspötter, D., Rijkers-Defrasne, S., Glauner, C., Korte, S., Zweck, A.: Aktuelle Technologieprognosen im internationalen Vergleich. Übersichtsstudie. Hrsg: VDI Technologiezentrum GmbH; 2006 (= Zukünftige Technologien Band 58)
[149] There are already examples of SMEs and spin-offs being founded through the development of new sensors.

Sensing Applications will improve safety, performance and comfort in various every-day-live situations. Also, positive effects for Luxembourg's health sector can be expected, e.g. by tele-monitoring of health functions or monitoring parameters relevant for environmental health applications (see chapter 6.4.2). In addition, the various demands for monitoring environmental parameters as outlined in chapter 6.2 offer a wide range of applications for new sensor devices developed in Luxembourg, helping to reach the envisioned sustainability goals.

More education and information in nanosciences and nanotechnologies is seen as an opportunity for Luxembourg. Research and education in this domain should be accompanied by efforts to improve the public understanding of nanosciences and nanotechnology as their applications may arise new challenges in the safety, regulatory or ethical domains that will require societal debate. In this context nano-risks need to be addressed in a proactive way.

6.4 Biomedical Sciences

Biomedical Sciences is a research field which receives very high attention globally, not only in terms of financial support from governments but also in terms of public media attention. This is due to its utmost importance for individual and public health issues and for improving quality of life. High hopes are put into cures for currently untreatable diseases like certain forms of cancer and AIDS/HIV but also into cures promising a longer and healthier life. New scientific and business opportunities are created by tissue engineering, genomics and proteomics, even though they evoke some public rejection when it comes to establishing the needed tissue banks or to genetically modified organisms. Facing those public acceptance problems needs to go hand in hand with establishing these research fields.

Of national relevance are of course public health issues, especially regarding the health system, and environmental health challenges. They gain importance due to a rapidly ageing Luxembourg population requiring appropriate health and vitality measures, as well as new treatments to cope with the expected increase of age-related diseases.

The umbrella priority "Biomedical Sciences" was defined as encompassing the 3 research areas related to biomedical sciences that were assessed as important for Luxembourg by the experts involved in the FNR Foresight exercise and where significant progress is expected in the next decade:

- Regenerative Medicine in Age-related Diseases - as a promising new area of research expected to significantly improve the therapeutic arsenal of so far untreated severe diseases,
- Public Health, including aspects of Environmental Health
- Translational Biomedical Research - to be carried out in multidisciplinary teams which foster the collaboration between scientists, engineers and clinicians and hence accelerate the basic research concepts towards clinical application.

Overall this umbrella priority should aim at increasing critical mass and rendering Luxembourg research in life sciences internationally competitive as well as stimulating the establishment of a biomedical industry in Luxembourg over the next 5-10-years.

The three research approaches in the umbrella of "Biomedical Sciences" will be presented in detail in the following sub-sections. Besides the fact that these domains are very diverse there are many links; connecting these research domains therefore is essential in order to create wholesome results which benefit the Luxembourg society, economy and environment alike.

6.4.1 Regenerative Medicine in Age-related Diseases

Regenerative medicine is an applied field of tissue engineering that holds the realistic promise of regenerating damaged tissues in vivo (in the living body) and externally creating "tissues for life" available for implantation. Tissue engineering, as defined by the European Commission's DG SANCO in 2001, is the regeneration of biological tissue through the use of cells, with the aid of supporting structures and/or biomolecules"[150]. This technology has the potential to develop therapies for previously untreatable diseases and conditions.[151] It offers, in particular, the prospect of extended healthy lifespans, as it may help repairing some of the damage caused by ageing, for instance by replacing tissues and organs to treat degenerative diseases and injury resulting from strokes, Alzheimer's and Parkinson's diseases, cardiovascular diseases, burns and spinal-cord injuries[152].[153] In the context of an ageing society[154] and the associated increase of age-related diseases, regenerative medicine may therefore help to reduce the very high socio-economic costs associated with age-related diseases.[155]

Whether regenerative medicine really is an opportunity for Luxembourg and a promising future field of research needs to be considered. International competition is rather strong in this

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[150] Bock, A. K., Ibarreta, D., Rodriguez-Cerezo, E. (2003) ESTO/IPTS Report "Human tissue-engineered products - Today's markets and future prospects". Seville: IPTS- Institute for Prospective Technological Studies. Another definition, given by the World Technology Evaluation Center, describes tissue engineering as the application of principles and methods of engineering and life sciences toward fundamental understanding of structure-function relationships in normal and pathological mammalian tissues, and the development of biological substitutes to restore, maintain, or improve tissue function. WTEC Panel Report on Tissue Engineering Research, International Technology Research Institute, 2002. http://www.wtec.org/loyola/te/final/te_final.pdf

[151] 2020: A New Vision - A Future for Regenerative Medicine, U.S. Department of Health and Human Services. http://www.hhs.gov/reference/newfuture.shtml#head1

[152] http://www.scienceboard.net/community/perspectives.15.html; "Life Sciences and Biotechnology: A Strategy for Europe", Communication from the Commission to
the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions COM(2002) 27.

[153] There is also a lot of hope connected to this novel biotechnology development concerning the ability to overcome in the long run the constant shortage of donor organs for transplantation. [Source: WTEC Panel Report on Tissue Engineering Research, International Technology Research Institute, 2002. http://www.wtec.org/loyola/te/final/te_final.pdf]

[154] In the EU, the share of people older than 65 is expected to increase from about 15.7% in 2000 to 22.7% in 2025 and 30.3% in 2050. [Source: EC-Green Paper "Confronting demographic change: a new solidarity between the generations", Communication from the Commission COM(2005) 94 final, Brussels, 16.3.2005].

[155] The pure demographic effect of an ageing population is projected to push up healthcare spending by between 1 and 2 % of GDP in most Member States. [Source: "The impact of ageing on public expenditure: projections for the EU-25 Member States on pensions, healthcare, long-term care, education and unemployment transfers (2004–50)", EC, DG ECFIN, 2006.] For instance, the total (direct and indirect) costs caused by Alzheimer's disease are estimated in the range from 2,470 € to 32,000 € per patient per year. In Parkinson's disease, these estimates average 13,800 € per patient. These costs and the overall health care costs for age-related diseases are likely to rise due to potentially increasing number of cases given the expected demographic shifts in all countries.[Source: Bock, A. K. et al. (2003) ESTO/IPTS Report "Human tissue-engineered products - Today's markets and future prospects"]

emerging field. Regenerative medicine's promise of revolutionary curative treatments has been recognized by many countries in the world: the USA[156], Great Britain[157], Germany[158], and Sweden, as well as Japan[159], China[160], Singapore[161] and Australia have all begun making strong national commitments with hopes of achieving their own advances in regenerative medicine technology.[162] This research area is also already an important research field in EU research policy (with about 17 research centres engaged in the field)[163] and will receive even more budget in FP7.[164]

Given this high international competition and the limited human resources in public research in Luxembourg, Luxembourg should concentrate its efforts on some sub-domains and build on existing competencies in order to be able to achieve critical mass for internationally recognised research.[165] Apart from the field Environmental Health addressed as such by another priority, the biggest active groups and research projects relate to the areas of oncology, cardiovascular diseases, neurodegenerative diseases. About 120 people (including researchers, but also technicians) are carrying out research in these fields. With the BIOSAN[166] and the PROVIE[167] programmes, there are also two important life sciences research programmes funded by the FNR and addressing ageing and age-related diseases. Therefore, public research in regenerative medicine should primarily address the so-called age-related diseases: cancer, cardiovascular diseases and neurodegenerative diseases and focus on cell therapy, including the following

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[156] For instance, California passed in 2004 a measure devoting $3 billion to human embryonic stem-cell experiments, putting California at the forefront of the field and dwarfing all current stem-cell projects in the United States, whether privately or publicly financed.

[157] For instance, with the Manchester/Liverpool Tissue Engineering Centre.

[158] Important research programme running on rare diseases, handicaps and regenerative medicine.

[159] Cell therapy and regenerative medicine research are one of the key components of the Kobe Medical Industry Development program (spending a total of ¥91 trillion ($831 billion) by the year 2010) aiming to nurture an industry in the fields of advanced medical care and welfare to meet the new requirements of Japan's rapidly aging society.

[160] China has committed a $1 billion initial investment towards establishing regenerative medicine research.

[161] In Singapore, for instance, the Biomedical Research Council (BMRC) and the Juvenile Diabetes Research Foundation International (JDRF) established in 2004 a S$5.2 million (ca. US$3.4 million) funding programme to promote quality research in human pluripotent stem cells.

[162] WTEC Panel Report on Tissue Engineering Research, International Technology Research Institute, 2002. http://www.wtec.org/loyola/te/final/te_final.pdf

[163] 13 institutions from 4 EU Member States are represented in the Top 50 of public institutions with most authors occurring in scientific publications related to tissue engineering research: UK (University College London, Imperial College), Germany (Humboldt University, Universities of Munich, Heidelberg, Freiburg, Hamburg, Regensburg, Hannover, Medical School, TH Aachen), The Netherlands (University of Nijmegen, Erasmus University) and Sweden (Karolinska Institute). [Source: Bock, A. K. et al. (2003) ESTO/IPTS Report "Human tissue-engineered products - Today's markets and future prospects"]

[164] Furthermore, strong international public R&D funding activities have been noticed for instance in the domain of Neurosciences, neurological and mental diseases / mental health particularly in France and in the UK. There also important research activities in the broad area of biotechnology, for instance in the UK and in Finland.

[165] This is corroborated by the fact that, in contrast to other scientific fields, there is no industrial basis in Life Sciences in Luxembourg and research in "Life Sciences" has only an academic basis to build upon. Therefore it was suggested during this Foresight exercise that a different approach and perhaps different ways of funding are needed for this field. This might be accounted for during the implementation phase.

[166] http://cordis.europa.eu/erawatch/index.cfm?fuseaction=prog.document&uuid=7D87C419-FF57-E82D-3E16EBF18AD0AED9;

[167] http://cordis.europa.eu/erawatch/index.cfm?fuseaction=prog.document&uuid=7D87C552-0956-9587-B07EBDF85E9D9BFB]

aspects: biomaterials, tissue engineering, research on pluripotent cells[168], development of appropriate modelling and imaging tools, etc. Luxembourg should aim at becoming highly competitive in one or two of these areas within the next 10 years.

List of research issues in the domain of Regenerative Medicine in Age-related Diseases

• **Tissue and cell therapy**
  • tissue engineering
  • biomaterials
  • development of appropriate modelling and imaging tools

Age-related medical indications:
• Cardio-vascular Diseases • Oncology • Neurodegenerative Diseases

Tissue engineering applications in regenerative medicine for age-related diseases is an interesting opportunity for Luxembourg as progress in this research area is expected in the next 5-10 years and will be without doubt of high societal and economic importance for an ageing population[169].

Furthermore, there is already some expertise in this area in the public sector in Luxembourg (see criteria table, C7)[170]. Research in tissue engineering is from a scientific point of view very attractive and despite of the high international competition in this field, there seems to be a lot of entry points[171]. It was even argued that a high competitive field might be more attractive for scientists as they may reach a bigger impact and greater rewards in case of success. It might be, for instance, promising to develop tissue and cell engineering in combination with the development of novel materials for bio-devices (cardio-vascular and other prostheses, encapsulation devices for cells or bioactive molecules etc.[172]), especially when linked to the priority domain "New functional and intelligent materials and surfaces, and new sensing applications".

Furthermore, tissue engineering has the potential of replacing some existing pharmaceutical treatments provided the costs of (future) tissue engineering based therapies are competitive. Therefore research in this domain, even if not directly business-oriented, might have an important economic impact on the long run: estimations of the potential markets for tissue engineering products lie in the range of € 4 to € 400 billion per year world-wide[173] - according to

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[168] It should be noted that ethical concerns of the public might still be an obstacle to research focusing on stem cell research as the public debate on stem cell research has been very limited so far in Luxembourg.

[169] Even if the ageing trend is actually slower in Luxembourg than in many European countries, the number of people aged 65 and over is expected to grow from 14% of the population in 2003 to an estimated 18% in 2030. [Source: http://www.euro.who.int/eprise/main/who/progs/chhlux/demographic/20050131_1]

[170] In contrast, there is not much R&D activity in the industry in Luxembourg focusing on tissue engineering, but this applies to most other European countries where only small start-up companies exist.

[171] Since the very tight time frame of this FNR Foresight exercise did not allow performing a detailed market analysis and a comparison of the international R&D performance in the field of tissue engineering, these analyses should be carried out at a later date during the implementation phase to identify adequate entry points for Luxembourg's research. Such studies should in particular highlight current challenges of tissue engineering research and applications such as, for instance, scaling up tissue engineering for mass production, quality and monitoring issues.

[172] Clinical and applied research aiming at bio-devices or encapsulation techniques exists already in Luxembourg.

[173] Bock, A. K. et al. (2003) ESTO/IPTS Report "Human tissue-engineered products - Today's markets and future prospects". Seville: IPTS- Institute for Prospective Technological Studies.

a study by CapGemini, a market volume of € 160 billion worldwide could be reached in 2012[174]. Tissue engineering research could therefore attract biotechnology companies to Luxembourg[175] and even lay the ground for a competitive industry (for regenerative medicine)[176]. This would be in line with the efforts currently carried out by the Ministry of Economic Affairs and Foreign Trade: Based upon a recent study on opportunities for biotechnologies in Luxembourg, the Ministry of Economic Affairs and Foreign Trade will set up an action plan to develop the (legal) framework for a flourishing biotechnology industry in Luxembourg[177]. In this context, specific aspects related to medical devices and diagnostic tools (bioengineering / artificial limbs and prosthetics) of the domain regenerative medicine may also be an opportunity on the long-run as research results and an appropriate technology transfer may support the development of a medical device industry in Luxembourg.

Despite the existing research basis in Luxembourg in the domain of age-related diseases, Luxembourg might not dispose of the necessary critical mass at the moment to achieve internationally recognized scientific excellence in regenerative medicine and tissue engineering. Therefore, it is of high importance to hire new and high-qualified researchers - senior scientists, researchers on sabbaticals, PhD and Postdocs - from abroad to be selected by international, non-local peer review. This effort has already been done by the University for a few years but has to be further strengthened. With regards to this, it could be interesting and fruitful to build on the FNR-funded ATTRACT programme aiming at hiring new scientists. Even if important incentives have to be developed to attract new scientists - besides competitive salaries, an attractive scientific environment and adequate infrastructures in Luxembourg are important[178] - it might be feasible, given the available (and increased) budget, to overcome in the next future the current lack of critical mass. Regardless of a non-existing reputation in the research field at the moment, Luxembourg might even have a competitive advantage compared to neighbouring countries like Germany or France, where the scientific environment is expected to become less attractive in the next years. Four to five groups of 10-15 people with an overall budget per group of 2-3 Mio Euro p.a. were stated as a good scale to develop internationally competitive research. International visibility - as in all research fields - should be reached through publications in top scientific journals[179]. Future research programs should furthermore allow for and support

[174] "Wirtschaftliche Entwicklung und Zukunft der Regenerativen Medizin in Deutschland", CapGemini, 2004.
[175] The lack of an adequate legal environment for tissue banks (see Annex A2) is still currently an obstacle to attracting tissue engineering companies or foster the creation of new ones - however, this obstacle may be overcome soon in the scope of the reforms of the legal framework for biotechnology / biotechnology companies planed by the Ministry of Economy and Foreign Trade.
[176] At the moment, the private tissue engineering sector as a whole is quite similar in Europe and the USA, characterised by young, small, research-based and technology oriented companies. In Europe, most tissue engineering companies (about 50%) are based in Germany and the UK, followed by France, Sweden and The Netherlands. [Source: Bock, A. K. et al. (2003) ESTO/IPTS Report "Human tissue-engineered products - Today's markets and future prospects"]
[177] Cf. Biotechnology and Biomedicine in Luxembourg: The Strengths and Weaknesses, Ministry of Economic Affairs and Foreign Trade, 2006.
[178] The possibility of creating an award for research teams and individual researchers was briefly discussed.
[179] In this respect, the fact that life sciences is already today the research field in Luxembourg with the highest publication rate could be an asset. As shown by a recent bibliometric study on Luxembourg science in an international perspective carried out at the University of Leiden, 139 publications were published in the broad field of life sciences (including the sub-domains basic life sciences, chemistry & chemical engineering and clinical medicine) between 1995 and 2004 and the actual impact score in this field was found to be 9.55 citation per publication. [Source:

interdisciplinary collaboration[180] (an asset for small groups) between the scientific and medical community in Luxembourg and between the public and private sector (Clusters of innovation, including the research clusters, are needed) - as well as international research collaboration[181]. Finally, these programs should foster start-up companies in a five years time frame.[182] This requires also developing competencies in intellectual property filing and management to support researchers. In addition, the importance of an efficient technology transfer was stressed - for the creation of start-ups and attracting foreign companies to Luxembourg. The development of biomedical Technology Platforms (see Annex A2) which may benefit from an increased funding in the next years will further push research in regenerative medicine.

In conclusion, regenerative medicine and especially tissue engineering for therapies of age-related diseases appear to be a promising issue for future public research in Luxembourg - despite of a very strong international competition in this area. The increased budget for public research - and the strengthening of Technology Platforms - as well as the reforms of the legal framework planed by the MECO in order to create a favourable environment for biotechnology and biomedical industry in Luxembourg will provide the grounds for developing a critical mass for research and related industrial applications in regenerative medicine.

6.4.2 Public and Environmental Health

Public health, defined as the approach to medicine concerned with the health of the community as a whole, encompasses: 1. the assessment and monitoring of the health of communities and populations at risk in order to identify health problems and priorities; 2. the formulation of public policies designed to solve identified local and national health problems and priorities; 3. assuring that all populations have access to appropriate and cost-effective care, including health promotion and disease prevention services, and evaluation of the effectiveness of that care.[183] In particular, effective public health action depends upon an understanding of the *determinants of health*[184] - social and economic environment, physical environment and the person's individual characteristics and behaviours- and the contexts in which these determinants operate - values, beliefs, and traditions of individuals and communities. Research in public health and epidemiology as its basic science - studying the distribution and determinants of health-related

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T.N. van Leeuwen (2006), Results of the bibliometric study on Luxembourg science in an international perspective, Center for Science and Technology Studies (CWTS), Leiden University.]

[180] The domain Regenerative Medicine / Tissue Engineering in Age-related Diseases is a highly interdisciplinary field, linking different fields as modelling of cell functions, transcription cell biology, clinical studies etc.

[181] This was seen as a sine qua non to achieve international excellence in research.

[182] The project "Successful Ageing" in Flanders is an example for a successful strategy of building up a research base in collaboration with the industry. This project follows an interdisciplinary approach including research specialists in cardiovascular diseases, epidemiology, metabolomics, stem cells, etc. As this research is of high interest in particular for the pharmaceutical industry, several companies could be won over to participate. Two spin-off companies working on tissues regeneration have already emerged from this project. This example shows that promoting basic sciences might help to set foot in the field from a commercial and industrial point of view.

[183] http://www.medterms.com/script/main/art.asp?articlekey=14269

[184] According to the WHO, the determinants of health include: - Income and social status; - Education level; - Physical environment; - Employment and working conditions; - Social support networks; - Culture; - Genetics ; - Personal behaviour and coping skills; - Health services; Gender. [Source: http://www.who.int/hia/evidence/doh/en/index.html]

states in specific populations and the application of this study to the control of health problems[185] - is therefore crucial for effective public health policy[186].

Luxembourg Public Health research should focus on issues related to health information and promotion and to the assessment and improvement of the health care system.

List of research issues in the domain of Public Health
• Health information o Databases • Health promotion o Disease prevention o Work-related diseases o Improving mental health in occupational settings o Health education / promoting health o Tools to assess health promoting programs • Health system o Collective and institutional factors o Health economics o Quality of health care system o Rational drug use in private practice o Optimizing delivery of health care (quality of life, patient security, efficient eHealth) o Assessment of programmes

Health information and promotion: Luxembourg research should contribute to develop and implement a proactive approach to health with the aim to raise the awareness among citizens on health issues and to enhance health promoting behaviours. This includes the dissemination of health-related information and the promotion of health behaviour education - and is in line with the objectives of the European Community Action Programme for Public Health for 2003-2008[187], the New Health Strategy to be adopted by the EU in 2007[188] and FP7, where health policy driven research will be strongly reinforced (see criteria table, C9). According to a study carried out in 2004 by the Robert Wood Johnson Foundation, up to 67% of the healthcare costs can be prevented and are due to unhealthy behaviours and risks which could be reduced or even eliminated. This especially holds for the so-called life style diseases, cardio-vascular diseases - main cause of illness and premature death in the EU, accounting for approximately 40% of deaths in the EU and 33% in Luxembourg[189] - and obesity[190], which are of increasing concern for all Western countries. Research in Luxembourg should therefore address risk factors and genetics aspects[191] of obesity and cardiovascular diseases and has to be carried out in

[185] A Brief Introduction to Epidemiology, Betty C. Jung, RN, MPH, CHES, University of Pittsburgh. http://www.pitt.edu/~super1/main/index.htm

[186] National Public Health Partnership Background Paper, Australia, 1998. Further important aspects of public health research - not highlighted in this Foresight exercise - concern e.g. public health economics and ethics in public health.

[187] Decision No 1786/2002/EC of the European Parliament and of the Council of 23 September 2002 adopting a programme of Community action in the field of public health (2003-2008).

[188] Health in Europe: Strategic Approach-Discussion Document for a Health Strategy, EC-DG SANCO, 2007.

[189] WHO Highlights on Health for Luxembourg, 2004.

[190] At present, in the EU countries, up to 27% of the male population and 38% of females, including more than 3 million children, suffer from obesity. [Source: http://www.europa.eu/scadplus/leg/en/cha/c11542b.htm]

[191] Competencies in this area already exist for instance at the CRP Santé (Laboratory of Molecular Biology, Genomics and Modelling, Epidemiology and Technology Transfer Service).

collaboration with social scientists in order to account for behavioural aspects of the genesis of these diseases. An additional lifestyle related issue pertinent to the Luxembourg society relates to the effects of stress on health (immunological, psychological aspects, etc.)[192].

Further important research issues relate to mental health[193] - a growing challenge and a public health priority for the EU as a whole, as underlined in the EC Green Paper on Mental Health[194] - and drug addiction. As depression is expected to be in a few years the disease group with the second heaviest toll globally - associated with huge social and economic costs-[195], there is a need for monitoring and preventing depression at work and after retirement. These topics concern partly labour market issues (working conditions[196]) and also relate to population ageing: it becomes more and more relevant to think of new retirement mechanisms or new living structures (housing, urban planning, etc.) avoiding isolation and depression in old age. Another typical cross-cutting question is the social impact of drug use and the relation with infectious diseases like hepatitis C.

As Luxembourg has one of the highest suicide rates in the EU-15[197], research aiming at determining the reasons for suicide and at addressing prevention issues could be also highly relevant[198].

ICT applications to health, like e-Health and telemedicine[199], though not discussed in-depth in this FNR Foresight exercise[200], are deemed at European level as important tools for improving people's access to healthcare and health information services[201]. It may therefore be worthwhile

[192] Related to stress prevention, competences exist at the University and the National Health Laboratory as well as institutionalised international links through graduate school for psychobiology (2 of 6 professors are based in Luxembourg) and the International research training group IRTG (linking graduate student training in Luxembourg, Trier and Leiden) funded by the Deutsche Forschungsgemeinschaft (DFG).

[193] The WHO describes mental health as: "a state of well-being in which the individual realizes his or her abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community". [Source: WHO, Strengthening mental health promotion, Geneva 2001 (Fact sheet no. 220)]

[194] More than 27% of adult Europeans are estimated to experience at least one form of mental ill health during any one year. By the year 2020, depression is expected to be the highest ranking cause of disease in the developed world. [Source: Green Paper Improving the mental health of the population: Towards a strategy on mental health for the European Union. Brussels, 14.10.2005 COM(2005)484]

[195] "The State of Mental Health in the European Union", EC, DG SANCO, 2004.

[196] The German regional foresight study "Zukunfstradar2030" emphasizes for instance the future role of the workplace and of working conditions in preventing mental health of the employees. [Source: Braun, A.; Rijkers-Defrasne, S.; Amanatidou, E. ; Damvakeraki, T. ; Pechmann, A. "Healthy Ageing: Challenges and Options for Research". EFMN ISSUE ANALYSIS REPORT 2006]

[197] Luxembourg's official standardised suicide death rate amounted to 13.2 per 100 000 persons in 2004 (Eurostat).

[198] It was nevertheless questioned whether a critical mass of research in these specific questions can be established in Luxembourg.

[199] e.g. Self-monitoring and self-diagnosis tools for age-related diseases are thought to be on the rise.

[200] E-Health applications were only named as potential future applications for e-services.

[201] The European eHealth action plan, adopted on April 30 of 2004, takes a twin track approach: making the most of new information and communication technologies in the health sector and better integrating a range of e-Health policies and activities. It will provide a framework for exchanging best practices and experience and enable common approaches to shared problems to be developed over time. http://www.ec.europa.eu/information_society/qualif/health/index_en.htm. The recently launched Health-EU Portal (http://ec.europa.eu/health-eu/index_en.htm) contributes to achieving the aim of providing European citizens with easy access to comprehensive information on Public Health initiatives and programmes at both EU level and

to assess the potential for Luxembourg of research in this area.

Assessment and Improvement of the health care: In international comparison, Luxembourg has a high quality health system. However, the efficiency of the health care system needs to be improved to cope with rising health costs - with impacts on the social system and the economy - and future challenges posed by the ageing population[202]. Today, the monitoring and assessment of the Luxembourg health care system (regarding e.g. accessibility and equity of health care) are not sufficiently developed, which hampers decision making, the allocation of funding, etc. It is therefore highly important to develop evaluation tools for the Luxembourg health care system, taking into account the patient's perspective - in line with FP7-[203] and OECD-priorities[204]. In particular, regarding to the ageing population, research should address the evaluation of economic and social effects of home-based health care.

Luxembourg has an interest in promoting domestic research in public health - regardless of potential high international competition in this field - in order to tackle Luxembourg specific needs and obligations. Such research, providing information to policy makers with the overall objective of contributing to guarantee high quality health services and to improve public health, is obviously of highest social relevance. The economic impact of research, also, cannot be underestimated. The successful implementation of research results into public health policies[205] will contribute to: reduce the number of days of sick-leave and increase the labour productivity; increase the education level of the whole population[206] (as children with better health and nutrition achieve higher educational attainment) - to name but a few positive indirect impacts of successful public health research[207]. Research in public health is furthermore of high importance to reduce the additional health care costs due to the ageing of the population - Health improvements could reduce by 50% the predicted increase in spending due to ageing by 2050[208] as "the demand for healthcare depends ultimately on the health status and functional ability of (elderly) citizens, and not on age *per se*".[209]

Research in public health is scientifically attractive and future research programmes can capitalise on a wide set of skills in Luxembourg (see criteria table, C7) and on existing links

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international level. The portal is an important instrument to positively influence behaviour and promote the steady improvement of public health in the 25 EU Member States.

[202] The pure demographic effect of an ageing population is projected to push up healthcare spending by between 1 and 2 % of GDP in most Member States. [Source: "The impact of ageing on public expenditure: projections for the EU-25 Member States on pensions, healthcare, long-term care, education and unemployment transfers (2004–50)", EC, DG ECFIN, 2006.]

[203] Cf. Area "Quality, efficiency and solidarity of health systems" of FP7 health-related activities.

[204] http://www.oecd.org/dataoecd/10/57/35101765.pdf. It should be noted that research activities focusing on the assessment of the efficiency of the public health care system are carried out in most countries at national level.

[205] According to the Hope Health Special Report, 2003, for every dollar invested in health promotion, the savings in medical costs and absenteeism range from $2.30 to $10.10.

[206] This is in line with the goals of the Lisbon strategy.

[207] Suhrcke, M.; McKee, M.; Sauto Arce, R.; Tsolova, S.; Mortensen, J. (2005) "The contribution of health to the economy in the European Union". EC, DG Health and Consumer Protection.

[208] Estimations of the Economic and Financial Affairs Directorate General of the European Commission. [Source: Braun, A.; Rijkers-Defrasne, S.; Amanatidou, E. ; Damvakeraki, T. ; Pechmann, A. "Healthy Ageing: Challenges and Options for Research". EFMN ISSUE ANALYSIS REPORT 2006].

[209] "The impact of ageing on public expenditure: projections for the EU-25 Member States on pensions, healthcare, long-term care, education and unemployment transfers (2004–50)", EC, DG ECFIN, 2006.

within the Great Region with epidemiology institutes and public health institutes. However, high class foreign scientists still need to be attracted to Luxembourg to reach critical mass. The current lack of data on risks factors and of health monitoring systems (high quality screening) - for which existing European standards are still to be introduced and implemented in Luxembourg - are currently serious impediment for research. Databases, the necessary precondition of epidemiology and of public health decision making, exist e. g. at social insurance organizations (and data needs of various ministries are surely a supportive factor) but are not sufficiently utilised and interlinked[210]. Improvements could be made by setting up a surveillance system: taking Luxembourg's size into account, it should be possible to uniformly collect medical records and to efficiently access and link data[211]. Furthermore, all topics of public health research require sound scientific Technology Platforms (see Annex A2): state of the art bio-banking and bioinformatics, versatile laboratories using up–to-date analytical tools, etc.

Environmental Health

Environmental health as defined by the WHO Regional Office for Europe, includes both the direct pathological effects of chemicals, radiation and some biological agents, and the (often indirect) effects on health and wellbeing of the broad physical, psychological, social and aesthetic environment which includes housing, urban development, land use and transport.[212] Ensuring environmental health is one aspect of public health policies. Research in environmental health was identified during Phase 2 of the FNR Foresight exercise as a stand-alone priority for public research in Luxembourg; however, the FNR administrative and scientific boards recommended combining public health and environmental health into one priority.

It is estimated that 25 – 33%[213] of the major causes for the global burden of disease are associated with environmental factors. Recent studies[214] on the link between the environment and health include for instance estimates that each year between six and nine thousand French city dwellers die prematurely because of air pollution and that about one sixth of the total burden of death and disease for children can be attributed to environmental factors. The effect of the environment on health is therefore not surprisingly a major concern of the European public: in a recent survey, some 89% are worried about the potential impact of the environment on their health. Furthermore, new technologies, changing lifestyles, work and life patterns, present new and sometimes unexpected impacts on the environment and its influence on health.[215]

[210] Ethical questions need to be addressed and the regulatory framework may need to be adapted.

[211] In that regard, politics might have an interest in collaborating with insurances and the Union des Caisses Maladies, as these institutions do have many data on their patients, which are not accessible by researchers now.

[212] Environment and Health, the European Charter and Commentary, Frankfurt, 1989

[213] Smith, K. et al. 'How much global ill health is attributable to environmental factors ?', Epidemiology 1999, pp573-584

[214] [Sources: French Agency for Environmental Health Safety 2004 report: (http://www.afsse.fr/documents/Rapport_1.pdf); Burden of Disease and Injuries Attributable to Selected Environmental Factors among Europe's Children and Adolescents, Francesca Valent, D'Anna Little, Fabio Barbone, Giorgio Tamburlini; WHO, Geneva 2004]

[215] http://ec.europa.eu/environment/health/index_en.htm

Environmental Health policy[216], combining monitoring / traceability technologies and risk reduction strategies on the level of the exposed individuals (immunological approaches) - including the genetic susceptibility of individuals -, is high on the agenda in Europe[217] and naturally also of importance for Luxembourg at national level. Research in environmental health is crucially important in establishing the knowledge base and providing concrete measures by which environment and health research results will be fed into policy-making, for analysing and filling the gaps in environment and health activities.[218] Today, there is reasonable understanding of cause and effect relationships between 'some' environmental factors, e.g. air, water, and human health. However, the consequences on health of some other environmental factors, such as those resulting from climate change and chemicals are a result of complex interactions between the environment and humans that are far less understood. For some chemicals, such as endocrine disruptors, the effects on humans are particularly difficult to unravel but the impacts on wildlife have been substantial, with implications for human health.[219]

List of research issues in the domain of Environmental Health
• **Impact of environmental factors on human health**
• Pollutants in the environment (occupational health, indoor and outdoor environment)
• Atmospheric pollution and health (particular matter, nano-particles)
• Study of allergens
• Study of low-dose long-term effects of industrial and agricultural pollution
• Micro-organismic "pollutants" / pathogens
• **Monitoring in environmental health**
• Biomonitoring, incl. bio indicators and human bio-monitoring (diagnostic devices)
• Tools for biomonitoring (exposure markers, effect markers)
• Monitoring of medical environment
• **Prevention and treatment of environment diseases**
• Linking human nutrition (food as a vector of pollutants) and health and environmental needs
• Traceability and labelling of industrial products (indoor environment)
• Reducing the use of antibiotics

As indoor and outdoor air pollution are the environmental factors with the greatest impact on health in Europe and as they are responsible for the largest burden of environment-related

[216] Environmental Health policy is not to be confounded with policies aiming at guaranteeing a "*healthy environment*", meaning at reducing the negative influence of human activities on the natural environment.

[217] The European Commission developed a Environment and Health Action Plan 2004-2010, presented at the Fourth Ministerial Conference on Environment & Health in Budapest in June 2004, designed to give the EU the scientifically grounded information needed to help all 25 EU Member States reduce the adverse health impacts of certain environmental factors and to endorse better cooperation between actors in the environment, health and research fields. [Source: Communication from the Commission to the Council, the European Parliament, the European Economic and Social Comittee: "The European Environment & Health Action Plan 2004-2010", Brussels, 9.6.2004 COM(2004) 416 final, http://ec.europa.eu/environment/health/pdf/com2004416.pdf]

[218] Communication from the Commission to the Council, the European Parliament, the European Economic and Social Comittee: "The European Environment & Health Action Plan 2004-2010", Brussels, 9.6.2004 COM(2004) 416 final, http://ec.europa.eu/environment/health/pdf/com2004416.pdf

[219] [Source: „Health and the environment in the WHO European Region: Situation and policy at the beginning of the 21st century", Background Document to the Fourth Ministerial Conference on Environment and Health, Budapest, Hungary, 23-25 June 2004]

diseases[220], the main objective of Luxembourg's public research should be to study time related effects of indoor and outdoor environments on human health. By linking exposure to effect data in long-term research project (longitudinal studies, time frame approx. 20 years), it will be possible to identify sources and causes of pollution and their impact on the population, as well as to develop monitoring, traceability and analysis tools to better understand, predict and reduce negative effects of pollution in the future. Such tools could then be used subsequently for legislation, the assessment of its impact and for educational programs.

Further promising research issues for Luxembourg concern occupational health[221], the reduction of the use of antibiotics[222], the treatment of environment related diseases like asthma, allergies and possibly also the "chronic fatigue syndrome" as well as the field of preventions, e.g. by providing data for labelling products. Listing pollutants in consumer products, e.g. mattresses or furniture, enables people to establish a healthy indoor environment for themselves. Another example is the currently introduced EU directive on nano-particles. In many countries, not only in Luxembourg, the particle density is above the recommended levels. In order to implement this new directive it is of great importance for Luxembourg to have competences in the field of monitoring nano-particles. And as in the next 10-15 years a growing number of nano-materials will enter the market, it would be sensible to analyse their long-term impact on human health, which up until now would be unique in the European research community.

On the national level it could be of interest to build up alert systems to inform the public on daily impacts of their outdoor environment[223] [224].

Public research in environmental health will have a very important socio-economic, as well as environmental impact. As the social cost of disease burden is clearly the loss of wellbeing on the part of those suffering from disease and the distress caused to their friends and relatives, research in environmental health aiming at improving the quality of life and the health of the population is of crucial importance. There are however also economic rationales for this type of

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[220] Recent estimates indicate that 20 million Europeans suffer from respiratory problems every day. Particulate matter and especially small particles with a diameter less than 2.5 micrometres (PM2.5) are associated with increased mortality, especially from cardiovascular and cardiopulmonary diseases. Also asthma is increasing all over Europe, laying to societal costs of about EUR 3 billion/year. Although it is still unclear, to what extent air pollution initiates asthma, several studies show a strong association between exposure to air pollution and the aggravation of asthma. [Source: Environment and Health, European Commission, EEA Report, No10/2005, http://reports.eea.europa.eu/eea_report_2005_10/en/EEA_report_10_2005.pdf]

[221] Occupational Health is the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations by preventing departures from health, controlling risks and the adaptation of work to people, and people to their jobs. (ILO/WHO 1950) http://www.agius.com/hew/resource/ohsilo.htm It therefore encompasses designing, implementing and evaluating comprehensive health and safety programs to improve safety and increase productivity in the workplace. http://www.foh.dhhs.gov/Public/WhatWeDo/OHDefinition.asp

[222] Research is needed into the environmental impacts of the widespread use of antibiotics on the development of reservoirs of resistant bacteria in nature from which resistance could be transferred into human and animal disease organisms. [Source: R. Laxminarayan, "Antibiotic Resistance: An Emerging Environmental Health Threat", Resources for the future, August 2002 · Issue Brief 02 – 19, http://www.rff.org/Documents/RFF-IB-02-19.pdf]

[223] This would be in line with the results of a recent study on Public views on air pollution in Europe putting out that most individuals don't feel well informed about air quality and its implications. [Source: "Public views on air pollution in the European Union", TNO-Report, B&O-A R 2005/100, 2005]

[224] In that regard, the domain is linked - at least to some extent - with the aspects of crisis management of the priority "Telecommunications and Multimedia", see chapter 6.1.5.

research: the economic cost of remediating the disease burden that can be attributed to environmental factors is very high, and can be estimated to around 2-3% of the GDP in Europe.[225] In addition, there is the cost to society in lost productivity over the lifetime of the affected individual.[226] Therefore research in environmental health may help to reduce the burden on the social security system, as well as to increase the productivity of the affected individuals.

Given that a major difficulty within the field of environmental health are combinatory effects (humans are exposed to a multitude of pollutants everyday) Luxembourg has a distinctive advantage: research issues in environmental health are usually of a workable scale for Luxembourg and taking the size of the country into account, quasi exhaustive data collections are feasible. Luxembourg already has some research experience in this field (see criteria table, C7) and some actors are already engaged in collaborations (including public private partnerships) for sampling, analysis and treatment- this basis should be built upon and Luxembourg should aim at becoming within the next 10 years a model region for the linkages between health, the environment and social issues. A lot of scientific opportunities as well as opportunities in applications could derive from Luxembourg's distinctive advantage, e.g. predictive studies, setting critical limits for noxious agents, such as heavy metals, pollution or toxic elements in consumer products or the evaluation of political measures. Research studies show, for example, that combined bio-monitoring and human bio-monitoring can allow a precise evaluation of the outcome of political measures, e.g. after reducing lead in fuel the lead level in human blood dropped.

However, up until now the data collected by Luxembourg researchers are not sufficiently linked. The centralised database on cancer tissues in Luxembourg (tumour bank), for example, is in fact linked to medical data, but not to the available data on environmental developments. Furthermore, there is sometimes a lack of coordination between the (possible) collaborators. More importantly, environmental health research suffers from a lack of continuity (due to the short term projects and contracts) and – in some cases – from a lack of competence within Luxembourg, e.g. in the field of indoor environment impacts. These weaknesses should be overcome in order for Luxembourg to be able to do excellent research in environmental health[227]. For instance, multi-annual stable funding schemes would allow the field to gain in quality and international competitiveness. The creation of a biobank of living people supplementing the existing biobank of deceased people at the National Health Laboratory should be supported[228]. To cope with the interdisciplinary complexity of environmental health

[225] Commission Staff Working Document, Communication From The Commission To The Council, The European Parliament, The European Economic And Social Committee "The European Environment & Health Action Plan 2004-2010", Extended Impact Assessment {COM(2004) 416 final, Brussels, 9.6.2004, SEC(2004) 729

[226] This is particularly significant for child health problems, where disease can make the difference between a productive lifetime and a lifetime of remedial medication.

[227] In particular, in order to link all data related to environmental health issues, Luxembourg research should find a way to cope with certain EU and/or national regulations on data protection (EU Directives 95/46/EC and 2002/58/EC implemented in national law in 2002 and 2005). http://ec.europa.eu/justice_home/fsj/privacy/law/implementation_en.htm#luxembourg

[228] In that regard, ethical concerns will have to be taken into account: up to now, the Luxembourg National Ethics Committee provided an official opinion on human biobanks but no important public debate has taken place. [Source: Braun, A; Rijkers-Defrasne, S.; Deschênes, M.; Scerri, C. A.; Laage-Hellman, J. (2006) ESTO/IPTS Report "Biobanks in

research issues, future research groups should be multidisciplinary and PPP involving private laboratories, physicians and the medical sector as a whole should be fostered. Technology Platforms (e.g. genomics, metabolomics, proteomics, etc. see Annex A2) may have to be developed to support future research focusing on environmental health.

6.4.3 Translational biomedical research

Translational Biomedical Research refers to research at the interface between fundamental research and clinical applications. To improve human health, scientific discoveries must be translated into practical applications. Such discoveries typically begin at "the bench" with basic research — when scientists study disease at a molecular or cellular level — then progress to the clinical level, or the patient's "bedside." Scientists are increasingly aware that this *bench-to-bedside* approach to translational research is really a two-way street: Basic scientists provide clinicians with new tools for use in patients and for assessment of their impact, and clinical researchers make novel observations about the nature and progression of disease that often stimulate basic investigations. Translational research has therefore proven to be a powerful process that drives the clinical research engine.[229]

The priority domain "Translational Biomedical Research" is obviously related to Public Health research (which has a more macro-view, looking at the whole population) and the Public Health sector as the transfer of research results from the laboratory to the hospital and public health services (generating applicability) will provide new impulses for improving public health measures, clinical procedures and cures[230]. Biomedical research, translating research into treatment on the patient level, is also, of course, closely linked to clinical research[231]. Last but not least, translational research can lead to the development of new technology e. g. technology transfer to the diagnostic industry. Luxembourg research in this area should therefore aim to bridge between fundamental research, clinical application and public health and technology transfer - as illustrated in the chart below.

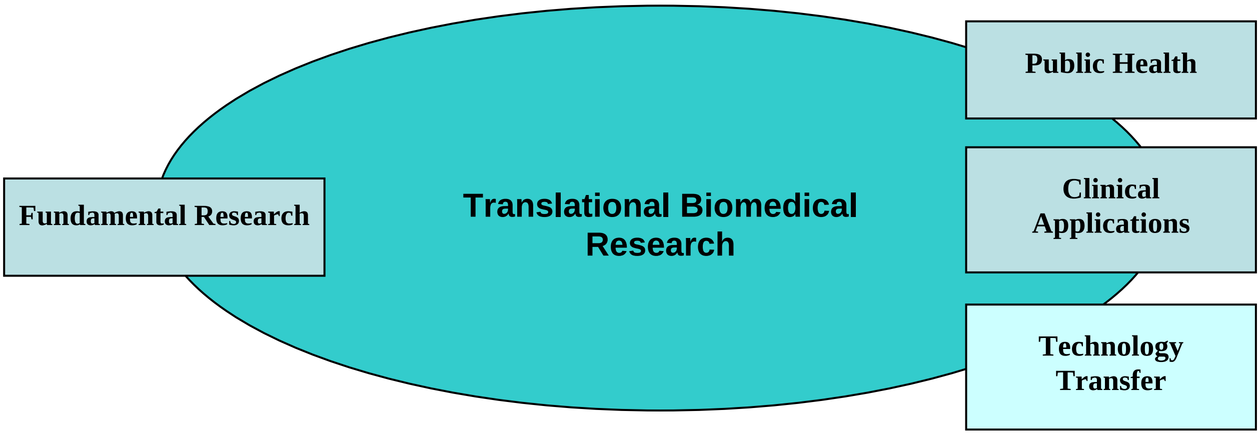
Europe: Prospects for Harmonization and Net-working". Seville: IPTS- Institute for Prospective Technological Studies.]

229 US National Institutes of Health, http://nihroadmap.nih.gov/clinicalresearch/overview-translational.asp

230 There are also linkages between translational research and research in Environmental Health as research results in this last field have also to be implemented into practice to reduce the negative effects of the environment on human health.

231 Clinical research can be defined as: - Patient-oriented research. Research conducted with human subjects (or on material of human origin such as tissues, specimens and cognitive phenomena) for which an investigator (or colleague) directly interacts with human subjects. This area of research includes: Mechanisms of human disease, Therapeutic interventions, Clinical trials and the Development of new technologies. - Epidemiologic and behavioral studies; - Outcomes research and health services research.

[Source: NIH Director's Panel on Clinical Research Report to the Advisory Committee to the NIH Director, December, 1997. http://www.nih.gov/news/crp/97report/index.htm]



Translational Biomedical Research

One promising line for translational research could be personalized medicine. The concept of '*Personalized Medicine*'[232] is used to describe the expected reform in medicine that is projected to happen in the coming decades, harnessing genomics and proteomics technologies for tailoring the most suitable pharmacotherapy for the each patient, based on individual profiling. High public expectations[233] are raised by personalized medicine for better pharmacotherapy, allowing for instance drastic reductions in the rates of adverse drug reactions, accounting to almost 7% of new hospital admissions.[234] Following the recent success of drug tailoring in oncology with the aid of genomic and proteomic tools, personalized medicine is also projected to allow improved treatment efficacies for many diseases and better diagnostic tools to improve treatment outcomes in other fields of medicine.[235]

Luxembourg activities in translational research should therefore focus on personalized medicine, the control of antiviral and antimicrobial drug resistance and the translation of clinical research into clinical practice for the treatment of cardiovascular, neurological and infectious diseases and cancer. Luxembourg translational research will obviously benefit from activities and existing expertise developed on the Technology Platforms (see Annex A2) where synergies can be built.

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[232] First mentioned in modern scientific literature in 1999.

[233] Recent reports about drug safety issues and the withdrawal of well-known drugs from the marketplace, most notably Vioxx, have contributed to strengthened public awareness about the scope of adverse drug reactions and the potential of personalized medicine to minimize them.[Source: Gurwitz, D., Livshits, G. Personalized Medicine Europe: Health, Genes and Society: Tel-Aviv University, Tel-Aviv, Israel, June 19–21, 2005.]

[234] Lazarou J, Pomeranz BH, Corey PN: Incidence of adverse drug reactions in hospitalized patients. JAMA 1998; 279: 1200–1205.

Pirmohamed M, James S, Meakin S *et al*: Adverse drug reactions as cause of admission to hospital: prospective analysis of 18 820 patients. Br Med J 2004; 329: 15–19.

[235] Gurwitz, D., Livshits, G. Personalized Medicine Europe: Health, Genes and Society: Tel-Aviv University, Tel-Aviv, Israel, June 19–21, 2005.

[Source: Nebert DW, Vesell ES: Advances in pharmacogenomics and individualized drug therapy: exciting challenges that lie ahead. Eur J Pharmacol 2004; 500: 267–280.]

List of research issues in the domain of Translational Biomedical Research
• Diagnostics and Personalised medicine • Control of antiviral and antimicrobial drug resistance • Specific groups of diseases[236] • Cardiology and cardiovascular diseases • Infectious Diseases • Oncology • Neurology • Individualised prevention of age-related diseases • Molecular pathways & diseases

The specific diseases to be addressed by Luxembourg research are in line with the FP7-objectives: Translational research - already supported within the 6th Framework Programme[237] - is emphasized in the 7th Framework Programme[238] where research activities addressing translational research related to cancer, cardiovascular diseases, diabetes / obesity but also rare and chronic diseases as well as infectious diseases will be funded in order to confront major threats to public health. Apart from the planed FP7-activities, the importance of translational research is underlined by the amount of international activities in this field, for instance, in the USA (e.g. Center for Clinical and Translational Sciences (CCTS) of the University of Texas, Irving Institute for Clinical and Translational Research of the Columbia University, etc.[239]), in Japan (Kobe Translational research centre), in the UK[240], France, Italy - to name but a few. Improving the efficiency of the translation of medical research results into practice is one of the aims of the Roadmap for Medical Research set up by the US-National Health Institutes in 2006[241] and translational research is also highlighted in the new "High-tech Strategy for Germany"[242]

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[236] Luxembourg has a lot of experience and capacities in different categories of diseases (from infectious diseases to cancer). But existing expertise is not a sufficient reason to prioritize research on these topics. The list of diseases in itself is not as important as the interface between fundamental research and clinical application (translational research).

[237] http://ec.europa.eu/research/fp6/index_en.cfm?p=1. The total EC contribution committed to discovery and translational research activities for PRD under FP6 is more than 255M euros. http://ec.europa.eu/research/health/poverty-diseases/fp6projects_en.html

[238] Translational research activities in FP7 include:
- Integrating biological data and processes: large-scale data gathering, systems biology. To generate and analyse the vast amount of data needed to understand better the complete regulatory networks of thousands of genes and gene-products controlling important biological processes.
- Research on the brain and related diseases, human development and ageing. To explore the process of healthy ageing and the way genes and environment interact with brain activity, under normal conditions as well as in brain diseases.
- Translational research in infectious diseases. To address anti-microbial drug resistance, the global threats of HIV/AIDS, malaria and tuberculosis as well as emerging epidemics (e.g. SARS and highly pathogenic influenza).
- Translational research in major diseases: cancer, cardiovascular disease, diabetes/obesity; rare diseases; and other chronic diseases (e.g. osteoarthritis). To develop patient-oriented strategies from prevention to diagnosis and treatment including clinical research.
[Source: http://www.technion.ac.il/~liaison/fp7/health.html#2]

[239] A list of translational research activities funded by the National Institutes of Health in the USA can be found on: http://nihroadmap.nih.gov/clinicalresearch/fundedresearch.asp.

[240] In the UK, the importance of translational research has been highlighted for instance in the 'Science & Innovation Investment Framework 2004-2014: next steps' has a stated objective – '*to ensure the delivery of high-quality translational health research to deliver real economic, as well as health, benefits, from the UK's excellent science base*' (2006).

[241] http://nihroadmap.nih.gov/clinicalresearch/index.asp

[242] http://www.bmbf.de/pub/bmbf_hts_lang.pdf

which foresees the set up of "Translational research clusters" with the aim of accelerating the translation of research findings into public health and practice.

Due to its contribution to the improvement of public health and clinical practice, translational research is of course of high social relevance and will obtain high public acceptance. The economic impact of translational research will also be important as this research field may allow reducing the health costs by increasing the efficiency of health care delivery[243]. Therefore, in view of expected rising health costs in the future due to an ageing population[244], successful translational research will be an asset for Luxembourg. Furthermore, translational research may promote biomedical spin-offs capitalizing on patents derived from research results and therefore help laying the ground for a new biomedical industry in Luxembourg - in line with the objective of future action plan of the Ministry of Economy and Foreign Trade (MECO)[245]. Lastly, in the scope of international collaboration and development aid projects - like, for instance, the European and Developing Countries Clinical Trials Partnership (EDCTP)[246] created by the European Commission in 2003 or projects coordinated by the Ministry of Cooperation -, translational research done in Luxembourg can play a role in bridging the health care divide separating developed and developing countries[247].

Translational research is *per se* an interdisciplinary research domain and synergies between this domain and the priorities Public Health, Environmental Health and Technology Platforms should be exploited when designing future research programmes. Some activities exist in this field and future research programmes should build on competences in fundamental research on the specific disease groups listed above and the technological know-how existing at the University of Luxembourg, the National Health Laboratories and at the CRP Santé and the CRP Gabriel Lippmann. However, as it might be difficult for Luxembourg to reach critical mass for

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243 For instance, when new prevention strategies and treatments can be developed, tested, and brought into medical practice more rapidly. [Source: Alving, B. (2006) "Re-Engineering Clinical Research Through the Clinical and Translational Science Awards: Potential Benefit for Development", National Center for Research Resources, NIH. http://nihroadmap.nih.gov/clinicalresearch/BIO_2006_Alving.pdf

244 The pure demographic effect of an ageing population is projected to push up healthcare spending by between 1 and 2 % of GDP in most Member States. [Source: "The impact of ageing on public expenditure: projections for the EU-25 Member States on pensions, healthcare, long-term care, education and unemployment transfers (2004–50)", EC, DG ECFIN, 2006.]

245 The MECO's action plan for developing a favourable environment for biotechnological and biomedical industry in Luxembourg will focus on two points: 1. Attract companies mainly in medical devices and diagnostic tools 2. ***Focus also on commercialization and extension***. Cf. Biotechnology and Biomedicine in Luxembourg: Strength and Weaknesses, Ministry of Economic Affairs and Foreign Trade, 2006.

246 The EDCTP aims to translate medical research results into clinical applications tailored to the needs of developing countries. Based on an African-European partnership, this initiative illustrates the strong commitment to fight these major scourges of the developing countries. The Parliament and Council decided on 16 June 2003 that the European Commission would support a long-term partnership between Europe and Developing Countries by providing €200 million for the development of new medicines and vaccines against HIV/AIDS, malaria and tuberculosis (TB). This European and Developing Countries Clinical Trials Partnership (EDCTP) brings together EU Member States plus Norway, Developing Countries, other donors and industry in a joint effort to combat poverty-related diseases. http://ec.europa.eu/research/info/conferences/edctp/edctpini_en.html

247 One example of such development aid projects is the Netherlands-African Partnership for Capacity Development and Clinical Interventions against Poverty-related Diseases. The specific objective of the second NACCAP call, launched in 2006, is to strengthen capacity of African owned (pharmaceutical or biotechnological) R&D institutes by technology transfer between African and European private and public institutes and the call will focus on translational research. [Source: http://www.edctp.org/]

internationally recognized research related to all specific diseases listed above, future translational research projects might rather focus on some specific aspects. Future research should capitalise on the existing renommée of Luxembourg research in medical sciences - compared to other research fields - documented through the solid publication record.[248] Given an adequate legal framework for biomedical research, translational research would profit from the set up of a tissue bank (see Annex A2) and a pathogen bank as well as from the set up of a clinical investigation centre carrying out applied clinical research - which would also benefit to new public health research and policies.

6.5 Labour Market, Educational requirements and Social Protection

Research on labour market and social security issues is a well established field of social and economic sciences, combining empirical studies, modelling and concept development, studies on the macro level of national economies with studies on the micro level of the individual. This research is interdisciplinary by nature. It includes demographic and psychological aspects and addresses all facets of the labour market, ranging from education (in terms of educational and training requirements of the labour market) to the impacts of an efficient or inefficient labour market on welfare and social security vs. poverty and social decline.

Although Luxembourg has the highest living standard and one of the lowest unemployment rates in Europe, unemployment and more generally imbalances of the labour market pose a real challenge. One peculiarity of the Luxembourg labour market consists in the tremendous dependence on foreign workforce. The number of cross-border workers which was 13.400 in 1980 and 33.700 in 1990 reached 111.900 in 2004 and is still growing. The proportion of foreigners (including cross-border workers) in the total of domestic employment stands at over 65%, with cross-border workers alone accounting for 38%.[249] Changes in the sectoral structure of the economy – decline of industrial production and an extraordinary boom in services (financial services, public sector) – have had a major influence on the structure and development of employment, in particular the higher levels of qualifications asked for. About half of those seeking employment have a low level of education and often, therefore, have insufficient professional qualifications.

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[248] As shown by a recent bibliometric study on Luxembourg science in an international perspective, carried out at the University of Leiden, 139 publications were published in the broad field of life sciences (including the sub-domains basic life sciences, chemistry & chemical engineering and clinical medicine) between 1995 and 2004 and the actual impact score in this field was found to be 9.55 citation per publication. In clinical medicine the largest output of Luxembourg scientists was retrieved. The 324 papers in this discipline get cited on average 7.49 times. This is compared to both the journal average as well as to the field impact score, a good performance. In Clinical-experimental basic medicine we find 223 publications, thereby the second largest field in the Luxembourg profile. [Source: T.N. van Leeuwen (2006), Results of the bibliometric study on Luxembourg science in an international perspective, Center for Science and Technology Studies (CWTS), Leiden University.]

[249] Statec: "Luxemburg in Zahlen 2005", OECD Economic Surveys, Luxembourg, Vol. 2006/9, July 2006, and Eurostat http://forum.europa.eu.int/irc/dsis/regportraits/info/data/en/lu_geo.htm. It should also be noticed that very few persons resident in Luxembourg are employed in the neighbouring countries, although the nearly 8.000 residents working for the international institutions are considered as extraterritorial. From another perspective, Luxembourg can be regarded as a pioneering country for an open, integrated European labour market – in line with EU liberalization policies.

Unemployment has risen since the beginning of the decade, partly as a result of an administrative reform that shifted the disabled and partially disabled job-seekers to the unemployment insurance scheme. However, there has also been an increase in the number of unemployed people among regular residents.[250] According to the OECD[251], Luxembourg will be unable in the long run to avoid the upward trend in structural unemployment that can be seen in other countries: even if unemployment decreases in a period of economic growth it is unlikely to reach the lower level prevailing before the downturn.

Both unemployment and demographic ageing have impacts on the social security system. Although the pension scheme appears to be in good financial shape for the time being, it is projected to deteriorate progressively and incur large liabilities after 2030, when the ratio of contributors to beneficiaries will become much less favourable. Longer life expectancy means that pensions will be paid for a longer period than at present, thus increasing future spending. Without reform, liabilities could accumulate and reach between 49% and 151% of the GDP by 2050, depending on the future rate of growth of real GDP. The financial position of the social security system will initially deteriorate at a gradual pace, providing breathing space for reform which, if implemented rapidly, could re-establish the long-term viability of the system without causing disruptive adjustments.

Research is therefore facing the triple task

- to gain a better understanding of the functioning of the labour market and the social system,
- to provide the government[252] with scientific expertise (data, intervention studies, policy evaluation…) for successful, evidence-based policy making (e.g. adapting educational policy), and
- to assist developing (involving all stakeholders) new models for work and social protection.

Research addressing the welfare state is especially important as it concerns the long-term sustainability of the social and economic system. A comprehensive research approach to the labour market would consider aspects like social inclusion, gender issues, migration issues, etc., which still seem to be poorly explored in Luxembourg.

List of research issues in the domain Labour Market, Educational Requirements and Social Protection
Analysis and understanding of labour supply in Luxembourg: • Incentives for work participation • Immigrants and cross-border workers: Work qualifications and motivations • Consequences of an ageing population and a shrinking workforce on the labour market • Maintaining and developing a multicultural and qualified workforce (incl. education and training issues)

[250] The mean unemployment rate of Luxembourg was 2.6% for the years 1996 to 2002, and rose to 4.2% in 2004 – as compared to figures above 8% in the EU-15. It must be noticed however that cross-border workers employed in Luxembourg who loose their jobs are not included in the Luxembourg unemployment statistics. According to the assessment of the OECD, the fact that a growing proportion of residents fail to find an occupation seems to result from their having high reservation wages, reflecting the high levels of replacement incomes. – OECD review of Luxembourg's Innovation Policy, 2006.

[251] OECD, ibid.

[252] The Luxembourg government is the primary, but not the only addressee of labour market research. Other "clients" are social and business organizations (trade unions, professional associations…).

Analysis of labour demand:
- Diversification of the economy: Workforce demand for diversification
- Labour demand of private and public organisations
- Hiring behaviour of private and public organisations (in terms of qualification levels, origin, age, gender…)

Analysis of the relation between labour supply and demand / Recruitment problems:
- Structure of the mismatch between labour supply and demand (in terms of qualifications, origin…)
- Factors leading to this mismatch
- Possible remedies (qualification, regulatory framework, incentives, work models…)

Social system and welfare:
- Impact of cross-border and immigrant workforce on the economy
- Ageing workforce and intergenerational relations
- Population at risk (less qualified, handicapped, elderly persons…)
- Labour market transitions and social security
- New work models
- Gender issues
- Luxembourg welfare state in the larger context (Greater Region and EU internal market / regulation)

Educational issues:
- Determinants of educational achievement / failure
- Individual learning paths and differentiated learning and management of heterogeneity
- Validation of professional experience
- Transition from education system to labour market and issue of life-long learning
- Effectiveness of educational system from an economical point of view

Labour market and work models

Improving the match between labour supply and labour demand is a real challenge for Luxembourg – and has implications for education, immigration/cross-border relations, etc. A necessary precondition for moving from reactive towards proactive policymaking is a better understanding of the labour market structure including quantitative and qualitative aspects of labour market supply and demand. It might therefore be very promising to support research addressing how the following aspects influence the labour market and the economy: unemployment replacement rates, shrinking and ageing working population, retirement schemes, high proportion of immigrants and cross-border workers, hiring behaviour of the private and public sectors. Public research focused on these issues should aim at developing new or better incentives for work participation (i.e. new retirement schemes) and diversifying Luxembourg's economy while maintaining social cohesion, stability and security. New and/or more flexible work models – adapted to a "knowledge economy" and combined with life-long learning and work-life balancing – could play an important role here. It seems evident that the work models of the industrial society are in retreat while part time, multi-job and work of loan are on the rise. One of the pressing research issues is the relation of so-called "a-typical" work models[253] and social security (catchword *précariat*). Research that fosters the development of new work models and the diversification of the economy would also help to avoid "brain drain" and to attract high skills to Luxembourg.

Qualification issues

Nevertheless, work participation of people with low qualification levels remains a research issue. Ways have to be found to provide perspectives for the "working poor" (about 12.000 persons in Luxemburg). One may also add here that the European Commission has recently

[253] Whether these work models are "a-typical" or represent the new types of a knowledge and service economy still remains to be clarified.

recommended that employment participation, particularly by women and older people, should be improved as well as the investment in human resources especially in the young generation. Greater efforts should also be made to integrate young people into the labour market and to support them to cope with the special demands of flexible, "non-linear" careers that alternate between employment, study, unemployment, retraining or the updating of skills and new employment[254].

These efforts have to be based on research about preconditions for "smooth" and successful transitions from the education system (including adult training) to the labour market. Life-long learning is a necessity in an economy that, driven by R&D, constantly produces knowledge – and depreciates obsolete qualifications.[255] Without relinquishing humanistic ideals, the efficiency of the education system has to be assessed from an economic point of view. Determinants of educational achievement have to be identified, and performance measures of the education system have to be established.

With the advent of the knowledge society and new educational techniques like tele-learning / e-learning and ubiquitous access to information, the concepts of training and competence are changing. Formal certificates like school grades become less relevant for employers with respect to estimate the potential of an employee. It is crucial that Luxembourg provides itself with an adequate evaluation system of competences, adapted to the local context – taking into account that international standard methodologies are mainly adapted to the US labour market and will not provide adequate results in a Luxembourg context.

Luxembourg peculiarities and attractiveness of research

Luxembourg's labour market has many specific and intriguing features, which make this domain scientifically attractive for researchers. As a small economy with a large proportion of immigrants and cross-border workers in the working population, Luxembourg has a quite peculiar labour market. For this reason, research results stemming from other countries can not simply be "translated" for Luxembourg; there is a need for domestic research in this domain. From a scientific point of view, the economic literature lacks a theoretical framework and relevant methodologies to develop and carry out studies about the labour market of small-sized and very open economies. Advances concerning this topic will be useful for undertaking studies about Luxembourg's economy.[256] Public research should therefore aim at both adapting instruments and tools used abroad to the specificities of Luxembourg and developing new tools and concepts. One point in case is to extend the concepts and to enlarge the field of new surveys to some parts of the Greater Region. To put it in short: Cross-border labour markets need cross-border labour market research.

[254] See for instance: Commission of the European Communities (2005). Lisbon Action Plan incorporating EU Lisbon program and recommendations for actions to member states for inclusion in their national Lisbon programs. Retrieved from: http://ec.europa.eu/growthandjobs/pdf/SEC2005_192_en.pdf

[255] Ageing of the workforce is an additional reason to invest into life-long learning.

[256] However, it should be noted that because of the very peculiar Luxembourg labour market, Luxembourg-related research will probably only be of limited interest internationally. It might therefore be difficult to attract highly qualified researchers from abroad.

The size of Luxembourg brings with it relatively high expense for representative surveys compared to bigger countries and the small sample sizes can hamper the representative character of research where small statistical distortions might have a big influence on outcomes. Models and statistics used for bigger countries frequently cannot be applied to Luxembourg. Furthermore, the success of such research will depend on the availability and efficient exploitation of (longitudinal) data, from sources such as the "Administration de l'Emploi" (ADEM) or the "Inspection Générale de la Sécurité Sociale" (IGSS) and a well equipped and well managed database infrastructure (which has to be created).[257] Luxembourg data protection laws, however, prohibit the merger of datasets from different sources, so that in many cases data has to be collected several times by the various actors. This represents a severe handicap for research on the labour market and can jeopardise its success. The issue of data protection needs to be debated, bearing in mind the legal and ethical aspects associated with handling the datasets, in view of creating a research friendly environment.

Implementation issues

There are already established competences and public research activities on the labour market in Luxembourg (see criteria table, C7). Studies are carried out on the macro level (national economy level) as well as on the micro level. But there seems to be a need for more research on the micro level, addressing career trajectories ("transitional labour markets"). Basic knowledge has to be built up, e. g. information about trajectories of different categories of people (natives, immigrants, cross-border workers) who either move into or out of the labour market (or specific segments of it). These transitions entail usually some other changes: of place, of housing, of family relations, etc. Again, a big challenge consists in adjusting social security to these increasingly frequent transitions. Since it is uncertain how the general public perceives the necessity of changes in the social system and how it will react to them, some research has also to be performed on the social representations and expectations concerning the welfare state in Luxembourg.

But what Luxembourg really needs in this domain is not just more studies (there are plenty of very pertinent studies available), but long term, sustained lines of research. Beyond statutory or contracted studies, researchers should be in the position to engage in more fundamental questions, to go beyond applying existing methodologies and to consider longer time horizons. This would – last but not least – enable them to build scientific reputation and to obtain results that are relevant and internationally "visible". On the whole, more researchers are needed, from short term scholarships or visiting scientists to attracting excellent researchers from abroad with long-term contracts.

[257] Surveys, exchange of data, and running databases are typical fields for partnerships between public research and private organizations.

6.6 Identities, Diversity and Integration

As a complement to the other research domains put forward under the Foresight exercise, the domain *Identities, diversity, and integration*[258] responds to the need of the Luxembourg society to reflect upon itself in order to understand the current very important transitions of society.

In a multicultural and multilingual society, social cohesion depends to a large degree on the respectful manner of 'living together'. Research has to address the construction of identities, cultural diversity and the various aspects of social, political and work participation. This kind of research is by its nature interdisciplinary, capitalizing from many branches of social sciences and humanities – from psychology to empirical social research, from cultural studies to history, from linguistics to educational research.

"Identity",[259] the central notion, is a complex concept which has to be seen in its plural form (identities) and in a dynamic way, and by taking into account individual and national identities. Both are subject to the influence of external factors. At the one hand, education at school, the languages used in everyday life, the history of the country and the memories of the social group one belongs to, nationality or citizenship, intergenerational relations are all elements of an individual's identity. At the other hand, the national identity is shaped mainly by the Luxembourg and European history and the processes of European integration, the relationship to the neighbouring countries and the impact of globalisation.

Research on *identities, diversity, and integration* therefore has:

- to contribute to understanding the dynamics of change of the Luxembourg society under internal and external influences, and in particular in a context of immigration and migration flows,
- to empirically analyse the present state of society, in particular with respect to cultural identities, barriers for political, social and work participation, segregation trends in education, housing, etc.,
- to support policy making with data, conceptual clarifications, and recommendations.

[258] "Integration" as used here has to be associated with inclusiveness and participation – and to be distinguished from assimilation. Integration usually refers to the integration of people, territories and activities in order to allow smooth processes with low conflict levels and a long-term sustainable development of society, economy and ecology. Integration forms an active civil society and prevents social segregation or exclusion. – cf. Berger-Schmitt, R.: Social Cohesion as an Aspect of the Quality of Societies: Concept and Measurement. EuReporting Working Paper No. 14, Subproject "European System of Social Indicators". Mannheim: Centre for Survey Research and Methodology (ZUMA), Social Indicators Department, 2000.

[259] "Identity is an umbrella term used throughout the social sciences for an individual's comprehension of him or herself as a discrete, separate entity. This term, though generic, can be specified by the disciplines of psychology and sociology […] In sociology and political science, the notion of social identity is individuals' labelling of themselves as members of particular groups (i.e. nation, social class, subculture, ethnicity, gender, etc.). It is in this sense which sociologists and historians speak of a national identity of a particular country." - http://en.wikipedia.org/ For the methodological difficulties and political problems connected with collective forms of identity, see e. g. Lutz Niethammer: Kollektive Identität. Heimliche Quellen einer unheimlichen Konjunktur, Reinbek 2000.

Identities, immigration and cultural transmission

Research on identities and cultural transmissions is already being carried out to some extent in Luxembourg (see criteria table, C7). There is, however, little advanced research on the socio-cultural aspects of migration, despite the fact that immigration and transborder flows are an increasingly important characteristic of the Luxembourg society. It is quite certain that the demographic structure of the population will become even more diverse than today. In 2005, there were about 177.400 immigrant inhabitants as compared to 277.600 native Luxembourgers. Besides, the daily inflow of workforce from the neighbouring countries is constantly growing and constitutes more than a third of the total workforce (in 2004: 111.900 non resident borderers out of 301.600 domestic workforce).

Whereas research on national and regional identities is performed by many universities and institutes throughout Europe[260], research on a genuine multicultural and multilingual society might be rather unique and could thus contribute to Luxembourg's international reputation. Due to its trilingual population, Luxembourg might even be an adequate test bed for social studies with a specific European dimension. From the practical social and political point of view, research would also contribute to social cohesion and to the integration of immigrants in Luxembourg by promoting the understanding different population groups have of each other and by guiding social policies. Research focusing on the issues considered here can also build on the natural interest of the public in the culture and history of the country.

Language, identity, education

The second set of research issues is concerned with the benefits and challenges of a **multilingual** society. Since different languages might convey different views, the languages used and spoken are very closely related to the construction of identity. In general, language diversity is seen as important aspect of the cultural richness of a society, but at the same time it poses a lot of problems for integration and social cohesion.[261]

The Luxembourg system may be defined as a "federative multilingualism" which constitutes a socio-politically highly relevant and scientifically intriguing research topic. A positive public opinion concerning the trilingualism of Luxembourg exists. However, there seems to be a certain lack of political will to take advantage of the linguistic potential and to define a coherent language policy based on scientific evidence.

Specific research questions include: the impact of the knowledge of languages on the labour market, the relationship between success/failure at school and socio-economical and/or linguistic background,[262] the place of *Lëtzebuergesch*, French, German, English and Portuguese and Italian in society, and in the education system. The education system doesn't match the

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[260] A point in case is the programme "Identities and Social Action", a five year research programme funded by the UK Economic and Social Research Council and running until December 2008. It is a £4 million public investment in social scientific research on identities and identity issues. One of the projects supported is "Identities in transition: a longitudinal study of immigrant children." – cf. www.identities.org.uk. For more information, see also the criteria table, C9.

[261] See e. g. Guus Extra and Kutlay Yagmur: Language diversity in multicultural Europe, UNESCO, Management of Social Transformations MOST Discussion Paper 63, Paris 2002.

[262] The relations between an immigration background, educational level achieved and success on the labour market have been recently studied, cf. Jean Langers: Immigration et education, Statec, series "économie et statistiques 16", February 2007.

needs of the population anymore. Especially the needs of the immigrant, mostly Portuguese, are not taken into account. As the native language of 17% of the pupils in Luxembourg is Portuguese, it would be worth to consider how to take into account the specific needs of Portuguese pupils. It could also be enriching to include the literature and culture of Portuguese and other population groups to a certain extent in the curriculum of Luxembourg schools and draw on the presence of pupils of very different backgrounds.

In terms of more fundamental research, a specialisation in cognitive and brain processes for language acquisition may be an interesting alternative, for example by including researchers from the relatively new field of neurosciences in view of testing and developing efficient language teaching methods. A performing multilingual education system would be the best way to integrate foreign population groups and to ensure social cohesion. The current problem of Luxembourg's education system not being able to ensure social integration and cohesion, however, does not seem to stem from language problems only. The education system is very stratified at the moment and this contributes largely to amplify social inequalities. Luxembourg's results in the PISA survey underline the need for re-assessing and analysing the structure of the education system.

Research should also address *Lëtzebuergesch* as a language, and in particular as a foreign language. The need exists to develop reference books for *Lëtzebuergesch* and comparative grammars.

Last but not least the advantages of ICT and in particular multimedia applications should be exploited (see chapter 6.1.5). As a multilingual country, Luxembourg may be interested in offering multilingual ICT services and tools, e.g. language learning tools and multilingual information retrieval or translation tools. Automatic processing of both written and spoken *Lëtzebuergesch* documents can be an incentive to learn and practice *Lëtzebuergesch*, or at least to facilitate integration. ICT may contribute to promote *Lëtzebuergesch* as a living language. Opportunities for cooperation are given within FP7, where "ICT for content, creativity and personal development, in particular in the areas of media, technology-enhanced learning and accessibility of cultural and scientific resources in a multilingual and multicultural environment" are earmarked.[263]

Implementation issues

In order to govern social change processes, it is necessary to understand the dynamics of change and their impact on society. Social sciences and humanities have to provide decision makers with sound and comprehensive information about these processes and assess impacts of

[263] Cf. ftp://ftp.cordis.europa.eu/pub/fp7/docs/ec_fp7_amended_en.pdf. One point in case is the project SMART (Statistical Multilingual Analysis for Retrieval and Translation) – cf. www.smart-project.eu It should be noted that the EU has been supporting ICT research focused on languages already for a long period, e. g. "Language engineering" in FP4 and FP5, "Human language technologies" in FP6. The main objective of these programs was to promote machine translation between member state languages. Furthermore, multilingualism is promoted in FP7 through a variety of actions in the framework of education, training and research programmes, such as language learning programmes, research in linguistic diversity and human language technologies as well as digital content programmes.

political decisions. This includes systematic, long-term data collection, but also new ways of thinking ("*conceptualizing*") change.

A major objective of socio-cultural research is to improve governance. Policies (e.g. education, language, migration policies) should be based on sound scientific data and fundamental knowledge of reforms in other countries; they should be "evidence based" as opposed to "ideological" policies. Accompanying reforms by research (e.g. through an "observatory for educational reforms") is a necessity for successful "change management"[264] on the national level.

Databases free of an ideological bias are important prerequisites for the proposed lines of research. In addition to a better use of available databases, new ones have to be built up and to be managed in a professional way. Questions of data access and data protection, confidentiality etc. have to be settled. Apart from databases, well equipped and well managed archives and libraries are basic infrastructural requirements (see Annex A2). Private public partnerships could be useful to develop access and retrieval tools.

New axes of research cannot be established without groups of scientific collaborators with a long-term perspective, including appropriate career opportunities for younger researchers. It is therefore recommended that a small research institute should be build up with long-term basic funding. Such an institute may consider implementing a graduate school on the culture and society of Luxembourg to foster a productive, attractive and enjoyable environment for doctoral and post-doctoral students.

Concepts like "identity", "diversity", and "integration" are both concrete enough to allow for interesting and productive research and flexible enough to allow for interdisciplinary and transdisciplinary research and foster synergies. A research priority in this field could stimulate a broad range of social sciences and humanities. Last but not least, this domain – while focussing on issues like integration – will guarantee that research will give voice to and involve non-academics (ministries, NGOs) in a fruitful manner.

List of research issues in the domain Identities, Diversity and Integration[265]

Identities, immigration, cultural transmissions

- Luxembourg history(ies), language(s) and culture(s)
- Concepts and facets of identity and culture:
    - Identity and cultural self-consciousness
    - Dynamics and diversity of identities
    - Role of education and language in identity building
    - Identity in a small country, in the context of the Greater Region, Luxembourg/European identity
    - Family and individual identities in a multicultural society
- Migration flows towards or out of Luxembourg
    - Migration: the concept of 'living together' vs. 'integration'
    - Immigration and social cohesion
- Intergenerational relations
    - Transmission of values and memories

[264] The term change management is as a rule applied to business organizations. The experiences made there can be transferred to in the public sphere. Cf. Klaus Doppler / Christoph Lauterburg: Change Management. Frankfurt & New York 2005.

[265] Reorganized and abbreviated after the second workshop on Social Sciences and Humanities.

- Intergenerational solidarity
- Generations in family and society

Language, identity, education

- Federative multilingualism
  - Managing the heterogeneity of the population at school and in society
  - Language diversity and language policy: Which place and role for *Lëtzebuergesch*, French, German, English, Portuguese, Italian?
- Education
  - Multicultural didactics
  - Outcome oriented assessment tools for educational achievements
  - Testing educational reforms
  - ICT language teaching tools
  - ICT multilingual tools and ICT language services research
- Political participation and representation:
  - Political culture, citizenship
  - Influence of EU on the national policies
  - Decision structures (local, regional, national)

7. Assessment of the National Research Priorities

The 11 criteria presented in Chapter 2.4 allow for a systematic assessment of the research priorities identified in the FNR Foresight process. This chapter presents the results of the assessment of each priority along the 11 criteria defined in table form (The quantitative criteria are marked in red and the qualitative criteria in green). Each assessment is consolidated by a short justification. In the subchapters 7.7 and 7.8 a presentation of the cross-linkages between the priorities and a direct comparison of all priorities in a single table summarizing the individual results are given.

7.1 Innovation in Services

The following table summarizes the assessment of the umbrella priority "Innovation in Services" along the criteria presented in chapter 2.4. It should be noted that the assessment of this umbrella priority in the criteria table will *not include any additional information* not already given for one of the correspondent subdomains. **However, the criteria values for the "umbrella" notion can not be expected to be the exact sum (or average) of the individual criteria values obtained for each research subdomain.** Rather, the assessment of the "umbrella" notion "Innovation in Services" allows for adding weight to specific perspectives, emphasizing for instance some specific aspect within the broad domain "Innovation in Services" on which research should focus on, or for highlighting specific strengths or weaknesses.

Criteria		**Assessment**	**Justification**
Socio-economic	C1. Environment	No impact	There is practically no direct or indirect impact of research in this domain on environmental aspects.

contribution	C2. Economy	High	The service sector (commerce, financial services, property and business services, but also tourist services, public services, education, etc.) is already Luxembourg's most important economic sector. Since the weight of this sector will further increase with the transition to a knowledge economy, it is crucial for Luxembourg's long-term economic sustainability to have a thriving and internationally competitive service sector. It is furthermore of highest importance for Luxembourg, on the one hand, to consolidate the competitiveness of its most important economic sector, the financial sector, and on the other hand, to strengthen the innovation capacity in all sectors in order to diversify the economy and to minimize the risks associated with a strong dependency of the economy on the finance sector. Public research on Innovation in Services – combining economic/organizational, legal and technical aspects (see the sub-priorities) – makes an indispensable contribution to these aims. As central pieces, fostering innovation in financial and business services as well as in ICT services (and infrastructure) has favourable repercussions on almost all sectors from tourism and transportation to multimedia and broadcasting. It contributes to provide an adequate legal, administrative and infrastructural environment for the creation of new fields of growth / new competence niches, to maintain competitiveness at high level of salaries and to curb the vulnerability to economic fluctuations.
	C3. Society	High	Since Luxembourg's economy - and therefore indirectly Luxembourg's high standard of living - is largely based on the service sector and this dependence is even expected to rise in the future and since employment in services (including financial services, education, health care services, social services, public administration, as well as commerce, hotel industry, catering industry, transport, communications and real estate industry[266]) accounts for about 75 % of total employment in Luxembourg, it is clearly of high societal importance to further consolidate the (international) competitiveness of the service sector. Therefore public research focusing on innovation in services with the aim to safeguard employment in the service sector and to further the creation of new jobs - this is especially important in view of the rising unemployment rate in Luxembourg - will have a very high social impact. However, as the education level required for these jobs is probably generally too high for the large majority of unemployed in Luxembourg, Priority 2.4 (Labour market, educational requirement and social protection) is important to tackle this problem.
C4. Accordance with the political agenda in Luxembourg		High	This umbrella priority is in line with the government's programme presented in August 2004 and the objectives of the National Plan for Innovation and Full Employment, set up in 2006. For more information, see 2.1.1 through 2.1.5.
Feasibility	C5. Public and political acceptance	Favourable	Public acceptance for research on Innovation in services is high as the service sector represents 75 % of total employment in Luxembourg and accounts for more than 80 % of the total value added. There are no legal hurdles or ethical concerns.
	C6. Private sector activities in Luxembourg	High	As the service sector is the predominant pillar of Luxembourg's economy, it is the domain with the strongest potential for private R&D activities. For details see 2.1.1 through 2.1.5

[266] For more information, see "Le Luxembourg en chiffres 2006 », STATEC.

<table>
<tr><td rowspan="2"></td><td>C7. Public research capacity in Luxembourg</td><td>High</td><td>High level of public research activities in Business Service Design and Innovation, Information Security and Trust Management and Telecommunications and Multimedia;
Low level of public research activities regarding “Fostering the Economic and Legal Environment for Innovation” and “Performance and Development of Financial Systems”.</td></tr>
<tr><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 245 (sum of researchers from sub-priorities)</td></tr><tr><td>Infrastructure and Equipment</td><td>IT equipment, Technology Platform for Modelling and Simulation</td></tr></table>
The figure given above can be compared to the total staff of internationally renowned institutes. As an example, EDHEC has about 100 researchers and an annual research budget of 7.5 M€ (whereof 2.7 M€ stem from the private sector). This would cover the legal and purely business research side of the priority. For the IT related side, see sub-priorities 2.1.1, 2.1.4 and 2.1.5.
Given the already existing research infrastructure, critical mass can be built up within the next decade.</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">Given the importance of the services sector in all Western countries, as well as its importance for achieving a Knowledge and Information Society, the high amount of public research activities at international level related to all aspects of “Innovation in Services” is not surprising. Research in this priority domain, including infrastructural, economic and legal aspects, is highly competitive and will be also funded to a large extent within the 7th EU Framework Programme. Depending of which specific aspect is considered, there might be opportunities for Luxembourg researchers to collaborate with other research institutions within the Greater Region. For more information, see 2.1.1 through 2.1.5.</td></tr>
<tr><td colspan="2">C10. Contribution to national competences, scientific excellence and international reputation</td><td>High</td><td>The strong service sector of Luxembourg’s economy provides the opportunity and creates the necessity to build up research capacity in this domain. Internationally recognized scientific excellence will support Luxembourg’s reputation on the international financial market. In some sub-domains there are already promising public research activities to build upon. Luxembourg must increase its domestic research capacities in this domain to improve its innovation potential. It is also in Luxembourg’s interest to develop educational capacities in this domain and to strengthen competences for the future knowledge society.</td></tr>
<tr><td colspan="2">C11. Cross-linkages with other Priorities identified</td><td colspan="2">Justification</td></tr>
</table>

C11. Cross-linkages with other Priorities identified	Labour Market, Educational requirements and Social Protection	Since employment in services accounts for about 75 % of total employment in Luxembourg, there will clearly be some overlaps between research related to "Innovation in services" and research related to "Labour Market, Educational requirements and social protection". In particular, the trend towards knowledge-based and information intensive services has had an influence on the educational requirements, qualifications and skills needed in the labour market. For instance, specific issues regarding to life-long learning and specific work skills required in the information society should therefore be addressed in multidisciplinary research projects.
	Public and Environmental Health	Research focusing on new innovative health-related services, and especially on e-Health services (telemedicine, etc.) is deemed as very promising at the European level in order to improve the efficacy of Public Health policies and should therefore be addressed jointly with public health researchers.

7.1.1 Business Service Design and Innovation

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.
	C2. Economy	High	Luxembourg is facing the double challenge to restructure its economy from industry to services and to foster diversification. Public research in service sciences and in particular in Business Service Design and Innovation can make an important contribution to this goal; it may even be regarded as highly relevant for long-term economic sustainability. Research in Business Service Design and Innovation facilitates the development of new, innovative and high value-added (e-)services. Improving the service industry's operations, performance, and innovativeness contributes to increasing the international competitiveness of Luxembourg's growing business services sector; exceptionally efficient and easy-to-use interfaces between businesses, financial institutions and government could also help attracting businesses to Luxembourg. Given the structure of Luxembourg's economy, research should primarily answer the needs of the business and financial sector and address business model innovation, business process efficiency and business service regulation compliance.

	C3. Society	Medium	Research in the domain "Business Service Design and Innovation" is relevant to society as it contributes to build the Information and Knowledge society and to achieve the Lisbon goals; developments in this domain will bring deep changes in our way of working and living. In particular, progress in this area will lead to the development of a broad range of (new) e-services (e-health, e-government, e-business, etc.) in all aspects of social life. Since Luxembourg's economy - and therefore indirectly Luxembourg's high standard of living - is largely based on the service sector and this dependence is even expected to rise in the future, it is clearly of societal importance to further consolidate the (international) competitiveness of the service sector. The sector of business services in particular is a growing sector employing approximately 13% of total employment in the Luxembourg economy and therefore public research focusing at the improvement of business services - especially in a increasingly competitive context - and aiming at safeguarding employment in the business service sector and furthering the creation of new jobs will have a high indirect social impact - especially against the background of the rising unemployment rate in Luxembourg.
C4. Accordance with the political agenda in Luxembourg		High	This research priority is in line with the objectives of the "eLuxembourg" Action Plan, the National Plan for Innovation and Full Employment (2006) and the government's programme presented in August 2004, aiming at furthering the development of e-services in the public sector (e-government, e-voting, e-learning, etc.) as well as in the private sector.
Feasibility	C5. Public and political acceptance	Favourable	Public acceptance for research related to - and needed for - the alignment with the regulatory framework is high as economic prospects in this domain are of main concern for the public. The same goes for research on the interconnectivity and interoperability of information systems, esp. as E-Government and E-voting become more and more appealing to citizens. There are no legal hurdles or ethical concerns to research in the field; rather, the aim of this domain is to improve the legal environment e. g. in the design of E-Government or E-Trade systems.
	C6. Private sector activities in Luxembourg	High	There are several large companies (Siemens and P&T Luxembourg (e-Business & Resilience Centre), Imprimerie Centrale SA) and several SMEs (e.g. AS Mobile International - R&D, CETREL, GAX Technologies, MUM S.A., Primesphere, Secaron) and LuxTrust SA with competences in the domain of e-commerce. Research on services science is also of particular interest for the strong financial sector in Luxembourg, as the quality or performance of client services and product innovation are seen as the most important challenges by Luxembourg's banks (Source: PricewaterhouseCoopers: Luxembourg Banking Market Challenges and Opportunities Survey 2006).

	C7. Public research capacity in Luxembourg	High	There are large research activities in the domain at the University and at the two CRPs Tudor and Lippmann (more than 100 R&D engineers active on the experimental side and according to a recent survey[267] there are about 84 FTE researchers involved in research in this domain at the two CRPs), addressing e-services in the public sector (interoperability standards), e-business and knowledge management, the quality and certification of e-services, e-government and e-learning. The multi-annual FNR programme SE-COM, running from 2000 to 2008 and with a total budget of 7,500,000 EUR, is also related to Security and efficiency of new practices in e-commerce for all socio-economic actors. Moreover several projects recently started developing new services in the financial domain and in supply chain in cooperation with actors from the public sector. With LuxTrust, Luxembourg has gained some experience in developing a Public Key Infrastructure for e-commerce and e-government applications.

[267] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current public research capacities in Luxembourg.

C8. Infrastructure / Critical Mass

Critical mass (researchers)	About 40
Infrastructure and Equipment	IT equipment

Business service design (IT related service science) is in itself a broad field and research tasks are rather freely scalable. The figures below indicate a lower limit. Specific research teams for service science e. g. related to the health sector could be added if necessary.
The main tasks are:

- Creating a hub / reference point at a public research institution. Following the example of the Institute for Information and Market Engineering at Karlsruhe University (http://www.wirtschaftsinformatik.uni-frankfurt.de), which would imply: at least 1 internationally renowned professor as head, about 10 researchers, about 6 personnel (secretariat/technicians).
- Additional and in combination to that: Clearing house functionality for information exchange in various sectors (e.g. health services for cross-border workers, clearing house between national standards) to make it easy to create, share and use knowledge in business, scientific and societal applications, including a technical platform for exchange (interoperability and interconnectivity of information): about 10 researchers, 5 technicians.

With already existing research at UL, CRP-HT and CRP-GL, critical mass can be achieved in particular in collaboration on a multidisciplinary level, incl. public-private partnerships.

C9. International research context

The research priority "Business Service Design and Innovation" is in line with FP7 and priorities set abroad:

- The topic of Service and Software Architecture, infrastructures and engineering was one of the main topics of the first call for projects in the ICT specific programme of FP7 (Planned budget: 120 M€) [Sources: European Commission, ICT in FP7 At A Glance, 2006[268];EC, Information and Communication Technologies, Work Programme 2007-2008[269]].
- In the "Socio-economic sciences & the humanities (SSH)", FP7 will support research projects related to the implications of developments in the service economy for the European economy and society (SSH-2007-1.2.2) – including interactions between the dissemination of knowledge, service innovation, technical, organisational change and other factors in generating productivity growth and performance in the public and private sectors. Different categories of services can be covered, including knowledge-intensive services, business services, etc.
- According to its High-Tech Strategy for Germany, the German government aims to duplicate throughout the individual service sectors the same level of high quality in innovation management that Germany has already achieved in the manufacturing sector. It is working to improve both investment and development conditions for new types of services arising from the increased interplay between service advances and technological advances. [Source: The High-Tech Strategy for Germany, Federal Ministry of Education

[268] http://ec.europa.eu/information_society/research/documents/fp7-ict-4poverview.pdf
[269] ftp://ftp.cordis.lu/pub/fp7/ict/docs/ict-wp-2007-08_en.pdf

	and Research, 2006] "Service Science", seen in the FNR process as important to support the development and improvement of services in Luxembourg, is a quite new research discipline. The international Service Research and Innovation Initiative (SRII), regrouping top research institutions and business companies in the domain of services, was set up very recently, on 29 March 2007, with the objective of increasing the amount of funding for service research, development and innovation in the technology industry[270]. A number of scientific labs (like the US's Massachusetts Institute of Technology and University of California, Berkeley, Switzerland's École Polytechnique Fédérale de Lausanne; Italy's Bocconi School of Management; and the UK's University of Manchester) have already started their positioning but there are still opportunities in service science for Luxembourg to develop competences and gain critical mass at an international level. Within the Greater Region, there might be opportunities for researchers in this domain to collaborate with the Competence Center E-Business (CEB) of the University of Trier and the University of Applied Sciences in Trier.	
C10. Contribution to national competences, scientific excellence and international reputation	High	Service science is a relatively new field of science. Regarding the strong service sector in Luxembourg, there is an opportunity to increase scientific reputation in this domain by fostering innovation for the service and especially financial sector by establishing multidisciplinary projects with private partners and by developing a university course/degree on service science. Luxembourg should aim at becoming a hub/reference point for service science.

C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities identified	Fostering the economic and legal environment for innovation	Research aiming at fostering the economic and legal environment for innovation should contribute to supporting the development of new business (e-)services and other e-services. In particular, issues related to the regulatory framework for e-services – especially in the context of the European harmonisation -, the certification of e-services and the funding mechanisms and financing of new (e-)services firms are deemed as very promising.
	Performance and Development of Financial Systems	Research in Business Service Design and Innovation cover applications in the financial sector, for instance e-banking applications, and therefore specific synergies between research in "Business Service Design and Innovation" and research related to the "Performance and Development of Financial Systems" should obviously be exploited.
	Information Security and Trust Management	Some important research questions related to (new) business e-services deal with IT security topics and hence strong ties with the research priority Information security and trust management will arise.

270 The founding Service Research and Innovation Initiative members have formed an advisory board whose members include Accenture, Cisco, CSC, EMC, HP, Microsoft and Xerox. Academic participants include top researchers from UCLA, Cranfield School of Management, Wharton School of Business, Arizona State University, University of Maryland and University of California Silicon Valley Center at Santa Cruz. Government and research institutions include the European Commission and the Fraunhofer Institute in Germany. Fore more information, see: http://www.thesri.org/news.asp?current=three&sub=none

	Telecommunications and Multimedia	Some research questions related to (new) business e-services deal with seamless service architecture and IT architecture in general. There are therefore obvious links between the 2 priorities "Telecommunications and Multimedia" and "Business Service Design and Innovation". The specific aspect of business services related to real-time logistics is also of tremendous importance to crisis management infrastructures covered by the domain "Telecommunications and Multimedia".
	Identities, Diversity and Integration	Some aspects of research in "Business Service Design and Innovation" leading to e-Health, e-administration, e-government or e-voting applications are clearly linked to research related to social inclusion and political participation.
	Labour Market, Educational requirements and Social Protection	Applications of research in "Business Service Design and Innovation" leading to new e-learning tools and services, adapted to the requirements of a new knowledge economy, are of course, strongly linked to the priority "Labour Market, Educational requirements and Social Protection".
	Public Health, including aspects of Environmental Health	As research in "Business Service Design and Innovation" also covers e-Health applications - seen as very promising for future Public Health policies and actions, there will obviously be some overlaps between research in "Business Service Design and Innovation" and Public Health research.

7.1.2 Fostering the Economic and Legal Environment for Innovation

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	Low	Research in this domain should have a positive effect on the innovation potential of companies (especially SMEs) in all branches, including the environmental and resource management sector. It might also lead to the development of new products and processes with improved properties regarding sustainability and possible environmental impacts.
	C2. Economy	High	Despite its good general economic performance, Luxembourg performs less well in important innovation indicators, partly due to a lack in R&D, and partly due to obstacles and disadvantages in the economic and legal environment for innovation. Public research aiming at identifying these obstacles and at improving Luxembourg's innovation capacity in both small and medium-sized enterprises and large companies can decisively contribute to increasing Luxembourg's long-term competitiveness. Determining the right balance between European harmonisation and intergovernmental competition (esp. regarding investment fund law, contract law, company and commercial laws) can help to consolidate Luxembourg's existing legislative advantages, to address current legal constraints or to create new sovereignty niches, as well as to modernise Luxembourg's legislation. As a consequence, it contributes to diversifying the economy, to transforming Luxembourg from an economy primarily based on the financial market to a knowledge economy, to attracting more companies to Luxembourg and to creating new ones. It also fosters a culture of entrepreneurship and therefore job creation - especially important in view of the rising unemployment rate in Luxembourg.

	C3. Society	Medium	Public research in this domain will contribute to increase Luxembourg's competitiveness, diversify the economy and hence minimize the risks associated with Luxembourg's specialization in financial services. Therefore, research will indirectly contribute to maintain Luxembourg's high standard of living and have a high - albeit partly indirect - impact on society. Furthermore, fostering a culture of entrepreneurship will have a direct and high impact on job creation - especially important in view of the rising unemployment rate in Luxembourg.
C4. Accordance with the political agenda in Luxembourg		High	This research priority is in line with Luxembourg's (research and) innovation policy aiming at facilitating innovation in all its forms and in particular at creating a more competitive business environment and encouraging private initiative and entrepreneurship (example for action: Education and Training for Entrepreneurial Spirit in Companies) by improving regulations (better legislation and regulation); ensuring open and competitive markets inside and outside Europe and reaping the rewards of globalization; strengthening innovation in SME- as highlighted in the National Plan for Innovation and Full Employment issued in 2006.
Feasibility	C5. Public and political acceptance	Favourable	With innovation being the key to growth, research on improving the economic and legal environment for innovation is of high public interest. There are no legal constraints to this research; rather the research domain itself deals with the legal regulations of e.g. EU harmonisation, cross border commerce of services etc. that may foster or limit innovation capacity.
	C6. Private sector activities in Luxembourg	High	There is a very strong interest of the strong financial sector and all other sectors in this research domain. Luxembourg's banks regard the innovation of products and services as one of the key challenges for the future and see the dialogue and collaboration between private and public research as an important measure to address this challenge (Source: PricewaterhouseCoopers: Luxembourg Banking Market Challenges and Opportunities Survey 2006). (Potential) actors are R&D and legal divisions of banks and other service providers, consulting companies (e.g. PricewaterhouseCoopers, Siemens IT Solutions and Services), and institutions like the Association Luxembourgeoise des Juristes de Banque (ALJB), the Association Européenne de Droit Bancaire et Financier (AEDBF), the Association des Banques et Banquiers, Luxembourg (ABBL), the Luxembourg Bar Association, or the Chambre de Commerce.

<table>
<tr><td></td><td>C7. Public research capacity in Luxembourg</td><td>Medium</td><td>Research competencies in law are quite limited for the moment – the University with its two research centres « Centre de Droit Européen » and « Laboratoire de Droit Économique » focusing on the impact of EU law on Luxembourg economy and listing “European Law and Business Law” among its seven top priorities for 2006-2009 in its 4 year plan, is the only important actor in public research on law – and Luxembourg doesn’t dispose of a critical mass for internationally recognised research; yet, existing international research networks may help to increase reputation and capacities. Furthermore, some studies on entrepreneurship have been launched by STATEC. Also research activities at the CEPS/INSTEAD (about 4 FTE researchers involved in this domain according to a recent survey[271]) and the CITI (Centre d’innovation par les Techniques de l’Information) at the CRP Tudor (10 FTE researchers involved in this domain) are a good basis to build upon.</td></tr>
<tr><td></td><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 25</td></tr><tr><td>Infrastructure and Equipment</td><td>No large infrastructure demands</td></tr></table>
There are already two research centres at the university (« Centre de Droit Européen » and « Laboratoire de Droit Économique ») whose capacities are to be increased. Workshop participants indicated that about 25 additional researchers in the existing groups would give the necessary momentum. For comparison: The Research Unit for Economic Law at the K. U. Leuven (www.kuleuven.be/kuleuven/kul_en.html) has a senior academic staff of 19 researchers. Another example is the Law Research Unit of Leeds Business School (www.leedsmet.ac.uk/lbs/lawru/index.htm).</td></tr>
</table>

[271] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT;
Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

C9. International research context	This research domain is in line with the objectives of the European 7th Framework Programme. The Commission's proposals for the FP7 Capacities programme[272], with a budget of EUR 4 097 million, aim to enhance research and innovation capacities throughout Europe. In particular, the area "Research for the benefit of SMEs" aims to strengthen the 'innovation capacity' of small and medium-sized enterprises (SMEs) in Europe and their contribution to the development of new technology based products and markets. Within the FP7 Cooperation programme, emphasis will be given to innovation, competitiveness and labour market policies within the area "Growth, employment and competitiveness in a knowledge society" (Socio-economic sciences & the humanities). In particular, research focusing on the ways in which the relative sizes, structures and economic and social contributions of services are affected by regulatory and institutional frameworks will be funded (SSH-2007-1.2.2). [Sources: http://cordis.europa.eu/fp7/capacities/home_en.html; http://cordis.europa.eu/fp7/cooperation/socio-economic_en.html] The new measure announced recently by the Minister of the Economy and Foreign Trade, in order to incite companies to submit projects proposals within the framework of FP6/7, ESA or EUREKA, by guaranteed - under conditions - partial reimbursement of the costs linked to the preparation of the proposal, may be an opportunity to associate Luxembourg private firms to European public research. Future research in this domain can build on existing research networks including foreign research institutions in Paris, Strasbourg, Geneva, Gand and Namur. Additionally, within the Greater Region, there might be opportunities for researchers in this domain to collaborate with the "Institut Droit et Économie des Dynamiques en Europe" of the University of Metz, the "Bureau d'Economie Théorique et Appliquée" of the University of Strasbourg and the "Centre de recherches Informatique et Droit" of the University of Namur.	
C10. Contribution to national competences, scientific excellence and international reputation	Medium	Providing a positive economic and legal environment for innovation is a very competitive domain, since European harmonisation, impact of globalisation, regulatory competition, and the Lisbon Strategy are of highest concern for all EU member states. So far, Luxembourg performs below EU average in innovation and its formal innovation policy is still very young. Luxembourg needs to build up competences in this field in order to improve its innovation performance, but it will be hard to reach international visibility here. The extension of existing collaborations with reputable international partners is seen as the most promising way to improve the situation especially in the law sector. The fact that Luxembourg is close to EU law and institutions as well as the small size of the country allowing for an efficient communication between all actors concerned might be a chance to increase Luxembourg's capacity in this domain.
C11. Cross-linkages with other Priorities identified	Justification	

[272] The Capacities programme will operate in six broad areas: Research infrastructures; Research for the benefit of SMEs; Regions of knowledge and support for regional research-driven clusters; Research potential of Convergence Regions; Science in society; Support to the coherent development of research policies; International cooperation. [Source: http://cordis.europa.eu/fp7/capacities/home_en.html]

C11. Cross-linkages with other Priorities identified	Business Service Design and Innovation	Research aiming at fostering the economic and legal environment for innovation should contribute to supporting the development of new business (e-)services and other e-services. In particular, issues related to the regulatory framework for e-services – especially in the context of the European harmonisation -, the certification of e-services and the funding mechanisms and financing of new (e-)services firms are deemed as very promising. The establishment of new e-commerce businesses for example does not only require technological solutions and access to venture capital, but also an elaborate legal framework as well as logistic infrastructure, not to mention a well-educated workforce.
	Performance and Development of Financial Systems	There are strong overlaps between the two priorities "Fostering the legal and economic framework for innovation" and "Performance and Development of Financial Systems" regarding the following research issues: - the consolidation of Luxembourg's regulatory advantages in the financial sector – Determination of the right balance between European competition and intergovernmental competition in the financial sector is essential – especially regarding investment fund laws.
	Information Security and Trust Management	As the availability of ICT tools and applications in general and of ICT security tools in particular are important enablers for innovation in economy, finance and in the services sector as a whole, there are strong overlaps between the two priorities "Fostering the economic and legal framework for Innovation" and "Information Security and Trust Management" – for instance regarding issues like identity management and privacy and Intellectual Property Rights.
	Telecommunications and Multimedia	Research aiming at "Fostering the economic and legal framework for innovation" should take aspects related to the ICT and Telecommunications infrastructure into account.
	Labour Market, Educational requirements and Social Protection	Research aiming at "Fostering the economic and legal framework for innovation" should take aspects related to education, work qualifications, ageing workforce (how innovative will an ageing workforce be?), etc. into account.
	Biomedical Sciences	Research aiming at "Fostering the economic and legal environment for innovation" should take ethical and legal aspects of biomedical research into account, especially the commercialization of research results, and contribute to overcoming current legal hurdles in order to avoid potential failure in developing a future competitive biotechnological industry in Luxembourg due to the lack of an adequate legal framework.
	Regenerative Medicine in Age-related Diseases	Regenerative medicine and tissue engineering research offer the potential for laying the ground for a flourishing biomedical industry in Luxembourg, providing the right and adequate legal framework can be developed in Luxembourg. Research aiming at "Fostering the economic and legal environment for innovation" should therefore take ethical and legal aspects of research in regenerative medicine and especially of the commercialization of research results *explicitly* into account and contribute to overcoming current legal hurdles in order to avoid potential failure in developing a future competitive biotechnological industry in Luxembourg due to the lack of an adequate legal framework.
	Translational Biomedical Research	Given the right legal framework, translational research may promote biomedical spin-offs capitalizing on patents derived from research results and therefore help laying the ground for a new biomedical industry in Luxembourg. Hence, given this important economic potential of translational research, research aiming at "Fostering the economic and legal environment for innovation" should take the requirements of translational research - regarding patenting, commercializing or research results, etc. - *explicitly* into account and contribute to overcoming current legal hurdles.

7.1.3 Performance and Development of Financial Systems

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.
	C2. Economy	High	Since the financial sector has a predominant role in Luxembourg's economy, public finance research, focusing not only on the macro-economic financial system but also on developing and improving performance *of all financial subsystems* from the investment fund industry to private banking is of highest economic relevance. It is mostly through private public partnership, that research could help the banking industry to address the most important challenges and opportunities: the quality of services provided, the development of new high added value products and services and the managing of distribution channels – but also the optimisation of revenue generation, recruitment, and regulatory compliance. Given the fact that Luxembourg's financial sector is largely an export sector, research related to Performance and Development of Financial Systems is of high importance to maintain the international competitive position of Luxembourg as financial market place and in order to minimize the risks associated with the dependency on the financial sector. This is also in line with a strategy of ensuring the long-term sustainability of the whole economy, as the financial sector has an important "multiplier" effect on the rest of the economy.
	C3. Society	High	The financial sector is the *heart of the Luxembourg economy* and the outstanding performance of the financial services contributed mostly to Luxembourg high economic growth during the last two decades - and therefore to Luxembourg's high standard of living. Furthermore, the financial sector has an important "multiplier" effect on the rest of the economy, obviously nurturing highly skilled professions like lawyers, accountants or engineers but also such sectors as hotels, catering, air transport, business services (consulting, advertising, cleaning, security), law services, and IT services. Also sectors like civil engineering and construction sector have benefited enormously in the past, and will probably continue to benefit in the future from the healthy general economic situation - meaning that today, many jobs, including less-qualified jobs depend on the good performance of the financial sector as one of the main drivers of the Luxembourg economy. Research aiming at consolidating and improving the performance of the financial system will therefore have a high direct and indirect impact on society.
C4. Accordance with the political agenda in Luxembourg		High	Because of the prominent role of the financial system in the Luxembourg economy, this research is obviously in accordance with the policy objectives - as set in the National Plan for Innovation and Full Employment (2005) of ensuring long-term sustainability and competitiveness of the economy.

Feasibility	C5. Public and political acceptance	Favourable	Luxembourg's economy is highly dependent on the performance of the financial sector. Also, retirement planning and financing is one of the key societal challenges in most western European countries including Luxembourg. Public acceptance of research on the development and future sustainability of the Luxembourg financial sector is therefore of high interest. There are no legal hurdles or ethical concerns in conducting research on financial systems. It is possible that the difficult question to separate research for public interest from research for private interest of the industry may pose minor problems in public perception.
	C6. Private sector activities in Luxembourg	High	There is a general strong interest of the financial sector in this research domain and there are research activities by the numerous banks on financial issues such as portfolio management, risk management, retirement planning and financing etc. Major banks in Luxembourg have stated their interest in joint projects with public research partners (Source: PricewaterhouseCoopers: Luxembourg Banking Market Challenges and Opportunities Survey 2006). Other partners for PPPs could be consulting firms (e.g. PricewaterhouseCoopers, Aubay) and SMEs in the sector of data processing.
	C7. Public research capacity in Luxembourg	Low	Luxembourg's research resources in the financial domain are still very scarce, despite some activities at The Luxembourg School of Finance (research focusing on Finance and Institutions, Quantitative Finance, Risk Management and Financial Governance and Behavioral finance at the Center of Research in Finance), at the Faculty of Economy and Law of the University of Luxembourg, at the Central Bank of Luxembourg and at the CITI - Centre d'Innovation par les Technologies de l'Information - CRP Tudor (according to a recent survey[273], 15 FTE researchers involved in research in this domain). However, recently, - and as a consequence of the dialogue platform provided by the FNR Foresight exercise - a platform for dialogue between research actors and private actors (users) on common (future) research needs has been set up between the University of Luxembourg and Pricewaterhouse & Coopers. In the future, the LSF will rely on a privileged partnership with the "Luxembourg School of Finance Foundation", a public private partnership with the financial centre of Luxembourg.

[273] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT;
Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

<table>
<tr>
<td></td>
<td>C8. Infrastructure / Critical Mass</td>
<td colspan="2">
<table>
<tr><td>Critical mass (researchers)</td><td>About 40</td></tr>
<tr><td>Infrastructure and Equipment</td><td>No large infrastructure demands, but some modelling and simulation</td></tr>
</table>
Current competences, in particular at the UL's Faculty of Law, Economy and Finance and the Luxembourg School of Finance are a good basis for expansion. Several interdisciplinary groups of about 5 to 10 researchers (combined with good quality PhD programmes) are needed to cover the research domains identified, starting with perhaps two or three focused groups in close international cooperation and with the support of the private sector (public private partnership in particular through the Luxembourg School of Finance Foundation). International models can be taken from the Manchester Business School (www.mbs.ac.uk), the London Business School (www.london.edu) or the Open University Business School (www7.open.ac.uk/research/oubs/default.asp) in the UK, the INSEAD (www.insead.com) or the EDHEC Business Schools (www.edhec.com) in France. Naturally, all of these cover much more ground than this priority. At London Business School, about 40 professors belong to the faculty of finance. Individual topics can be treated by smaller teams of 5 researchers. (This is e. g. the size of the highly specialized Centre for the Analysis of Investment Risks at the Manchester Accounting and Finance Group, part of Manchester Business School - http://www.mbs.ac.uk/research/analysisinvestment/our-team.aspx.).
</td>
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<tr>
<td colspan="2">C9. International research context</td>
<td colspan="2">There are many international research institutions in this domain, like the Manchester Business School and the London Business School in the UK, the INSEAD and the EDHEC Business Schools in France or the Swiss Finance Institute - to name but a few.
The 7th EU Framework Programme will fund research projects dealing with the "role of finance in growth, employment and competitiveness in Europe" (SSH-2007-1.2.3) and addressing the changing relations introduced by the world of finance at all economic levels (financial markets, innovations in financial services and products, socially responsible investment, internationalisation of banking and insurance). In particular, the following issues will be addressed: supply and demand on financial markets, including changing savings patterns of households, innovations in financial services and products, socially responsible investment, capital mobility, the integration of capital markets, and internationalisation of banking and insurance activities. Research issues should include relations of finance with the real economy, such as on the financing of start-up businesses as well as the growth and expansion of established enterprises, taking into account the role of banks and insurance activities, stock markets, investment funds and venture capital, other financial sector investments and speculative investment, including the impact on the behaviour of companies and their time horizons.
[Source: http://cordis.europa.eu/fp7/cooperation/socio-economic_en.html]
Within the Greater Region, there might be opportunities for researchers to collaborate in this domain with the "Groupe de Recherche en Économie Financière et Gestion des Entreprises" of the Universities of Metz/Nancy.</td>
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<tr>
<td colspan="2">C10. Contribution to national competences, scientific excellence and international reputation</td>
<td>Medium</td>
<td>This domain encompasses research issues that address concrete needs of Luxembourg for which Luxembourg has to develop and maintain its own capacities and, on the other hand, research with international scope which is very competitive with strong public and private players in the neighbouring countries. Luxembourg can improve its scientific reputation in this domain by focussing on specific aspects of development and improving performance of financial systems and by</td>
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</table>

		triggering the dialogue and collaboration between public research and the strong private financial sector. Building a high quality master and PhD programme around the most relevant research issues of this domain is also seen as a useful instrument.
C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities identified	Business Service Design and Innovation	Research in Business Service Design and Innovation cover applications in the financial sector, for instance e-banking applications, and therefore specific synergies between research in "Business Service Design and Innovation" and research related to the "Performance and Development of Financial Systems" should obviously be exploited.
	Fostering the economic and legal environment for innovation	There are strong overlaps between the two priorities "Fostering the legal and economic framework for innovation" and "Performance and Development of Financial Systems" regarding the following research issues: - the consolidation of Luxembourg's regulatory advantages in the financial sector – Determination of the right balance between European competition and intergovernmental competition in the financial sector is essential – (in areas like banking security, company law, retirement funds but especially investment fund laws). Research related to these issues will help to provide the right framework for improving the performance of the financial system.
	Information Security and Trust Management	As information security and trust management are a sine qua non for all financial applications, there are obvious linkages between research in "Performance and Development of Financial Systems" and research in "Information Security and Trust Management".
	Labour Market, Educational requirements and Social Protection	There are links between some research topics in "Performance and Development of Financial Systems" related to retirement funds and retirement planning or financial education and corresponding issues in the domain "Labour Market, Educational requirements and Social Protection".
	Technology Platform Modelling and Simulation	Quantitive methods (Financial Mathematics) are clearly important enablers for this research priority. Therefore research in "Performance and Development of Financial Systems" will benefit from setting up large modelling and simulation facilities.

7.1.4 Information Security and Trust Management

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.
	C2. Economy	High	Research in Information Security and Trust Management, focusing on the needs of Luxembourg as an export-oriented market place, is of high relevance as an enabler of the service industry and in order to consolidate Luxembourg's reputation as a safe harbour for information. Luxembourg can thus build on and strengthen an existing competitive advantage. Information Security and Trust Management is a "transversal" research domain of crucial and still growing importance not only for the banking industry, but for rather all ICT applications and e-services like e.g. security and privacy in e-commerce, privacy and trust in e-health and e-administration applications, identity management and digital rights management for the media / content / broadcasting industry, ICT security applications and risk management in critical infrastructures, etc. Public research in security and trust will in particular be beneficial for small and medium sized enterprises, as information security and trust are enablers for many business activities, drivers for innovation and the creation of new niches. Luxembourg as a safe harbour for information of all kinds would also attract new businesses and foster the development of an economy based on services and finance.
	C3. Society	Medium	Research in this domain will have a high indirect impact on society and employment as it will contribute to improve the efficiency and competitiveness of nearly all IT activities - the most dynamic sector of the Luxembourg economy in terms of employment. Furthermore, as Information Security and Trust Management are sine qua non for the success and competitiveness of the most important economic sector, namely the financial and banking sector, research in this domain will contribute to improve the performance of these sectors and of the Luxembourg economy as a whole and therefore, indirectly to maintain Luxembourg's standard of living. Furthermore, research projects focusing on Information security and Trust management and especially on social behavioural aspects of security and trust, may have a high indirect impact on society and behaviours as they might help to increase the acceptance and use of new e-services (e-banking, e-health, e-government, etc.) and therefore - at least to some extent - help to reduce the digital divide in the society.
C4. Accordance with the political agenda in Luxembourg		High	This priority is in line with the objectives of the National Plan for Innovation and Full Employment, set up in 2006 and aiming at reducing the "digital divide in the area of information security" and at promoting the spread and use of ICT in general. It is also in accordance with the aims of the "eLuxembourg" action plan and of the "Plan directeur de la Gouvernance électronique".

Feasibility	C5. Public and political acceptance	Mixed	As Information Security and Trust Management is of growing importance to the banking sector, other IT applications and e-services, public interest in the domain is high. At the same time, public awareness of the threats in e-services and e-applications are already high and may still grow, thus increasing the need for research on social and behavioural aspects of security and trust, esp. how to communicate these issues to the general public and how to implement them sensibly with public administration. The legal framework repeatedly limits (sometimes for good reasons) the use and implementation of new security and identity management solutions. Research in this field needs to balance security and privacy needs (see e. g. controversies about copyright and digital rights management). Its public acceptance will therefore depend on good communication of its aims and goals.
	C6. Private sector activities in Luxembourg	High	There are extensive private R&D activities in this domain[274]. Several ICT companies (large ones as well as SMEs) are specialized and carry out research on cryptology, information security and trust technologies. Also the major banks have ongoing research activities in this field.

[274] The following private companies are carrying out R&D activities in the field of „Cryptology, Information Security and Trust" in Luxembourg: Conostix, eBRC - e-Business & Resilience Centre, Flowing Content, M-PLIFY, Secaron Luxembourg, Telindus PSF - SAGS, A. MULLER ET FILS S. à r. l., AVIDACOM S.A., CEGELEC S.A., GROUP 4 SECURICOR Technologies Luxembourg S.à r.l., NOUVELLE LUXELEC S.A., OMNISECURITY S.A. Security and Management Technologies, PHILIPS LUXEMBOURG S.A., C.T.T.L. S.A. Centre de Télécommunications et Téléinformatique, SIEMENS S.A..

<table>
<tr><td></td><td>C7. Public research capacity in Luxembourg</td><td>High</td><td>Security and Trust is one of the top priorities of the University of Luxembourg, with the LACS research lab working on cryptography, system and network security and information security management. The CRP Henri Tudor has established a research platform “Security of Information Systems” (addressing issues like intrusion detection and protocols), with a close link to e-services (quality and certification of e-services). According to a recent survey[275], there are 15 FTE researchers involved in research related to information security and trust management at the CRP Henri Tudor (CITI division) and altogether there are about 32 FTE researchers involved in research in this domain in Luxembourg.
The multi-annual FNR programme SE-COM, running from 2000 to 2008 and with a total budget of 7,500,000 EUR, funds projects at the CRPs and the University focussing on security and efficiency issues of new practices in e-commerce.
In order to reach internationally recognized excellence and visibility, an increase by approximately 100 researches would be sufficient.</td></tr>
<tr><td></td><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 100</td></tr><tr><td>Infrastructure and Equipment</td><td>High performance IT infrastructure</td></tr></table>
During the second workshop, an increase of existing units at the UL and CRP-HT by approximately 100 researchers was stated as a good scale. This figure takes into account that information security is a top priority at the UL and the CRP-HT, and that it can be substantiated by a comparison with international research activities. The unit for Information Security at Technical University Darmstadt (covering only a part of the priority) has a staff of 16 researchers (http://www.sec.informatik.tu-darmstadt.de); the unit for Computer Security and Industrial Cryptography at K. U. Leuven has a core staff of only five, but 12 post-docs and 36 research assistants (http://www.esat.kuleuven.be/scd/people.php).</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">The objective of ICT research under the EU’s Seventh Framework Programme (FP7) is to improve the competitiveness of European industry – as well as to enable Europe to master and shape the future developments of these technologies so that the demands of its society and economy are met. The EU Member States have earmarked a total of € 9.1 billion for funding ICT over the duration of FP7; making it the largest research theme in the Cooperation programme, which is itself the largest specific programme of FP7. In particular, research focusing on “Secure, dependable and trusted Infrastructures” will be funded with an approximative budget of 90 M€.</td></tr>
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[275] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

		At an international level, there are currently dedicated public R&D funding activities in a number of countries (UK, Netherlands, Ireland, etc.) making this priority a very competitive research domain. For instance, the German Federal Ministry of Education and Research is currently developing the new ICT 2020 research funding programme in consultation with science and industry. Within this programme, research focusing on IT security and reliability will be funded, addressing the following issues: integrity, confidentiality and availability (protective installations in manufacturing plants, navigation systems in aircraft, driver assistance systems in cars or transport systems (e-safety). Also processes and technologies to ward off malicious software programmes and to detect threats early will be addressed by research. [Source: The High-Tech Strategy for Germany, Federal Ministry of Education and Research, 2006] In France, the Provence-Alpes-Côte d'Azur Competitiveness Cluster "Secure Communication Solutions" cluster specializes in software solutions and microchips for secure data exchange, bringing together a hundred enterprises including Alcatel, Gemplus, IBM, Hewlett Packard, Philips, and STMicroelectronics. [Source: Competitiveness Clusters in France, 2006, http://competitivite.gouv.fr/IMG/pdf/poles_plaquette_en.pdf] The Competitiveness Cluster "Transactions électroniques sécurisées" also addresses security of IT services. [http://www.competitivite.gouv.fr]
C10. Contribution to national competences, scientific excellence and international reputation	High	Given the dominating role of the banking and service sector for Luxembourg's economy, building a strong capacity in this domain is of primordial importance. Luxembourg can build on already existing competencies and ongoing research activities in the public as well as in the private sector. In order to reach internationally recognized excellence and visibility in this domain, it is still necessary to further increase public research capacities in ICT at the UL and the CRPs.
C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities identified	Business Service Design and Innovation	Some important research questions related to (new) business e-services deal with IT security topics and hence strong ties with the research priority Information security and trust management will arise.
	Fostering the economic and legal environment for innovation	As the availability of ICT tools and applications in general and of ICT security tools in particular are important enablers for innovation in economy, finance and in the service sector as a whole, there are strong overlaps between the two priorities "Fostering the economic and legal framework for Innovation" and "Information Security and Trust Management" – for instance regarding issues like identity management, privacy and Intellectual Property Rights.
	Performance and Development of Financial Systems	As information security and trust management are a sine qua non for all financial applications, there are obvious linkages between research in "Performance and Development of Financial Systems" and research in "Information Security and Trust Management".
	Telecommunications and Multimedia	Research in "Information Security and Trust Management" for applications in the telecommunications sector, especially for the broadcasting industry has obvious overlaps with the priority "Telecommunications and Multimedia".
	Biomedical Sciences	Research in information security and trust management should aim at ensuring the protection of data privacy so as to contribute to increasing the public acceptance of new e-Health solutions and biobanks.

	Public Health, including aspects of Environmental Health	Research in Public Health related to e-Health applications should take progress in research in "Information Security and Trust Management" into account, since implementing the best secure IT solutions available will contribute to increasing the acceptance of new e-Health solutions.
	Translational Biomedical Research	The necessity of the availability of tissue banks and biobanks for the successful development of translational research poses new challenges to research in information security: research in this domain should aim at ensuring the protection of data privacy so as to overcome some ethical problems related to biobanks and increase the public acceptance of biobanks.

7.1.5 Telecommunications and Multimedia

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.
	C2. Economy	Medium	Generally, research in this domain will help the private telecommunications sector become more competitive, and – in combination with the other domains of Innovations in Services – make Luxembourg more attractive for companies from abroad. Public research aiming at developing and improving the technical ICT infrastructures for the aggregation and distribution of content – including multimedia applications – is of high importance for the transition of Luxembourg to a knowledge society and contributes (e. g. by increased connectivity for enterprises and private persons) to the creation of new innovative services. As points in case, personalised services, multilingual multimedia applications and data retrieval tools, geolocalisation, and lifelong learning tools can be mentioned as important new economic niches. An advanced ICT architecture could also lead to improved crisis and disaster management tools for public bodies and for companies. In some cases, research could help to give Luxembourg a say in the EU / international context relevant for business (e. g. standardisation procedures).

	C3. Society	High	Research in the domain "Telecommunications and Multimedia" is of highest social relevance as it contributes to build the Information and Knowledge society and to achieve the Lisbon goals; developments in this domain will bring deep changes in our way of working and living. In particular, progress in this area will lead to the development of a broad range of (new) e-services (e-health, e-government, e-business, etc.) in all aspects of social life. Bridging the digital divide in society will depend on the development of telecommunications infrastructures, broadband access, low-cost hardware, open software, network applications, etc. as well as of the broad public acceptance of these new services. The development of efficient crisis management systems was identified during the FNR Foresight as very promising research issue in this domain. Of course, such systems are also of high societal importance. Specifically in the Luxembourg context, the development of new multilingual, multimedia applications can contribute to consolidate the visibility of Luxembourg's culture and language on the web, promote a specific Luxembourg identity and make the Luxembourg cultural heritage available to more people - and have therefore a high social impact furthering for instance social cohesion and inclusion. Furthermore, multilingual, multimedia applications can lead to diversify the range of available lifelong-learning tools, therefore indirectly contributing to strengthening social inclusion in the labour market (especially against the background of an ageing workforce).
C4. Accordance with the political agenda in Luxembourg		High	This priority is in line with the objectives of the National Plan for Innovation and Full Employment aiming at promoting the spread and use of ICT in general and with the government's programme presented in August 2004.
Feasibility	C5. Public and political acceptance	Favourable	As the multimedia sector contributes significantly to the Luxembourg economy, research for innovation in this domain finds high acceptance among the public, even more if it enhances multilingual applications and convergence of different applications and benefits crisis and disaster management. Unsolved or controversial legal questions on intellectual properties, digital rights management and generally in purchasing multimedia content may pose some minor problems for research.
	C6. Private sector activities in Luxembourg	High	There are several big companies and SMEs offering innovative products and services in the telecommunication and multimedia sector (e.g. RTL group, P&T Luxembourg, SES SA, Broadcasting Center Europe SA, Equant Luxembourg, Siemens SA, Hewlett Packard Luxembourg). Recently big players on the internet market with a high innovation potential like Amazon, e-bay or Skype have established themselves in the country.

	C7. Public research capacity in Luxembourg	High	The ComSys research laboratory at the University of Luxembourg is very active in this domain and involved in several national and international projects aiming at various research issues of the field; there are also activities at the CRPs Tudor and Lippmann. According to a recent survey[276], there are 20 FTE researchers involved in research in telecommunications and multimedia at the CRP Tudor (CITI division) and altogether there are about 48 FTE researchers involved in research in this domain in Luxembourg. The three EC-funded research projects U2010, Nartus and ARTUS5 conducted at the University of Luxembourg have provided some international visibility and competencies in the domain. Luxembourg could also build upon existing public research projects within the LIASIT programme. "Le centre virtuel de la connaissance sur l'Europe" (CVCE) has research projects on multimedia, esp. interoperability and multi-linguism. In the scope of the former CORTINA project ("Correction ORThographique Informatique Appliquée à la langue luxembourgeoise" – Computer spelling correction applied to the Luxembourgish language)., carried out by the CRP Lippmann in cooperation with the "Comité Permanent de la Langue Luxembourgeoise" (Permanent Committee of the Luxembourgish Language) a spelling correction programme which can be incorporated in various word processing tools was developed (http://cortina.lippmann.lu/site/index.php).

[276] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

C8. Infrastructure / Critical Mass

Critical mass (researchers)	About 40
Infrastructure and Equipment	High performance IT infrastructure

With the three EC-funded research projects U-2010, Nartus and ARTUS5, the University of Luxembourg has already acquired some international visibility and competencies, on which future similar research projects could be build. Teams of about 8-10 researchers (as in U-2010) for Luxembourg's public participation in large international (EU) projects seem appropriate. Considering the scope of the priority, five projects (from mobile communication to multilingual search and multilingual multimedia content generation) seem a realistic number. But project work should be backed up by a sufficiently large permanent staff combining ICT and linguistic competences (see also priority 2.3 Identities, Diversity and Integration). A model for this "centre of competence" could be derived from the LIASIT – Luxembourg International Advanced Studies in Information Technologies – with a staff of 8 professors (www.liasit.lu/people.html).
For comparison in the field of multilingual content: The Natural Language Processing Group at Sheffield University has an academic staff of 7 and 41 senior and associated researchers (http://nlp.shef.ac.uk/people.html). Another example in a bordering field is the DFKI – German Research Centre for Artificial Intelligence – in Saarbrücken with 35 researchers and 15 guest researchers (http://www.dfki.de/web/forschung/km/mitarbeiter).

C9. International research context

The research priority "Telecommunications and Multimedia" is in line with the specific research topics to be funded in FP7:

- The Network of the Future - ICT-2007.1.1 (Ubiquitous network infrastructures and architectures, Optimised control, management and flexibility of the future network infrastructure, Technologies and systems architectures for the Future Internet) with an approximative budget of 200 M€;
- Networked Media - ICT-2007.1.5 (Interoperable multimedia network and service infrastructures, End-to-end systems and application platforms) with an approximative budget of 85 M€;
- Intelligent Content and Semantics - (ICT-2007.4.4) with an approximative budget of 100 M€.

This priority domain is highly competitive and of course, most countries are supporting public research in Telecommunications and Multimedia. There are for instance strong international public R&D funding activities in the UK, Belgium, the Netherlands and Ireland.
According to its High-Tech Strategy, the German government aims to strengthen and consolidate Germany's top technological ranking in the ICT field and will further, among others, research on multimedia. ICT funding measures will be realigned in the multimedia field to link technology policy and economic policy (including relevant framework conditions such as legal and organisational issues) with one another even more than in the past. Planned priority fields for technology funding will include networked intelligent systems (NextGenerationMedia project: intelligent systems and environments, RFID technologies in manufacturing and logistics), etc.
[Source: The High-Tech Strategy for Germany, Federal Ministry of Education and Research, 2006]
In France, the Competitiveness Cluster "Image, Multimedia and Digital Lifestyle" in the Paris region specializes in the production, processing and dissemination of digital content. It works in the worlds of cinema, video games, music and multimedia services, as well as

	knowledge management. The Brittany "Images and Networks" cluster is specialised in the digitization and broadcasting of images, and concentrates on the markets for digital and terrestrial TV, the Internet and mobile television. Its research agenda is focused on the convergence of broadcasting, telecoms and new technologies. [Source: Competitiveness Clusters in France, 2006, http://competitivite.gouv.fr/IMG/pdf/poles_plaquette_en.pdf] Regarding research on multilingual multimedia applications, there might be opportunities for researchers in this domain to collaborate in the Greater Region with the International Graduate College "Language Technology and Cognitive Systems" of the Saarland University.	
C10. Contribution to national competences, scientific excellence and international reputation	High	Although this domain is highly competitive on the international level, Luxembourg can reach scientific recognition in this field. The presence of internationally operating companies of the telecommunication and multimedia sector and the ongoing research activities at the UL and the CRP Henri Tudor are a good base to build upon. Luxembourg is the core of the recognized EU project U2010. Creating competencies in the multimedia sector is also an important building block of the envisaged knowledge society.
C11. Cross-linkages with other Priorities identified	Justification	
C11. Cross-linkages with other Priorities identified	Business Service Design and Innovation	Some research questions related to (new) business e-services deal with seamless service architecture and IT architecture in general. There are therefore obvious links between the priorities "Telecommunications and Multimedia" and "Business Service Design and Innovation". The specific aspect of business services related to real-time logistics is also of tremendous importance to crisis management infrastructures covered by the domain Telecommunications and Multimedia.
	Fostering the Economic and Legal Framework for innovation	Research aiming at "Fostering the economic and legal framework for innovation" should take aspects related to the ICT and Telecommunications infrastructure into account.
	Information Security and Trust Management	Research in "Information Security and Trust Management" for applications in the telecommunications sector, especially for the broadcasting industry has obvious overlaps with the priority "Telecommunications and Multimedia".
	Identities, Diversity and Integration	Research in the domain "Telecommunications and Multimedia" contributing to building the Information and Knowledge society will bring deep changes in our way of working and living. There are therefore overlaps with the priority "Identities, Diversity and Integration" (e.g. how to bridge the digital divide in society?). Specifically in the Luxembourg context, the development of new multilingual, multimedia applications can contribute to consolidate the visibility of Luxembourg's culture and language on the web, promote a specific Luxembourg identity and make the Luxembourg cultural heritage available to more people - and have therefore a high social impact furthering for instance social cohesion and inclusion.
	Labour Market, Educational requirements and Social Protection	Research in "Multimedia" could lead to multilingual multimedia applications and especially to life-long learning tools or multilingual translation tools, also of interest for the research priority "Labour Market, Educational requirements and Social Protection", contributing to strengthening social inclusion in the labour market (especially against the background of an ageing workforce).

	Public Health, including aspects of Environmental Health	At a European level, ICT applications for health, like e-Health and telemedicine, are deemed to be an important future instrument of public health policies, providing tools for improving people's access to healthcare and health information services. Therefore synergies between the two domains "Public Health" and "Telecommunications and Multimedia" should be exploited in future research programmes in order for Luxembourg to exploit fully the potential of new ICT technologies for improving Public Health.

7.2 Sustainable Resource Management in Luxembourg

The following table summarizes the assessment of the umbrella priority "Sustainable Resource Management in Luxembourg" along the criteria presented in chapter 2.4. It should be noted that the assessment of this priority in the criteria table will *not include any additional information* not already given for one of the correspondent subdomains. **However, the criteria values for the "umbrella" notion** "Sustainable Resource Management in Luxembourg" **can not be expected to be the exact sum (or average) of the individual criteria values obtained for each research subdomain.** Rather, the assessment of the "umbrella" notion allows for adding weight to specific perspectives, emphasizing for instance some specific aspect within the broad domain "Sustainable Resource Management in Luxembourg" on which research should focus on, or for highlighting specific strengths or weaknesses.

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	High	Research activities in **all** sub-domains of this research field aim at gaining knowledge and developing tools that help to preserve natural resources and ecosystems in Luxembourg. Bundling the different research fields and issues under the concept of sustainable resource management will support an efficient transfer of research results to governmental action directly related to the improvement of Luxembourg's environment.

	C2. Economy	Medium	Sustainable Resources Management is, generally speaking, a prerequisite for long-term economy viability and sustainable economic growth. Luxembourg's economy depends much on imported resources, some of which are expected to become scarcer in the near future, and to a lesser degree on its own national resources, in particular on water, clean air, arable soil, space for housing and business activities, etc. An efficient management of these resources contributes to value added and cost savings. Despite the problems in attributing economic values to natural resources and even more to environmental quality, it is obvious that long-term economic development depends on the availability and quality of both. Public research on Sustainable Resource Management helps to maintain the delicate balance between the human need to improve lifestyles and well-being on the one hand, and preserving natural resources and ecosystems, on which we and future generations indirectly depend also in economic terms. Additionally, Sustainable Resource Management is a field with many business opportunities in particular for small and medium sized enterprises and it can therefore contribute to the diversification of Luxembourg's economy.
	C3. Society	Medium	Research related to "Sustainable resources management in Luxembourg" as a whole will have - at least indirectly- a high social impact, as it will contribute to promote a sustainable way of life in Luxembourg by maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on the one hand, and preserving natural resources and ecosystems, on which we and future generations depend, on the other hand.
C4. Accordance with the political agenda in Luxembourg		High	As stated in the government's programme presented in August 2004, Luxembourg's policies will be / are oriented towards sustainable development. This research priority is therefore of course in accordance with the political agenda in Luxembourg and in line with the objectives and future actions of the government as presented recently by Luxembourg's Prime Minister Jean-Claude Juncker on 9 May 2007 on the occasion of the traditional declaration on the social, economic and financial situation of the country. For more specific information, see 2.2.1 through 2.2.6. [Sources: Programme gouvernemental, 2004, http://www.gouvernement.lu/gouvernement/programme/programme2004/index.html; Jean-Claude Juncker, Déclaration du gouvernement sur la situation économique, sociale et financière du pays 2007, 09.05.2007, http://www.gouvernement.lu/salle_presse/actualite/2007/05/09etatnation/index.html#8]
Feasibility	C5. Public and political acceptance	Favourable	Sustainable Resources Management and its sub-domains are of medium public interest but high acceptance. Despite the high media coverage of issues like climate change the general public usually does not understand nor value the socio-economic benefits of functioning ecosystems, biodiversity, sustainable water management, etc. Therefore, stakeholder collaboration and citizen education e.g. through consumer information systems as well as the clear and transparent identification of business opportunities are essential to increase public acceptance of the sub-domains. There are no legal hurdles or ethical concerns the domains could encounter.

<table>
<tr><td rowspan="3"></td><td>C6. Private sector activities in Luxembourg</td><td>Low</td><td>Private sector research activities in most of the sub-domains of Sustainable Resource Management are low. However, there are some companies that may be potential collaborators in new research projects as outlined in 2.2.1 to 2.2.6.</td></tr>
<tr><td>C7. Public research capacity in Luxembourg</td><td>Medium</td><td>High Level of activities in Sustainable Management of Water resources;
Medium Level of activities in Sustainable Uses and Sources of Energy, Sustainable Agro-Systems Management, Understanding Ecosystems and Biodiversity;
Low Level of activities in Managing Sustainable development and Spatial and Urban development.</td></tr>
<tr><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 185 (sum of researchers from sub-priorities)</td></tr><tr><td>Infrastructure and Equipment</td><td>Analytical tools, Modelling and Simulation Platform</td></tr></table>
Given already existing competences and priority setting at the University, critical mass can be achieved within the next ten years with a number of additional researchers of somewhat below 200. With a focus on the sub-priorities given below, Luxembourg’s research in this field can attain international competitiveness. As a comparison, the German multi-annual framework programme “Research for Sustainability” (BMBF) can be quoted which has a total budget of 303 M€, of which about 60 M€ are attributed to Sustainable development and technology, 40 M€ to Sustainable use of landscapes, and 27 M€ to Biogeosystems dynamics and adaptation.</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">There are strong public research activities addressing all aspects of “Sustainable Management of Resources” at European level (7th Framework Programme) as well as at national level. For more information, see 2.2.1 through 2.2.6.</td></tr>
<tr><td colspan="2">C10. Contribution to national competences, scientific excellence and international reputation</td><td>Medium</td><td>The holistic research approach described in the sub-domain Managing Sustainable Development (2.2.1) implies a high potential for Luxembourg to gain international visibility. In most of the other sub-domains international competition is quite strong. However, for a successful sustainable development of the country, research capacities in Luxembourg and an intense cooperation with national stakeholders is needed.</td></tr>
<tr><td colspan="2">C11. Cross-linkages with other Priorities identified</td><td colspan="2">Justification</td></tr>
<tr><td>C11. Cross-linkages with other Priorities</td><td>New Functional and intelligent Materials and surfaces, and New Sensing Applications</td><td colspan="2">In many cases, new materials allow the replacement of toxic materials and thus improve recycling processes or contribute to energy savings due to an improved energy-efficiency in their application. Future research programmes should therefore exploit the synergies between research in the two domains “New Functional and Intelligent Materials and Surfaces” and “Sustainable Resources Management in Luxembourg” - in particular in the context of the implementation of the European REACH Directive.
Before optimizing resource use (water, energy, raw materials), it is essential to dispose of comprehensive data on the current use of environmental resources. This requires comprehensive monitoring and analysis tools for e.g. the water and soil quality, air pollution, etc. Therefore research in New Sensing Applications may lead to new tools for monitoring environmental functions.</td></tr>
</table>

	Technology Platform Modelling and Simulations	Before optimizing resource use (water, energy, raw materials), it is essential to dispose of comprehensive data on the current use of environmental resources. In particular, the environmental situation in Luxembourg has to be analysed and broken down to territorial / geographical levels, at which solutions and optimisation strategies should / could be implemented. This requires comprehensive monitoring and analysis tools, insufficiently available in Luxembourg at the moment. Setting up large modelling and simulation facilities will therefore boost the umbrella research priority "Sustainable Resource Management in Luxembourg". To some extent, the Platform "Modelling and Simulations" might build for instance on competencies at the CRP Tudor (LTI division) where 17 FTE researchers are involved in modelling and simulations of physical systems.

7.2.1 Managing Sustainable Development

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	High	This research domain aims at developing tools and strategies for a sustainable development regarding all natural resources by a systematic and holistic approach in order to achieve the highest possible beneficial impact for Luxembourg's environment. It offers support to the other environmental subdomains and it will also help to coordinate actions related to national environmental policy initiatives.
	C2. Economy	Medium	Public research in Managing Sustainable Development has direct and indirect economic impacts. In general, understanding the energy and material flows in Luxembourg helps companies to increase resource efficiency and to save costs. The development of eco-technologies increases the competitiveness and creates new economic niches and business opportunities in particular for small and medium sized companies not only in the agricultural sector. As points in case, environmental monitoring, life cycle assessment, material flow and energy management, risk assessment, etc. pose important opportunities in an "eco-knowledge economy". Clean technologies, sustainable production and products play an increasing role in the manufacturing industry and in agriculture. Last but not least, research about Managing Sustainable Development can assist companies to comply with increasing pressures from EU environmental regulation, and to address the necessities of climate protection and climate change.
	C3. Society	Medium	Research related to "Managing Sustainable Development", and especially focusing on the promotion of research related to ecotechnologies, clean technologies, highly efficient technologies, etc., is fundamental for the achievement of the sustainable development goals for Luxembourg's society and therefore indirectly relevant to society. Furthermore, some specific aspects of research in this domain - concerning consumer behaviours, public awareness - might have a high social impact and lead to a new "sustainable way of life".
C4. Accordance with the political		High	This research priority and the specific issues identified are in line with the government's programme presented in August

agenda in Luxembourg			2004: in particular, this programme pointed out the necessity of collecting and monitoring information and specific data related to sustainable development in order to provide the scientific basis for policy-making (for instance, based on the indicators for sustainable development defined in order to assess the results of the implementation of the National Action Plan for Sustainable Development (NAPSD), set up in 1999). The need for a holistic view of sustainability, including social, economic and ecological aspects is also highlighted in this programme. This research priority will also help to coordinate actions related to national environmental policy initiatives such as the National Action Plan for Sustainable Development, the National Plan for Rural Development, and the National Plan for Environmental Protection.
Feasibility	C5. Public and political acceptance	Mixed	As research in this domain requires comprehensive data collection there might be legal problems in obtaining certain data sets, e.g. emission counts of companies or households. Generally, there are no ethical concerns, and public acceptance of this domain is high, esp. among environmentally minded citizen groups or companies. However, there may be organisations or companies which favour differing perceptions of sustainability, e.g. those which are not willing to compromise economic goals for ecological ones.
	C6. Private sector activities in Luxembourg	Low	In general, the sustainability of production processes and products play an increasing role for all industrial sectors. However, ongoing private R&D activities on managing sustainable development in the sense of the holistic approach described in this domain can be considered low. Luxcontrol is a recognized medium-sized company with competences in environmental monitoring, pollution assessment, recycling, etc. Paul Wurth SA and ProfilARBED are carrying out R&D in the field of ecotechnologies. GIM and Luxspace could be potential partners with their activities in earth observation.
	C7. Public research capacity in Luxembourg	Low	The CRP Henri Tudor - Resource Centre for Environmental Technologies (CRTE) is conducting research on process engineering and modelling and sustainable resource management, for instance regarding the water resources in Luxembourg. According to a recent survey[277] there are about 17 FTE researchers involved at the CRTE in research in this domain. There are also existing capacities at the Département „Environnement et Agro-Biotechnologies“of the CRP Lippmann which will be useful in establishing this research domain - according to the same survey, about 51 FTE researchers are involved at the CRP Lippmann in the broad domain of Environmental Sciences.

[277] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

C8. Infrastructure / Critical Mass

Critical mass (researchers)	About 15
Infrastructure and Equipment	IT infrastructure for data collection, Simulation and Modelling Platform

This domain has an integrative function for the other sub-priorities within the umbrella of Sustainable Resource Management in Luxembourg. To perform this function, it has a double task:

- to serve as a platform for exchange that fosters networking and collaboration within the environmental research fields within Luxembourg and the Greater Region and to support project development and application (e. g. at the European level)
- to serve as an interdisciplinary competence centre that collects existing data, integrates them into holistic models, develops indicators and scenarios, and sets up an information base for decision-makers.

The working group of the second workshop estimated that it needs a core group of researchers of about 10 people and an annual budget of about 1 M€. But this refers mainly to the second task, and seems to be rather the lower limit if – at least – parts of integrative model development in collaboration with other teams are included. The platform functions can be supported by an additional staff of about 5 researchers.

C9. International research context

The recent developments of research and environmental policies in the European Union (Integrated Product Policy; Environmental Technologies Action Plan; Thematic Strategy on the Prevention and Recycling of Waste; Thematic Strategy on the Sustainable Use of Natural Resources; Sustainable Consumption and Production Strategy (to be issued by DG Environment this year) clearly show the need for tools and methodologies enabling the assessment of the sustainability of products, processes and management scenarios (e.g. life cycle assessment, material flow and energy management, risk assessment, etc.). This is also emphasized by the FP7 Work Programme for 2007 on the Environmental Theme (Theme 6), where life cycle assessments and/or material flow analyses have to be applied for project proposals to be accepted for funding.

Specifically, research addressing the sustainable management of all natural resources (cf. 2.2.2 through 2.2.5) will be funded by FP7 as well as research aiming at fostering participatory and constructively engaged international co-operation in the field of integrated resource management in order to support attaining the Millennium Development Goals (MDG) (ENV.2007.2.1.2.4.).

Additionally, within the theme of Socio-economic Sciences and the Humanities, research projects will be funded addressing "The extent to which trade-offs or synergies exist between the different aspects of sustainable development" (SSH-2007-2.1.2.)

Integrated environmental protection and resource conservation is one of the objectives of the German High Tech Strategy. In contrast to the 1970s and 1980s when centre stage was given to aftercare environmental engineering – such as filter systems to keep air and water clean – environmental protection considerations are today increasingly being taken into account during the development phase. With this approach, natural resources are to be used efficiently and harmful effects on the environment are to be minimised throughout a product's entire lifecycle. Specific goals concern energy efficiency, the sustainable management of water resources, the reduction of greenhouse gases and of land development (see also 2.2.3, 2.2.4 and 2.2.6).

	Within the Greater Region, there might be opportunities for researchers in this domain to collaborate with the "Trierer Arbeitsgemeinschaft für Umwelt-, Regional- und Strukturforschung e.V. (TAURUS)" and the Fachhochschule Birkenfeld.	
C10. Contribution to national competences, scientific excellence and international reputation	High	The holistic research approach addressed in this sub-domain offers a high potential for gaining international visibility as such integrative approaches are not yet widely developed internationally and in larger countries much more difficult to implement. Since the focus is not on developing new ecotechnological solutions but on developing a consistent approach on and implementation of existing and emerging technologies, it is possible for Luxembourg to reach international recognition in this domain. National research competencies in this field are also necessary to reach Luxembourg's sustainability goals.
C11. Cross-linkages with other Priorities identified	Justification	
C11. Cross-linkages with other Priorities identified	Understanding Ecosystems and Biodiversity	"Understand Ecosystems and Biodiversity" is a sine qua non to define valuable strategies for "Managing Sustainable Development". The two research domains are therefore closely interlinked.
	Sustainable Management of Water Resources	The "Sustainable Management of Water Resources" is clearly one aspect of "Managing Sustainable Development", there will be therefore obvious overlaps between these two research domains.
	Sustainable Uses and Sources of Energy	"Sustainable Uses and Sources of Energy" are one aspect of "Managing Sustainable Development", there will be therefore obvious overlaps between these two research domains.
	Sustainable Agro-Systems Management	"Sustainable Agro-Systems Management" is one aspect of "Managing Sustainable Development", there will be therefore obvious overlaps between these two research domains.
	Spatial and Urban Development	Aspects related to "Spatial and Urban Development" have to be taken into account in research projects related to "Managing Sustainable Development": In particular, the environmental situation in Luxembourg and environmental indicators have to be analysed and broken down to territorial / geographical levels, at which solutions and optimisation strategies should / could be implemented.
	Technology Platform Modelling and Simulations	Before optimizing resource use (water, energy, raw materials), it is essential to dispose of comprehensive data on the current use of environmental resources. In particular, the environmental situation in Luxembourg has to be analysed and broken down to territorial / geographical levels, at which solutions and optimisation strategies should / could be implemented. This requires comprehensive monitoring and analysis tools, insufficiently available in Luxembourg at the moment. Setting up large modelling and simulation facilities will therefore boost the umbrella research priority "Managing Sustainable Development".

7.2.2 Understanding Ecosystems and Biodiversity

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	High	Research in this domain will support the preservation of biodiversity, which is, in general, a fundamental component of any sustainable development. A comprehensive understanding of ecosystem functions and processes will help to reduce the fragmentation of ecosystems induced by human activities and to improve the sustainable management of Luxembourg's environment.
	C2. Economy	Low	Loss of biodiversity can impact the functioning of both natural and managed ecosystems and thus reduce their capacity to deliver ecological goods and ecosystem services which are essential to human well-being and important not only for the agricultural sector, but also for the attractiveness of Luxembourg in terms of attracting enterprises and workforce. In addition to obvious environmental implications, the economic relevance of biodiversity for Luxembourg should not be neglected. A point in case is genetic diversity and its relevance for agriculture – in particular in an age of climate change. Another point is the relevance of a healthy and diverse natural environment for tourism. But it is still a research task to identify more specific opportunities for economic growth through conservation of biodiversity.
	C3. Society	Medium	Research on Biodiversity and ecosystem functions, aiming at reversing the trend of ongoing loss of biodiversity, will have indirectly a medium to high societal impact, since it will contribute to maintain the capacity of impoverished ecosystems to deliver ecological goods and services (so-called "ecosystem services") which are essential to human well-being.
C4. Accordance with the political agenda in Luxembourg		High	As stated in the government's programme presented in August 2004, Luxembourg has many commitments to the EU which call for research on biodiversity and a better understanding of ecosystem functions and the government's policy related to biodiversity will be oriented towards the fulfilment of European directives - for instance the European Commission action plan aiming at conserving biodiversity and preventing biodiversity loss within the EU and internationally - Communication from the Commission, 2006: "Halting the loss of biodiversity by 2010 - and beyond. Sustaining ecosystem services for human well-being". Besides several objectives related to safeguarding important habitats and species, the action plan explicitly states the need for improving the knowledge base for conservation and sustainable use of biodiversity, which requires strengthening of the related research areas.
Feasibility	C5. Public and political acceptance	Mixed	Public acceptance is high as it is in every citizen's interest to preserve the local environment. Opposition may arise only as some policies made under the provision of research may curtail individual interests, e.g. regarding land use and emission allowances. This might also pose minor legal problems, as well as the process of extensive data mining and collection which is required for assessing biodiversity and ecosystems.

<table>
<tr><td rowspan="3"></td><td>C6. Private sector activities in Luxembourg</td><td>Low</td><td>Research in this domain is, in general, dominated by the public sector (not only in Luxembourg).</td></tr>
<tr><td>C7. Public research capacity in Luxembourg</td><td>Medium</td><td>The “Administration des Eaux et Forêts” is conducting studies on bioindicators, ecology and forestry inventories. According to a recent survey[278], about 5 FTE researchers are involved in research in this domain. The CRP Gabriel Lippmann has research projects on climatology and chemical pollution (according to the same survey, about 51 FTE researchers are involved at the CRP Lippmann in the broad domain of Environmental Sciences). Biodiversity is also a topic at the Museum of Natural History.</td></tr>
<tr><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 40</td></tr><tr><td>Infrastructure and Equipment</td><td>IT infrastructure for data collection, molecular analytical tools / laboratory</td></tr></table>
Research on ecosystems and biodiversity, even if closely focussed on task in connection with the other environmental research sub-priorities is a broad field with a scope from specimen and data collection and genetic analyses to bioinformatics and bio-statistical / ecological modelling. The CRP-GL, the National Museum of Natural History and others are already provided with a total staff of about 40 researchers in these fields. Within the given time horizon it seems sensible to add at least another 40 researchers to achieve critical mass and international visibility.
This corresponds to figures from international research: One example is Ireland’s National Platform for Biodiversity Research which consists of approximately 40 members (http://www.biodiversityresearch.ie/members.php). These members are, on the one hand, not necessarily engaged in biodiversity research on a full time basis, but they bring in, at the other hand, the competences of their organizations or research units.</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">The 7th Framework Programme (FP7) provides opportunity to support research addressing the safeguarding of important habitats and species, and improving the knowledge base for conservation and sustainable use of biodiversity. In particular, research projects will be</td></tr>
</table>

[278] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

	funded related to: - understanding how biological diversity terrestrial, inland waters and marine - at European and international levels - contributes to ecosystem goods and services and to livelihoods (ENV.2007.2.1.4.1. Contribution of biodiversity to ecosystem services); - understanding of how the use of and trade in natural resources at European and international levels affects biodiversity (marine, inland waters and terrestrial), ecosystem goods and services and the resilience and resistance of ecological-economic systems, and develop or improve methods to measure and value biodiversity and ecosystem resilience and detect when ecosystems are approaching the limits of their natural functioning or productive capacity (ENV.2007.2.1.4.2. Use of natural resources: the impact on biodiversity, ecosystem goods and services); - Increasing knowledge of the cultural, social, spiritual, economic and other values of biodiversity. Improve understanding of public beliefs, perceptions, attitudes and preferences regarding biodiversity and the drivers of biodiversity change, and how they influence human behaviour and public policy. (ENV.2007.2.1.4.3. Biodiversity values, sustainable use and livelihoods). [Source: EC, WORK PROGRAMME 2007, COOPERATION THEME 6 - ENVIRONMENT (INCLUDING CLIMATE CHANGE)] The European biodiversity research activities are also coordinated by the "European Platform for Biodiversity Research Strategy" (EPBRS) (http://www.epbrs.org/) and the BIOSTRAT Platform (http://www.biostrat.org/). Within the Greater Region, there might be opportunities for researchers in this domain to collaborate with the "Laboratoire Biodiversité et Fonctionnement des Écosystèmes" of the University of Metz.	
C10. Contribution to national competences, scientific excellence and international reputation	Medium	In order to guarantee the sustainable development of ecosystems and the preservation of biodiversity in Luxembourg it is necessary to foster know-how in this domain in the country. There are already ongoing projects and know-how in public research institutes to serve as a base for further capacity building. International visibility in certain research issues of this domain can be achieved with moderate financial effort. A strong cooperation with researchers in the other sub-domains of the domain Sustainable Resource Management in Luxembourg and the intense exploitation of capacities of the envisaged Modelling and Simulation Platform will help to increase Luxembourg's scientific excellence in this field.

C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities	Managing Sustainable Development	"Understand Ecosystems and Biodiversity" is a sine qua non to define valuable strategies for "Managing Sustainable Development". The two research domains are therefore closely interlinked.
	Sustainable Management of Water Resources	The research activities in "Sustainable Management of Water Resources" should also consider implications for biodiversity, since freshwater species are apparently more threatened by human activities than species in other realms. On average freshwater species populations fell by about 50% between 1970 and 2000, representing a sharper decline than measured in either terrestrial or marine biomes.[279]

[279] 2nd UN World Water Development Report, 2006

	Sustainable Uses and Sources of Energy	Research activities related to new sustainable energy from biomass - identified as promising for Luxembourg - should take into account the impact of biomass farming (for energy production) on biodiversity and ecosystems.
	Sustainable Agro-Systems Management	Research related to Sustainable Agro-Systems Management - biofarming, biodiversity and preservation and development of local genetic resources - are clearly linked to research aiming at "Understanding Ecosystems and Biodiversity".
	Spatial and Urban Development	"Understanding Ecosystems and Biodiversity" should clearly take the territorial dimension into consideration. In particular, the impact of spatial and urban development on biodiversity and ecosystems is extremely important and therefore research focusing on this issue is of high relevance.
	New Functional and intelligent Materials and surfaces, and New Sensing Applications	New Sensing Applications could be used to monitor biodiversity and the state of ecosystems.
	Public and Environmental Health	Although environmental health research and policies primarily aim to improve human health via the environment, and are not focused on protection of ecosystems per se, the measures taken to reduce human risk can have a purely environmental benefit, improving ecosystem functioning as a result of the measures taken to improve human health. The potential synergies between the priorities „Public Health, incl. aspects of Environmental Health" and „Understanding Ecosystems and Biodiversity" should therefore be exploited to the full when implementing future research programmes.
	Technology Platform Modelling and Simulations	Research in biodiversity is very dependent on new findings and on the availability (and processing) of environmental data related for instance to climate change, therefore this research priority will benefit from large modelling and simulation facilities.

7.2.3 Sustainable Management of Water Resources

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	High	Research in this domain will directly support actions to improve the quality of ground water, surface water and urban water. The positive effects of developing an efficient and sustainable management of water resources in Luxembourg is obvious in the light of the potential threats arising from water pollution, water scarcity, risk of floods and other hazards.

	C2. Economy	Medium	High quality water for human consumption, water for agricultural irrigation and for industry is becoming a scarce resource, even in Luxembourg. The need for an efficient and sustainable management of water resources is obvious in the light of the potential threats arising from water pollution, falling of water tables, changes in precipitation, risk of floods and other hazards. Luxembourg is already spending large amounts of money in water processing, waste water treatment, etc. Making intelligent and innovative technologies available and finding more efficient solutions in this field – taking into account climate change, new agricultural practices, etc. – will have a direct impact on the quality of water resources and thus - indirectly - an economic payback for Luxembourg. In the long run, decreasing public expenditures in water treatment etc. may be expected. Apart from water using industry and agriculture, businesses engaged in water technologies may benefit from public research about Sustainable Management of Water Resources. Technologies like online measuring and monitoring system for all water bodies, water treatment and water management systems that have been developed and successfully implemented in Luxembourg create opportunities for exportation.
	C3. Society	Medium	As for the sustainable use of energy, research aiming at promoting a "sustainable management of water resources" will have a medium direct impact on society since it will contribute to maintain Luxembourg's high standard of living - especially in view of the potential threats for water resources. Future research will / should also take the social dimension of a sustainable management and development of water resources into account and therefore, some specific research projects aiming e. g. at furthering a higher public awareness of the high value of quality and availability of the fundamental resource water will also have an impact on society and consumer behaviours in particular. This research domain contributes also to a better management of flood risks, an issue which is, of course, of high societal relevance.
C4. Accordance with the political agenda in Luxembourg		High	Improving the quality of watercourses is one of the main objectives of the National Action Plan for Sustainable Development (NPSD) set up by Luxembourg in 1999: "What is at issue is to protect the quality of water and guarantee the conservation, or even development, of a balanced ecosystem rich in biological diversity." Also a new law on the management of water resources is to be issued soon. [Source: Jean-Claude Juncker, Déclaration du gouvernement sur la situation économique, sociale et financière du pays 2007, 09.05.2007, http://www.gouvernement.lu/salle_presse/actualite/2007/05/09etatnation/index.html#8]
Feasibility	C5. Public and political acceptance	Favourable	The public will welcome further research on preserving and managing water resources. The research effort will be highly accepted (even if the *implementation* of the outcome of the research may be more controversial as it may require some restrictions on water use and pollution, esp. for industry). Accompanying research and implementation by thorough communication campaigns which provide information and transparency is therefore essential. There are neither ethical concerns nor legal hurdles to take, except potential data mining and collection problems.

	C6. Private sector activities in Luxembourg	Low	There is only a small number of SMEs working in the sector of water treatment (e.g. H2O-Products). Some larger companies of the metal industry have some experience in water treatment (e.g. Circuit Foil Luxembourg).
	C7. Public research capacity in Luxembourg	High	At a national level, there are ongoing, publicly financed research activities related to water resources management in Luxembourg. The multi-annual National Research Fund programme "Sustainable management of water resources" (EAU, 2000-2007)[280] aims at improving the understanding of the complex mechanisms of the natural water cycle, evaluating the means to protect water resources and water quality, developing technologies for control and water purification, and fighting against water wasting. The programme's general objective is to establish a centre of excellence in the field of water in order to achieve these goals. The CRP Tudor disposes of a specialised water research unit (According to a recent survey[281] there are also 7 FTE researchers involved in research related to Water Management at the CRTE (Centre de Ressources des Technologies pour l'Environnement)), the CRP Lippmann conducts research on water ecosystems - according to the same survey, about 51 FTE researchers are involved at the CRP Lippmann in the broad domain of Environmental Sciences. The University of Luxembourg-Physics Research Unit has some projects on geo-hydrology and ground water. Studies assessing water flows are being conducted by the "Administration de la Gestion de l'Eau".

[280] FNR, Multi-annual programme>EAU programme> Detailed programme p.11, www.fnr.lu/SIML_FNR/Channel/FNR.nsf/fs_Root?OpenFrameset,

[281] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

C8. Infrastructure / Critical Mass

Critical mass (researchers)	About 25
Infrastructure and Equipment	Simulation and Modelling Platform, hardware for monitoring water bodies, Earth observation tools

Monitoring, modelling and developing solutions for managing water resources needs an interdisciplinary approach with competences from quite different fields such as hydrology, environmental statistics, climate research, modelling and simulation, etc. Even taking into account that water research is already well established in Luxembourg, important new capacities are demanded e.g. for high performance modelling of water bodies / technical installations and corresponding monitoring tasks. A staff of 20 researchers – as indicated in the workshop – could be sufficient, if it is well networked.

A key instrument in this research domain is therefore the formation of a "water platform" which 1) facilitates the communication and networking between researchers and the pooling of competencies and information and 2) supports the interaction of research actors and public and private stakeholders, involved in water resources management. This platform could be run by a staff of about 5 researchers.

For comparison: The Groundwater Protection & Restoration Group at University of Sheffield can serve as an international example. It has an academic staff of 5 professors/ lecturers, 5 visiting academics, and 12 researchers, including post-docs (www.shef.ac.uk/gprg/people/directory.html).

C9. International research context

Research projects related to the management of water resources will be funded by FP7. Specific issues to be addressed are: the assessment of the ecological status of water bodies (ENV.2007.2.1.2.1); River basin twinning initiatives as a tool to implement EU water initiatives (ENV.2007.2.1.2.2.); Temporary water bodies management (ENV.2007.2.1.2.3).

[Source: EC, WORK PROGRAMME 2007, COOPERATION THEME 6 - ENVIRONMENT (INCLUDING CLIMATE CHANGE)]

The management of water resources is addressed by public research in many countries. Protecting the global water supply is for instance an important issue in the German High Tech Strategy and The German government is supporting the development of an integrated water resource management (IWRM) system in numerous partner countries, particularly in the Middle East and Africa. In addition to its development policy projects in this field – Germany is one of the world's largest donors in the water sector – the Federal Ministry of Education and Research also funds the continued development of IWRM methods and approaches. [Source: The High-Tech Strategy for Germany, Federal Ministry of Education and Research, 2006]. Denmark has also established a variety of different research programmes that support research activities in the ecotechnologies domain. For example, in the field of sustainable development, global change and ecosystem, the 'Water – the strategic resource of the future' programme supports research on technologies such as process technology, membrane technology, construction and renovation technology, pumps, earth observation data from satellites, new sensor and IT technology for automatic collection and transmission of field data and advanced hydrological models.

C10. Contribution to national competences, scientific excellence and international reputation	Medium	There is a high level of international research activities in this domain (especially in countries that are more threatened by eventual hazards) making it hard for Luxembourg to gain international visibility here. However, national scientific competence is needed to guarantee a sustainable management of the resource water.

C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities identified	Managing Sustainable Development	The "Sustainable Management of Water Resources" is clearly one aspect of "Managing Sustainable Development", there will be therefore obvious overlaps between these two research priorities.
	Understanding Ecosystems and Biodiversity	The research activities in "Sustainable Management of Water Resources" should also consider implications for biodiversity, since freshwater species are apparently more threatened by human activities than species in other realms.
	Sustainable Agro-Systems Management	Water needs and management in agriculture is clearly one aspect of the management of Water Resources. In particular, the water issues related to biomass farming should be investigated.
	Spatial and Urban Development	The territorial dimension should clearly be taken into account when managing water resources.
	New Functional and intelligent Materials and surfaces, and New Sensing Applications	New Sensing Applications could be used to monitor the state of water bodies and the water quality.
	Technology Platform Modelling and Simulations	The FNR Foresight pointed out the need for setting up large modelling and simulation facilities to monitor and analyse the state of waterbodies (pollution, impact of climate change, etc.).

7.2.4 Sustainable Uses and Sources of Energy

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	High	Research that leads to a higher share of regenerative and renewable energy sources in Luxembourg's energy mix and to a reduction of energy consumption by a more efficient use of provided energy will reduce Luxembourg's emission of CO_2 and other substances that have effects on the global climate effects as well as the local air quality.

	C2. Economy	High	Providing the country with sufficient energy is one of the most important tasks for Luxembourg in the future. Considering Luxembourg’s economic dependencies on energy imports but also the impacts of climate change and the generally limited availability of fossil energies, it is of high economic importance to increase energy efficiency as well as the share of regenerative / renewable energy sources and to develop competencies in these fields. Energy efficiency has direct paybacks for any business and in the end for consumers too. But new energy technologies have to be seen also in the light of continuously tightened EU regulations, e.g. with respect to CO_2 emissions or biofuels, which push “laggard” companies out of the market. In addition to the economic aim of reducing Luxembourg’s energy dependency, there is a high potential of exporting energy related technologies – despite strong competition at the European level. Both applied and basic energy research hold considerable potentials to produce high value added, as the market for energy technologies is continuously increasing. Energy technologies pose many opportunities as well for large as for small and medium sized companies – from equipment manufacturers and bio-energy companies to energy related service providers.
	C3. Society	Medium	Given Luxembourg’s per capita energy consumption, research in the domain “Sustainable Uses and Sources of Energy”, aiming at providing the country with sufficient energy will contribute to maintain the high standard of living of Luxembourg and therefore have, at least indirectly, a medium to high social impact. Furthermore, the development of energy efficient and renewable energy technologies in Luxembourg is expected to promote the creation of jobs in this sector, especially in SMEs, having therefore a medium to high direct impact on unemployment and some sectors of the labour market.
C4. Accordance with the political agenda in Luxembourg		High	As stated by Luxembourg's Prime Minister Jean-Claude Juncker on 9 May 2007 on the occasion of the traditional declaration on the social, economic and financial situation of the country, Luxembourg aims at reaching the EU environmental objectives, and in particular the objective of reducing the CO2 emissions. This research priority is therefore of course in line with the political agenda and can contribute to achieve these objectives. The Prime Minister also announced new regulations for the sustainable use of energy and the development of renewable energy sources - to be issued in the next weeks and to become effective in 2008. [Source: Jean-Claude Juncker, Déclaration du gouvernement sur la situation économique, sociale et financière du pays 2007, 09.05.2007, http://www.gouvernement.lu/salle_presse/actualite/2007/05/09etatnation/index.html#8] Improving energy efficiency and promoting the use of renewable resources was already one of the objectives of the National Plan for Sustainable Development (NPSD) which set the aim to reduce the energy intensity, i.e. the gross energy consumption per unit of GDP, by 20 % between 1993 and 2010. This objective has already been achieved. But this result is due mainly to growth in GDP which was higher than that of the gross consumption of energy defined by the total energy needs of the country (importation and energy produced on national soil). Due to an increased demand from transport (primarily truck transport and private automobile transport), the energy consumption is still growing. The NPSD set objectives of covering 45 % of the consumption of the national electricity grid from national production by 2005 and doubling the share of renewable energy and cogeneration by 2010. Biomass in particular is considered by the government to be of great importance, with a target of 20% of Luxembourg’s

			agriculturally usable surface to be planted by energy crops being under discussion.
Feasibility	C5. Public and political acceptance	Favourable	As Luxembourg is still highly dependent on energy imports, research for increasing the national supply of energy by using renewable energy sources and for decreasing the demand for energy is highly welcome by the general public, but also by businesses who may benefit from it. Minor concerns may arise only concerning the competition for land use among food and biomass production. There are no legal hurdles to take.
	C6. Private sector activities in Luxembourg	Medium	There are only few SMEs with R&D activities in the field of renewable energy technologies (e.g. L.E.E., Novigo) or energy efficiency and co-generation (e.g. LuxEnergie S.A.). Organisations like the Agence de l'Energie or Eurosolar Luxembourg may also trigger private sector R&D activities. DuPont Luxembourg and a number of construction and planning companies may be potential partners for projects in the field of energy efficient building and construction.
	C7. Public research capacity in Luxembourg	Medium	Research can build on existing competencies in the public research sector, for instance at the "Agence de l'Energie", the CRP Gabriel Lippmann (according to a recent survey[282], about 51 FTE researchers are involved at the CRP Lippmann in the broad domain of Environmental Sciences), the University of Luxembourg (research at the Engineering Research Unit focusing on energy efficiency in buildings and the TDK chair at the UL for photovoltaics) and the CRP Henri Tudor (According to the same recent survey there are also 4 FTE researchers involved in research in this domain at the Centre de Ressources des Technologies pour l'Environnement (CRTE)) which conduct research on e. g. renewable energies like bioenergy and photovoltaics and energy management. Also, there is a joint platform on energy efficient buildings initiated by Luxinnovation, the CRP Henri Tudor, and the University of Luxembourg.

[282] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

<table>
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<td></td>
<td>C8. Infrastructure / Critical Mass</td>
<td>
<table>
<tr><td>Critical mass (researchers)</td><td>At least 30</td></tr>
<tr><td>Infrastructure and Equipment</td><td>No major infrastructure needed</td></tr>
</table>

The domain Sustainable Uses and Sources of Energy is one of the broadest among the different fields of “Sustainable resource management in Luxembourg”, since it includes research in energy efficiency (domestic, industry, transportation) and research in renewable energy sources (in particular energy from biomass). (It excludes, however, most of purely technological research and development.) To cover some of these research issues adequately, at least 30 researchers – perhaps concentrated in a “Centre for Sustainable Energy” – seem necessary. Even taking into account that competence building starts from a very early stage, critical mass can be reached within 10 years.
An international benchmark can be taken from the Institut für Energiewirtschaft und Rationelle Energieanwendung of Stuttgart University, which has more than 50 collaborators (http://www.ier.uni-stuttgart.de/institut/mitarbeiterliste.php).
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<tr>
<td colspan="2">C9. International research context</td>
<td>
Within the Competitiveness and Innovation Framework Programme (CIP) (2007-2013), the EU is continuing its Intelligent Energy - Europe Programme. This programme supports improvements in energy efficiency, the adoption of new and renewable energy sources, greater market penetration for these energy sources, energy and fuel diversification, an increase in the share of renewable energy (the EU has set itself the objective of raising the share of renewable energy in gross domestic consumption to 12% by 2010) and a reduction in final energy consumption. The programme follows up the Intelligent Energy - Europe (2003-2006) programme, which expired on 31 December 2006.
Energy from biomass encompasses different technologies for various applications, of which heat production, electricity production and transport are identified to be prioritised by the EU. [Source: Biomass Action Plan of the EU; http://europa.eu/scadplus/leg/en/lvb/l27014.htm].
In the 7th Framework Programme, emphasis will be given to the following activities: - Hydrogen and fuel cells - supporting EU fuel cell and hydrogen industries, for stationary, portable and transport applications; - Renewable electricity generation - technologies to increase overall conversion efficiency, cost efficiency and reliability, driving down the cost of electricity production; - Renewable fuel production - fuel production systems and conversion technologies; - Renewables for heating and cooling - technologies for cheaper, more efficient active and passive heating and cooling from renewable energy sources; - CO_2 capture and storage technologies for zero emission power generation - technologies reducing the environmental impact of fossil fuel use by capturing CO_2; - Clean Coal Technologies - substantially improve power plant efficiency, reliability and reducing costs through research, development and demonstration of cleaner coal and other solid fuel conversion technologies, producing also secondary energy carriers (including hydrogen) and liquid or gaseous fuels; - Smart energy networks - increasing the efficiency, safety, reliability and quality of the European electricity and gas systems and networks in the context of a more integrated European energy market; - Energy efficiency and savings - technologies to improve energy efficiency and to enable final and primary energy consumption savings, over their life-cycle, for buildings (including lighting), transport, services and industry.
</td>
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</table>

	[Source: http://cordis.europa.eu/fp7/cooperation/energy_en.html] Research on biomass technologies is one of the top priority of FP7 with the following topics: Topic ENERGY.2007.2.2.1: Advanced gas cleaning technologies for biomass, Topic ENERGY.2007.2.2.2: Innovative technologies for efficient electricity production in biomass-fired IGCC, Topic ENERGY.2007.2.2.3: New and improved slagging and corrosion control technologies for large-scale biomass co-firing processes, Topic ENERGY.2007.2.2.4: Large-scale co-firing, Topic ENERGY.2007.2.2.5: Novel solid biofuels for electricity generation, Topic ENERGY.2007.2.2.6: High-efficiency medium-to-large scale electricity generation from biomass. [Source: European Commission, WORK PROGRAMME 2007, COOPERATION - THEME 5 ENERGY] Energy efficiency in buildings is one aspect to be addressed in the domain “Low resource consumption buildings and infrastructure” (ENV.2007.3.1.5.1.). [Source: EC, WORK PROGRAMME 2007, COOPERATION THEME 6 - ENVIRONMENT (INCLUDING CLIMATE CHANGE)] Additionally, in the “Socio-economic sciences and the humanities”, FP7 will address the socio-economic cultural and political factors that shape energy demand and use in various environments (transport, agro-food, materials, housing, consumer behaviour, etc.) and the necessary changes at systemic level that need to be initiated in order to develop an environmentally-friendly European model of energy policies that respond to the expectations and needs of European citizens, urban and rural communities. (Socio-economic factors and actors that shape the "postcarbon" society - SSH-2007-2.1.4). Energy is a highly competitive research domain - many countries support public research related to energy (it should be noted that in this domain, research activities from the private sector (global energy suppliers) are also very important). Finlands´ basic research programme is promoting environmentally friendly energy systems and supports five main areas of research[283], while through the programme “ClimBus” (Business Opportunities in the Mitigation of Climate Change - Tekes 2004-2008) Finland has invested 70M€ in ecotechnologies research in three main areas including: Clean energy production and fuels; business services; and technologies for energy efficiency and non-CO_2 greenhouse gases. Denmark’s investment in the field of sustainable energy sources has supported research into ecotechnologies, for example, through the ‘Systematised sustainable energy’ research programme, which covers the development of both individual technologies (wind, fuel cells and bioenergy) and systematic concepts that combine these technologies. The Danish Centre for Sustainable and Green Chemistry supports chemical research on: the discovery and development of new ecoefficient routes to energy currencies; base chemicals; and fine chemicals. High public research support has also been observed in the field of “bio-energies” from France and Denmark. The French bio energies research programme encompasses themes such as linocellulosic resources, thermochemical conversion; biological conversion and sociological, technical and economical evaluation. According to its High Tech Strategy, a comprehensive energy policy concept for Germany will bundle all measures being taken to ensure

[283] renewable energy sources and optimisation of the use of biomass and biodegradable waste for raw material, traffic fuel and energy; the reduction of specific consumption of energy in basic industry processes; research related to increased construction of technologies combining heat and power production; research related to nuclear power (fourth generation nuclear power plants of overcritical pressure, nuclear power and hydrogen economy, fusion energy, final disposal of waste); and research into factors affecting the functioning of energy markets.

		a sustainable energy supply. Germany aims to demonstrate its excellence in the area of environmental engineering and energy technology with beacon projects such as the CO2 Building Restoration program or the COORETEC project aiming at a power plant with zero CO_2 emissions. The Renewable Resources funding programme will support the development of conversion methods, pilot projects and the launch of renewable resources for use as raw materials or for generating energy. [Source: Federal Ministry of Education and Research, The High-Tech Strategy for Germany, 2006] In France, the Competitiveness Clusters "CAPENERGIES", "Tenerrdis" address research focusing on renewable energy sources (solar and wind energy, energy frm biomass). Within the Greater Region, there might be opportunities for researchers in this domain to collaborate with the International Graduate College "New High-Performance Materials for Efficient Energy Utilization" of the Saarland University, the University of Applied Sciences in Trier and the Fachhochschule Birkenfeld.
C10. Contribution to national competences, scientific excellence and international reputation	Medium	For most of the renewable energy sources, the industrial and research competition from other countries is too strong for Luxembourg to reach international visibility. In a few selected fields like energy from biomass and energy efficient building, recognized scientific excellence could be achieved. An overall solid national knowledge base in this domain is needed to decide on Luxembourg's future energy mix.
C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities identified	Managing Sustainable Development	"Sustainable Uses and Sources of Energy" are one aspect of "Managing Sustainable Development", there will be therefore obvious overlaps between these two research priorities.
	Understanding Ecosystems and Biodiversity	Research activities related to new sustainable energy from biomass - identified as promising for Luxembourg - should take into the account the impact of biomass farming (for energy production) on biodiversity and ecosystems.
	Sustainable Agro-Systems Management	There are clear links between the two priorities "Sustainable Agro-Systems Management" and "Sustainable Uses and Sources of Energy" regarding energy production from biomass (biomass farming).
	Spatial and Urban Development	Aspects related to the reduction of energy consumption in urban areas as well as biomass farming for energy has obviously a territorial dimension.
	New Functional and intelligent Materials and surfaces, and New Sensing Applications	In many cases, new materials can contribute to energy savings due to an improved energy-efficiency in their application. Future research programmes should therefore exploit the synergies between the two research domains "New Functional and Intelligent Materials and Surfaces" and "Sustainable Uses and Sources of Energy". New Sensing Applications could be used to monitor energy and heat consumption.

7.2.5 Sustainable Agro-Systems Management

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	High	Some research issues of this domain are directly related to the impact of farming (and also of biomass production) on the qualitative and quantitative state of the water resources or on the biodiversity of various ecosystems. Research in this field aims also at more natural and sustainable approaches related to animal health and livestock production as well as plant health and pest management, which is of immediate environmental relevance.
	C2. Economy	Low	Luxembourg's agriculture and food production have to adapt as well to EU regulations and a globally changing agrofood sector as to climate change and its consequences. Research on Sustainable Agro-Systems Management contributes to the modernization of Luxembourg's agro-industrial sector and helps its agriculture to stay viable and competitive. It also assists the creation of new growth niches (in particular for small and medium sized companies): Fostering sustainable food production, precision agriculture, biotechnologies related to food, spectroscopic or genetic methods to check food quality along the production chain, or energy production from biomass can stimulate new economic activities. It can be expected that Sustainable Agro-Systems Management has far reaching indirect positive economic effects: Reduction of environmental costs by decreasing the environmental impact of agriculture (on soil, water, ecosystems), and reduction of health costs by healthier nutrition.
	C3. Society	Medium	The main research issues identified in the domain "Sustainable Agro-Systems Management" are related to food production in a context of sustainable use of resources and will therefore have a medium indirect impact on society. However, some specific aspects to be addressed by future research in "Sustainable Agro-Systems Management" are of high social importance: healthy nutrition - especially in view of the drive towards prevention in Public Health -, a better understanding of consumer perceptions and needs and of the socio-economic interactions within the whole supply chain.
C4. Accordance with the political agenda in Luxembourg		High	This research priority and the specific research issues identified are in line with the government's programme presented in August 2004 and the objectives of a sustainable agriculture set by the Ministry of Agriculture, Viticulture and Rural Development.
Feasibility	C5. Public and political acceptance	Favourable	Acceptance by the public is high as there will be obvious benefits concerning health and food security, provided that research is accompanied by consumer education measures. Some problems may arise due to the (political) controversies between the "bio-ecological" and other factions of farming and food production. There are no legal hurdles or ethical concerns.
	C6. Private sector activities in Luxembourg	Low	There are only few SMEs (e.g. L.E.E.) active in this field. Luxlait and Food Ingredients Technology (FIT) could be industrial partners in projects related to nutrition.

<table>
<tr><td rowspan="2"></td><td>C7. Public research capacity in Luxembourg</td><td>Medium</td><td>On the national level, there is an existing basis in scientific fields related to this domain at the CRP Gabriel Lippmann with its department « Environnement et Agro-Biotechnologies » (EVA) (according to a recent survey[284], about 51 FTE researchers are involved at the CRP Lippmann in the broad domain of Environmental Sciences), the CRP Henri Tudor (according to the same recent survey, the Centre de Ressources des Technologies de l'Environnement has also some - though very limited - research competencies in this domain), the University of Luxembourg and also at the Laboratoire National de Santé (LNS); however, the collaboration between these research institutes is insufficient. Research activities in the laboratories at the Administration des services techniques de l'Agriculture (ASTA) and at CONVIS[285] are very application-orientated.</td></tr>
<tr><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 30</td></tr><tr><td>Infrastructure and Equipment</td><td>Laboratory infrastructure, experimental parcels and farming units</td></tr></table>
Existing competences at the CRPs, the University, and bodies like ASTA or CONVIS amount to about 50 to 60 researchers. To further develop, maintain and integrate competences on a multi-disciplinary basis, an expansion of that number is needed. With additional 30 researchers, these tasks and the function of a platform for exchange could be fulfilled.
(No direct international comparison was found. Research on sustainable agriculture is e. g. well established at Wageningen University and Research Centre in the Netherlands, but it is – as in other cases – distributed over several departments. See www.wur.nl/UK/research/research+themes/Agriculture/.)</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">Within the 7th Framework Programme, the EU has the objective of building a knowledge based bio-economy in Europe by bringing together science, industry and other stakeholders. The aim is to exploit new and emerging research opportunities, such as the growing demand for healthier and higher quality food, taking into account animal welfare and rural contexts, as well as the need for sustainable use and production of renewable bio-resources. Research issues related to the emerging threats to the sustainability and security of agricultural production resulting in particular from climate change are also in the focus of European research activities in this field.</td></tr>
</table>

[284] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

[285] Consortium of lifestock producers in Luxembourg, ‚Herdbuchverband Luxemburger Rinder- und Schweinezüchter' and ‚Service Elevage et Génétique'

<table>
<tr><td colspan="2"></td><td colspan="2">The German government aims to step up the development of a knowledge-based bioindustry in Germany. It is working to make Germany the European leader in plant biotechnology and plant breeding by the year 2015. Funding for genome research as a basis for plant breeding and plant design will be continued and supplemented by new funding campaigns in the systems biology field. The potential for innovation located along the interfaces between plant genome research, microbial genome research, animal genome research and nutritional research will be developed with the help of new funding measures that have been designed together with industry. A competitive process will bring about a concentration of agricultural and nutritional R&D capacities in Germany that the federal government in co-ordination with the Länder will support using suitable structure-building R&D funding measures.
[Source: Federal Ministry of Education and Research, The High-Tech Strategy for Germany, 2006]
In France, two Competitiveness Clusters address sustainable agro-systems management. The Champagne-Ardennes and Picardie “Industry and Agriresources” cluster targets the development of new products based on the innovative competitive and industrial exploitation of plant components. This includes plant refinery concept, bio-fuels and bio-lubricants, cosmetics, pharmaceuticals and chemicals. The goal is to address society’s demand for renewable products, environmentally safe procedures, and methods that reduce climate-change. “The specialized plant” cluster in the Loire Valley focuses on genomics and the production of high value-added seeds, trees, flowers and aromatic plants.
[Source: Competitiveness Clusters in France, 2006, http://competitivite.gouv.fr/IMG/pdf/poles_plaquette_en.pdf]
Within the Greater Region, there might be opportunities for researchers in this domain to collaborate with the Cluster “Agronomie, Agro-alimentaire, Biotechnologies“ of the Institut National Polytechnique de Lorraine.</td></tr>
<tr><td colspan="2">C10. Contribution to national competences, scientific excellence and international reputation</td><td>Medium</td><td>Research in this domain can make Luxembourg a model system for sustainable food production, consumption and resource use. The short decision paths in Luxembourg are seen as a unique opportunity to facilitate a fast transfer of knowledge in this domain. There are ongoing public research activities in the field to serve as base for further capacity building. International visibility might be achievable if the focus is set on integrated multi-disciplinary approaches and a good coordination and cooperation of all actors and stakeholders is supported.</td></tr>
<tr><td colspan="2">C11. Cross-linkages with other Priorities identified</td><td colspan="2">Justification</td></tr>
<tr><td rowspan="5">C11. Cross-linkages with other Priorities identified</td><td>Managing Sustainable Development</td><td colspan="2">“Sustainable Agro-Systems Management” is one aspect of “Managing Sustainable Development”, there will be therefore obvious overlaps between these two research priorities.</td></tr>
<tr><td>Understanding Ecosystems and Biodiversity</td><td colspan="2">Research related to Sustainable Agro-Systems Management - biofarming, biodiversity and preservation and development of local genetic resources - are clearly linked to research aiming at “Understanding Ecosystems and Biodiversity”.</td></tr>
<tr><td>Sustainable Management of Water Resources</td><td colspan="2">Water needs and management in agriculture is clearly one aspect of the management of Water Resources. In particular, the water issues related to biomass farming should be investigated.</td></tr>
<tr><td>Sustainable Uses and Sources of Energy</td><td colspan="2">There are clear links between the two priorities “Sustainable Agro-Systems Management” and “Sustainable Uses and Sources of Energy” regarding energy production from biomass (biomass farming).</td></tr>
<tr><td>Spatial and Urban Development</td><td colspan="2">Clearly, the management of Agro-Systems has a territorial dimension.</td></tr>
</table>

	New Functional and intelligent Materials and surfaces, and New Sensing Applications	Applications of research focusing on New Sensing Applications can lead to new sensors for measuring the quality and storage conditions of food (traceability). Furthermore, low-cost sensing devices combined with wireless technologies can be applied as sensor networks for monitoring parameters in the field.
	Public and Environmental Health	There are obvious links between nutritional aspects of Public Health research and research issues related to food production in the priority domain "Sustainable Agro-Systems Management".
	Technology Platform Modelling and Simulations	Monitoring tools become of increasing importance when studying large areas of land where traditional chemical analysis becomes too laborious. Telemonitoring is seen as a future technology in the surveillance of soil and large areas of land. Therefore this research priority will benefit from setting up large modelling and simulations facilities.

7.2.6 Spatial and Urban Development

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	High	Sustainable land use is becoming a real issue for Luxembourg. Research in this field directly addresses environmental problems related to spatial planning and development. Examples are the environmental health and ecological aspects of urban development (pollution, noise, ...) or the effects of increasing material flows, transport and mobility of workers on a local, regional, national, and even trans-national level. Research in spatial and urban development is closely linked to other lines of research on sustainable development and could be one of the cornerstones of a comprehensive research programme in this field.
	C2. Economy	Medium	In a context of globalization and competition (also on the regional level), research on Spatial Planning and Urban Development can reinforce the attractiveness of a country through increased living quality, higher efficiency of the transport system (intra-urban accessibility and metropolitan accessibility) and generally a high level infrastructure. As one of the means to influence land use and to curb real estate prices, spatial planning has a direct impact on the conditions of economic growth. The relevance of this research is emphasized by the fact that Luxembourg has become a hub of transportation as well in the North-South direction as in the East-West direction. Infrastructure development has to keep pace with growing inter-regional links and increasing traffic, in particular within the Greater Region. The economic need of a transition from industrial society to a knowledge society has given additional boost to territorial research with the concept of "knowledge regions": Its aim is to create favourable conditions for sustainable growth in (knowledge related and other) services, e. g. by attracting "high potentials" and by stimulating endogenous growth factors.

	C3. Society	High	Research in spatial and urban development can contribute to reduce spatial exclusion due to spatial segregation (in particular with respect to housing and mobility), to control urban sprawl, to manage Luxembourg's wide reaching urban effects over the national borders and to develop a traffic infrastructure to keep pace with increasing mobility and traffic within the Greater Region and Europe as a whole - some of the important challenges currently faced by Luxembourg. Research in this domain is therefore of high social importance since it contributes to strengthen social cohesion on the national level and to further European integration. One of the aims of research will be to implement a model of spatial development that counterbalances urban inequalities.
C4. Accordance with the political agenda in Luxembourg		High	This priority is in line with the objectives set in: • the National Plan for Sustainable Development (NPSD) related to urbanisation, urban vs. rural development and mobility; • the objective of the strategy "mobilitéit.lu" promoted by the Ministry of Transport with the aim "to guarantee and manage mobility for all, by limiting the environmental effects of road transport, without affecting economic growth"; • the law of 21 May 1999 relating to land use and the new land use steering plan established new planning instruments, including regional land use plans, sectoral land use plans and comprehensive development area maps, which should meet the requirements for an integrated approach in this field; • the "Programme Directeur d'Aménagement du Territoire" set up in 2003 by the Ministry of Home Affairs and Town and Country Planning. Furthermore, Luxembourg's Prime Minister Jean-Claude Juncker announced on 9 May 2007 on the occasion of the traditional declaration on the social, economic and financial situation of the country the creation of a new plan for rural development for the next 7 years. [Sources: Plan National pour un Développement Durable, 1999; STATEC (2003) Economic and social portrait of Luxembourg.pp. 175 ff.; Programme Directeur d'Aménagement du Territoire, Ministry of Home Affairs and Town and Country Planning, 2003; Jean-Claude Juncker, Déclaration du gouvernement sur la situation économique, sociale et financière du pays 2007, 09.05.2007]
Feasibility	C5. Public and political acceptance	Favourable	Given Luxembourg's spatial peculiarities and challenges research for improving the use of land and infrastructure is highly welcome. Acceptance of innovative measures, esp. regarding transport and land use, among the general public and businesses will highly depend on information and consumer education. There are no ethical concerns or legal hurdles in conducting this research.
	C6. Private sector activities in Luxembourg	Low	Research in this domain is, in general, dominated by the public sector (not only in Luxembourg). GIM has competencies in Geographic Information Systems.

<table>
<tr><td></td><td>C7. Public research capacity in Luxembourg</td><td>Low</td><td>Luxembourg has already an established knowledge base within this research domain with a chair for spatial development at the University[286], activities at CEPS/INSTEAD[287] (10 FTE researchers involved in research on spatial development, according to a recent survey[288]) on geo-informatics, close ties to European Spatial Planning Observation Network (ESPON), and a specific department at the Ministry of the Interior, the Direction de l'Aménagement du Territoire et de l'Urbanisme (DATUR), established in 1999. According to the survey cited above, there are also about 51 FTE researchers involved at the CRP Lippmann in the broad domain of Environmental Sciences, including Spatial and Urban Development.</td></tr>
<tr><td></td><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 20</td></tr><tr><td>Infrastructure and Equipment</td><td>No major infrastructure needed</td></tr></table>
Existing Spatial and Urban Development research nuclei at CEPS/INSTEAD, DATUR and UL possess a total staff of more than 20 persons. According to the breakout session of the second workshop these nuclei should be increased to a total number of 40 researchers in 2012. A unit of that size could attain a competitive status in Europe.
For comparison: Nordregio, a European centre for research, education and documentation on spatial development at Stockholm, established by the Nordic Council of Ministers has 35 researchers (www.nordregio.se/). In Germany, the Akademie für Raumforschung und Landesplanung (ARL) at Hannover is provided with an annual research budget of about 2 M€ (http://www.arl-net.de/).</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">The different aspects of spatial and urban development will be addressed by FP7. Devising innovative strategies for decoupling the impact from resource use from economic development and optimising the urban planning and design in order to accommodate increasing demand for space and resources while reducing material and energy consumption will be one focus (ENV.2007.2.1.5.1.</td></tr>
</table>

[286] In addition to the professorship in "European Sustainable Spatial Development and Analysis", a second professorship, dealing with quantitative spatial analysis, Geographic Information Systems (GIS), and digital mapping, will be added shortly. For the time being, a master program on territorial planning and development is under development. (http://wwwen.uni.lu/recherche/flshase/laboratoire_en_geographie_et_amenagement_du_territoire)

[287] Département GEODE (Géographie et Développement, http://www.ceps.lu/geode/dom_trav.cfm)

[288] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

	Urban metabolism and resource optimisation in the urban fabric). The aim of research should be to contribute to the development of new strategies and tools for a more sustainable use of energy and materials in urban planning. In the Socio-economic Sciences and the Humanities, FP7 will fund research projects related to regional, territorial and social cohesion with the objective to address challenges facing regional and social cohesion and regional and urban development, in the context of the broader economic, social, environmental and cultural changes taking place, the effectiveness of policy in addressing them, and lessons for policy. Additionally, a Social platform on cities and social cohesion will be set up (SSH-2007-2.2.3) with the aim to elaborate a focused research agenda, which addresses the role of cities in social cohesion, including related processes of social exclusion and inclusion and their consequences, and the key policy questions in this context. Opportunities are also posed by collaboration within the 7th Framework Program of the EU, in particular in a reinforced "Regions of Knowledge" action of the FP7's "Capacities" programme.[289] On the European level, territorial development and therefore research on territorial issues have gained in the last decade crucial relevance with the enlargement of the EU, the subsequent reframing of structural funds and the necessary redefinition of regional policy. Territorial and urban research is performed almost everywhere in the EU and beyond. As a point in case, Nordregio is a European centre for research, education and documentation on spatial development, established by the Nordic Council of Ministers (www.nordregio.se/). In Germany, the Akademie für Raumforschung und Landesplanung (ARL) investigates the impacts of human activities on the territory and analyses opportunities for a sustainable territorial development in the fields of economy, society and culture (http://www.arl-net.de/). There is a densely knit institutional fabric all over Europe. Recently, the economic need of a transition from industrial society to a knowledge society has given additional boost to territorial research with the concept of "knowledge regions": What are the specific conditions that enable a region to successfully manage this transition? Examples from Finland, Wallonia and other regions demonstrate that regional foresight can play an important role in the empowerment of regional actors. Within the Greater Region, there might be opportunities for researchers in this domain to collaborate with the "Trierer Arbeitsgemeinschaft für Umwelt-, Regional- und Strukturforschung e.V. (TAURUS)" and the "Centre d'Études Géographiques" of the University of Metz.	
C10. Contribution to national competences, scientific excellence and international reputation	Medium	Despite a strong European research tradition in spatial development, Luxembourg has to engage on its own in this field. Finding answers to the question of how Luxembourg can foster economic development, provide a liveable habitat for its population and protect its natural environment is crucial to the future quality of life within the country – and this "search process" can only be successfully organized within Luxembourg itself in combining research with stakeholder participation. Successful results may find recognition in the international research community.
C11. Cross-linkages with other Priorities identified	Justification	

[289] Almost €500 million have been earmarked for strengthening the research base of European regions (http://www.innovating-regions.org/).

C11. Cross-linkages with other Priorities identified	Managing Sustainable Development	Aspects related to "Spatial and Urban Development" have to be taken into account in research projects related to "Managing Sustainable Development": In particular, the environmental situation in Luxembourg and environmental indicators have to be analysed and broken down to territorial / geographical levels, at which solutions and optimisation strategies should / could be implemented.
	Understanding Ecosystems and Biodiversity	"Understanding Ecosystems and Biodiversity" should clearly take the territorial dimension into consideration. In particular, the impact of spatial and urban development on biodiversity and ecosystems is extremely important and therefore research focusing on this issue is of high relevance.
	Sustainable Management of Water Resources	The territorial dimension should clearly be taken into account when managing water resources.
	Sustainable Uses and Sources of Energy	Aspects related to the reduction of energy consumption in urban areas as well as biomass farming for energy has obviously a territorial dimension.
	Sustainable Agro-Systems Management	Clearly, the management of Agro-Systems has a territorial dimension.
	Identities, Diversity and Integration	The linkage between these domain becomes even more obvious when considering so-called „immaterial spaces"(Luxembourg consists not only of a political space defined by physical borders, it can also be described as a linguistic, living and working space and most of these spaces go beyond the mere geographical space Luxembourg occupies).
	Labour Market, Educational requirements and Social Protection	There are clear linkages between the priorities "Labour Market, Educational requirements and Social Protection" and "Spatial and Urban Development" related for instance to cross-border labour markets and the related transport/mobility/housing issues.
	Public and Environmental Health	Research in Public Health should aim at bridging the rural-urban health care divide and should therefore take aspects related to spatial and urban development into account.
	Technology Platform Modelling and Simulations	Within this research domain monitoring and simulation tools have to be employed or to be developed. This includes geographical information systems (GIS) but also empirical surveys and data bases on e.g. the mobility and habitat behaviour of people within and around Luxembourg. Therefore, this research priority will benefit from setting up large modelling and simulation facilities.

7.3 New Functional and Intelligent Materials and surfaces, and New Sensing Applications

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	Medium	Modern research on innovative materials always includes aspects of sustainability for the whole lifecycle of potential products ranging from production processes through the usage to recycling. In many cases, new materials allow the replacement of toxic materials and thus improve recycling processes or contribute to energy savings due to an improved energy-efficiency in their application. Furthermore, new and especially miniaturized sensing devices could be applied for monitoring environmental parameters in distributed networks in order to gather data for sustainable resource management strategies.
	C2. Economy	High	Developing novel knowledge-based materials and surfaces with tailored properties and functions (multifunctional or intelligent materials and surfaces on the basis of polymers, semiconductors, composites, ceramics, metals and nano-structured materials), as well as new sensing applications based on new sensing effects from nanotechnology, microelectronics, optics, etc. is a field of high promises offering a wide range of technological, scientific, and economic opportunities. Public research in this field plays the role of an enabler for new economic activities (spin-offs, start-ups, licensing) and can contribute to a high degree to the diversification of Luxembourg's economy. Novel materials and new sensing devices for applications in various fields, such as medical devices and implants, automotive, environmental technologies, information and communication technologies, etc., have generally a great potential of generating high value added and are interesting as well for large established companies as for the creation of new, highly specialised small and medium sized enterprises. International competition in this field is intense with important publicly funded research programs in all neighbouring countries, but the number of potential applications and therefore of possible niches is important as well.
	C3. Society	Low	There is no direct impact of research in this domain on society. However, this research field might contribute to diversifying the Luxembourg economy and job creation and therefore have - indirectly - a societal impact.
C4. Accordance with the political agenda in Luxembourg		High	In order to bolster and expand R&D facilities, the Government plans to promote the expansion of private research centres and the development of infrastructures for public research in a limited number of state-of-the-art areas. Treating or coating of surfaces, as well as plastic materials and plastics are among these areas. [Source: National Plan for Innovation and Full Employment, 2005]. Furthermore, this research field may contribute to diversifying the Luxembourg economy, in accordance with the objectives of the National Plan for Innovation and Full Employment and contribute to the development of new materials and technologies helping to comply with EU directives (e.g. to the REACH directive).

Feasibility	C5. Public and political acceptance	Favourable	The general public is not familiar with the details and benefits of this research domain and therefore will neither highly welcome nor reject public funding. In order to increase public acceptance, public information is needed, e.g. on economic and environmental benefits of novel materials, especially regarding the need to replace many toxic materials under the REACH directive, or social benefits like the generation of new jobs. One may speculate whether concerns about nanotechnology risks could hamper research in certain minor points. Also security applications of sensors give rise to some public concern, but these are not necessarily related to basic research.
	C6. Private sector activities in Luxembourg	High	The Portal for innovation and research in Luxembourg counts 39 larger and smaller companies with R&D activities in the field of material sciences (among them Amer-Sil, Ceratizit, DuPont de Nemours Luxembourg, Euro-Composites, IEE, LuxControl, Oerlikon Balzers, etc.). There are competencies for various classes of materials (metals, polymers, composites etc.). e-Xstream engineering developes material modelling software and IEE and ELTH are large companies developing sensors for various applications (e.g. automotive).

	C7. Public research capacity in Luxembourg	High	As far as public research in this domain is concerned, the NANO[290] and TRASU[291] programmes by the FNR have permitted the establishment of a European Centre for the development of analytical techniques for the characterisation of materials on the nanometre scale and research on surface treatment. The competences in the analysis field have been developed, interdisciplinary projects covering medical, biological and environmental research are currently being carried out and in both programmes the collaboration between public research centres (CRP Gabriel Lippmann and CRP Henri Tudor), national industry and academia from abroad is high. State-of-the-art analytical equipment has been purchased via the TRASU programme. Through the use of state-of-the-art equipment and techniques such as dynamic and static secondary ion mass spectrometry, transmission electron microscopy, scanning electron microscopy, researchers from the SAM department of the CRP Gabriel Lippmann (according to a recent survey[292] about 22 FTE researchers are involved in research in this domain) have become experts in the analysis of metals, semiconductors, glasses, ceramics and polymers. The CRP-GL is coordinating the Network of Excellence Nanobeams within the 6th Framework Programme of the EU.[293] The CRP Tudor has a Laboratory for Industrial Technologies and Materials (computational modelling) (according to the same recent survey, about 6 FTE researchers are involved in research in this domain at the LTI division of the CRP Tudor). The University of Luxembourg has competencies in some material sciences and has already set priorities for research on polymers and on silicon-free (semi-) conductors.

[290] The NANO programme (2000-2008) aims at creating 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. (http://www.fnr.lu/SIML_FNR/Channel/FNRen.nsf/fs_Root?OpenFrameset)

[291] The TRASU programme (2003-2009) relates to the development of new types of treatment in order to improve the properties sought, such as adhesion, wear, hardness and better environmental protection. Within this programme the joint research project "Development of Innovative Surfaces by Means of Optimised Plasma Techniques and Technology Transfer to Industries" was initiated. (http://www.fnr.lu/SIML_FNR/Channel/FNRen.nsf/fs_Root?OpenFrameset)

[292] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

[293] This project involves 80 researchers as well as 40 PhD students and has a budget of 5 million Euros for integration and 40 million Euros for research covering a period of 4 years. The research concentrates on analytical techniques using focused ion and electron beams in order to develop analytical techniques and instruments matching the requirements of nanomaterials. One of the strong points of the Nanobeams Network is the creation of a PhD school based in Luxembourg in close collaboration with the University of Luxembourg. This PhD school aims at forming PhDs specialised in the field of nanoanalysis. Correspondingly public research in this field has built renown in Luxembourg and abroad, and the PhD school based in Luxembourg might facilitate the recruitment of top scientists. (www.nanobeams.org)

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<td>C8. Infrastructure / Critical Mass</td>
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<table>
<tr><td>Critical mass (researchers)</td><td>About 250 (including New Sensing Applications)</td></tr>
<tr><td>Infrastructure and Equipment</td><td>Expensive analytical equipment, Modelling and Simulation Platform</td></tr>
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Materials research is expensive in terms of researchers and equipment, even taking into account that some equipment has been installed within the TRASU and NANO programme. Building up competences has to start with about 5 teams of 10 to 15 researchers, attached to existing structures in the CRP-GL, the CRP-HT and the University, which have to be expanded rapidly. During the workshop, a target figure of 250 researchers in 2015 was given as an estimate. The “absorption capacity” for such a rapid growth still has to be developed. Close collaboration between the public and the private sector is essential for success and in addition to the research, structures for an efficient technology transfer, e.g. encouraging spin-offs from the University, are needed in this field. Small teams (e.g. 3 to 4 groups of 5 researchers) can start to promote this thematic field and serve as a nucleus.
An international benchmark for competitive applied research is set by the German Fraunhofer Society. Several of its institutes are specialized in materials research. To mention only two: The Fraunhofer-Institut für Werkstoff- und Strahltechnik (which is one of the smaller institutes) has a scientific staff of 60 plus 39 technicians and an annual budget of 16.4 M€ (http://www.iws.fraunhofer.de/zahlen.html). The Fraunhofer-Institut für Fertigungstechnik und Materialforschung has a staff of about 250 researchers and technicians and an annual budget of about 24 M€ (http://www.ifam.fraunhofer.de/jahresberichte/jb06/jb2006_de.pdf, p. 16).
Regarding new sensing applications, the National Centre for Sensor Research at Dublin University has a staff of 11 professors plus 20 researchers (http://www.ncsr.ie/about/staff.html). The Sensors Research Laboratory at Warwick University counts 13 researchers (http://www2.warwick.ac.uk/fac/sci/eng/eed/research/srl/staff/). And the Transducers Science and Technology department at the University of Twente has a senior academic staff of 9 professors and a junior staff of 11 plus about 20 PhD students (http://tst.ewi.utwente.nl/members/index.html).
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<tr>
<td colspan="2">C9. International research context</td>
<td>In the European context, research related to new materials is a major topic of theme 4 (Nanosciences, Nanotechnologies, Materials and new Technologies) of the 7th Research Framework Programme (FP7) fostering international cooperation in this field.[294]
Research will focus on developing new knowledge-based multifunctional surfaces and materials with tailored properties and predictable performance, for new products and processes targeting a wide range of applications. This requires the control of intrinsic properties, processing and production, taking into account potential impacts on health, safety and the environment throughout their</td>
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</table>

[294] The high relevance of the research field of new materials is also emphasized by its occurence in a large number of recent foresight studies in other countries. For instance, the Swedish National Foresight - Teknisk Framsyn (Sweden, 2003-2004) sees functional materials under its top technology fields, the Teknologisk Femsyn - Technology Foresight in the Danish Ministry of Science (Denmark, 2003-2006) sees nano-materials with new functional properties as a prominent technology field, and the UK Foresight Programme (UK, since 2003) identifies the development of new materials as a key technology for the photonics sector.

	entire life-cycle. Emphasis will continue to be placed on new advanced materials and systems obtained using the potential of nanotechnologies and biotechnologies and/or “learning from nature”, in particular higher performance nanomaterials (e.g. nanocomposites), bio-materials, artificial materials with electromagnetic properties not found in nature, and hybrid materials, including design and control of their processing, properties and performance. [Source: EC, WORK PROGRAMME 2007, COOPERATION - THEME 4 NANOSCIENCES, NANOTECHNOLOGIES, MATERIALS AND NEW PRODUCTION TECHNOLOGIES – NMP] FP 7 will also support research an new materials with sensing functionalities: - NMP-2007-4.0-3 Multifunctional materials for future vehicles; - Nanotechnology-based portable sensing devices for security applications. [Source: EC, WORK PROGRAMME 2007, COOPERATION - THEME 4 NANOSCIENCES, NANOTECHNOLOGIES, MATERIALS AND NEW PRODUCTION TECHNOLOGIES – NMP] The development of new biomaterials, also of interest for the research priority Regenerative medicine/ Tissue engineering, is also addressed by FP7: area “NMP-2007-2.3-1 Highly porous bioactive scaffolds controlling angiogenesis for tissue engineering”. The high relevance of the research field of new materials is also emphasized by its occurrence in a large number of recent foresight studies in other countries. For instance, the Swedish National Foresight (2003-2004) sees functional materials under its top technology fields, the Technology Foresight in the Danish Ministry of Science (2003-2006) sees nano-materials with new functional properties as a prominent technology field, and the UK Foresight Programme (UK, since 2003) identifies the development of new materials as a key technology for the photonics sector. The German High Tech Strategy sees Nanotechnologies, Microtechnologies and Material Technologies as cross-cutting technologies with high innovation potential. Regarding nanotechnology, the German government aims to make the benefits of nanotechnology available to small and medium-sized businesses too. In late 2006, the 2010 Nanoinitiative campaign started to bring together all the players in this sector and foster the transfer of knowledge between them, aiming at speeding up the translation of nanotechnology research findings into a wide variety of innovations. Regarding materials technologies, the German government aims to boost the competitive strength of important branches of German industry with the help of innovative materials technologies. Funding provided for materials technologies is also directed at improving the conditions for the environment and people's health. The objectives of research should be: speeding up the development of new materials; increasing material efficiency; and establishing norms and standards for materials. Regarding microtechnologies, R&D funding aims not only to increase the use of microsystems technology in key industries but also at making Germany a technology leader in new fields like Polymer microsystems which have the potential to open up mass markets in the low-price segment. Examples of this include RFID smart tags in the logistics field, inexpensive biosensors or gas sensors, medical applications, and membranes for micro fuel cells in the power engineering field. Organic polymers can be made into components and more complex systems very easily with the help of, for example, printing or other reel-to-reel processes. [Source: Federal Ministry of Education and Research, The High-Tech Strategy for Germany, 2006] The French Competitive Cluster “Plastipolis” supports research on composites and polymers materials. Within the Greater Region, there might be many opportunities for researchers in this domain to engage in collaborations with foreign

	research institutions like the Collaborative Research Centre (SFB) "Interface-dominated materials" or with the International Graduate College "Physical Methods for the Structural Investigation of New Materials" of the Saarland University; with the INM Leibniz-Institut fuer Neue Materialien gGmbH, situated in Saarbruecken/Germany; with the University of Kaiserslautern (research on "Materials for micro and nanosystems (MINAS)"), the "Laboratoire de Physique et Mécanique des Matériaux" of the University of Metz, the „Laboratoire d'Etude des Textures et Applications aux Matériaux" of the „Ecole Nationale d'Ingénieurs de Metz" and the University of Applied Sciences in Trier. Regarding potential new sensing applications, there might be opportunities to collaborate with the "Kompetenzzentrum Sensor und Feinwertechnik" of the Saarland University of Applied Sciences and the "Laboratoire Interfaces, Capteurs et Microélectronique" of the University of Metz.		
C10. Contribution to national competences, scientific excellence and international reputation	Medium	The international competition in this domain both in the public and the private sector is very high. However, innovative materials are a key technology for many applications in which Luxembourg should build up own capacities (not only in research but also in education and training) in order to support the local economic sector. Furthermore, Luxembourg should only partly concentrate its capacities in material science and nanotechnology on sensing applications and stay flexible and open for other fields of applications. The activities at the CRPs and the UL represent so far a good base to build upon.	
C11. Cross-linkages with other Priorities identified	Justification		

C11. Cross-linkages with other Priorities identified	Sustainable Resource Management in Luxembourg	In many cases, new materials allow the replacement of toxic materials and thus improve recycling processes or contribute to energy savings due to an improved energy-efficiency in their application. Future research programmes should therefore exploit the synergies between research in the two domains "New Functional and Intelligent Materials and Surfaces, and new sensing applications" and "Sustainable Resources Management in Luxembourg" - in particular in the context of the implementation of the European REACH-Directive. Furthermore, before optimizing resource use (water, energy, raw materials), it is essential to dispose of comprehensive data on the current use of environmental resources. This requires comprehensive monitoring and analysis tools for e.g. the water and soil quality, air pollution, etc. Therefore New Sensing Applications can lead to new tools for monitoring environmental functions.
	Understanding Ecosystems and Biodiversity	New Sensing Applications could be used to monitor biodiversity and the state of ecosystems.
	Sustainable Management of Water Resources	New Sensing Applications could be used to monitor the state of waterbodies and the water quality.
	Sustainable Uses and Sources of Energy	In many cases, new materials allow the replacement of toxic materials and thus can contribute to energy savings due to an improved energy-efficiency in their application. Future research programmes should therefore exploit the synergies between the two research domains "New Functional and Intelligent Materials and Surfaces, and New Sensing Applications" and "Sustainable Uses and Sources of Energy". Furthermore, New Sensing Applications could be used to monitor energy and heat consumption.

	Biomedical Sciences	Combining research in Regenerative Medicine and tissue engineering and research in "New Functional and intelligent Materials and Surfaces, including New Sensing Applications" can lead to the development of novel materials for bio-devices (cardio-vascular and other prostheses, encapsulation devices for cells or bioactive molecules, etc.) as well as new diagnostic tools and portable and low-cost sensing devices controlling physiological functions for translational medicine, and may lay the ground for a Luxembourg medical devices and diagnostic tools industry, in line with the MECO strategy.
	Regenerative Medicine in Age-related Diseases	Combining research in Regenerative Medicine and tissue engineering and research in "New Functional and intelligent Materials and Surfaces" can lead to the development of novel materials for bio-devices (cardio-vascular and other prostheses, encapsulation devices for cells or bioactive molecules, etc.) and may lay the ground for a Luxembourg medical devices and diagnostic tools industry.
	Public and Environmental Health	Applications of research focusing on New Sensing Applications can lead to new medical diagnostic tools, portable and low-cost sensing devices controlling physiological functions, therefore contributing to allow the development of telemedicine applications - on a European level, these are seen as important tools for improving people's access to healthcare and health information services. Further applications could be the monitoring of working and living conditions (safety at workplace, temperature and air circulation quality control in households, etc.).
	Translational Biomedical Research	Specific aspects of the research domain "New Functional and intelligent Materials and Surfaces, including New Sensing Applications" could lead to new medical devices and diagnostic tools, portable and low-cost sensing devices controlling physiological functions, and therefore in combination with Translational research help the development of a new diagnostic industry in Luxembourg.
	Technology Platform Modelling and Simulations	An essential part of research on new materials and surfaces lies in the analysis and characterisation of the developed materials. State-of-the-art analytical equipment is based on highly sophisticated technology and is thus expensive. Some analytical equipment has already been bought and installed, e.g. in the TRASU programme, but further funding is needed for progress in this domain. Research into novel materials and surfaces is to a great extent based on computational models of the studied materials at a molecular level in order to understand (and predict) their properties and interactions with the environment. Therefore, projects in this research domain should be strongly supported by scientific computation activities based on the Modelling and Simulations Platform. The Platform "Modelling and Simulations" can build, for instance, on competencies at the CRP Tudor (LTI division) where 17 FTE researchers are involved in research in this domain.

7.4 Biomedical Sciences

The following table summarizes the assessment of the umbrella priority "Biomedical Sciences" along the criteria presented in chapter 2.4. It should be noted that the assessment of this priority in the criteria table will *not include any additional information* not already given for one of the correspondent subdomains. **However, the criteria values for the "umbrella" notion** "Biomedical Sciences" **can not be expected to be the exact sum (or average) of the individual criteria values obtained for each research subdomain.** Rather, the assessment of the "umbrella" notion allows for adding weight to specific perspectives, emphasizing for instance some specific aspect within the broad domain "Biomedical Sciences" on which research should focus on, or for highlighting specific strengths or weaknesses.

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	Low	Some aspects of environmental health, included in the priority domain Public Health may have a high relevance for the environment but the other research aspects included in the umbrella priority "Biomedical sciences" do not have any direct or indirect impacts for the environment.
	C2. Economy	Medium	Biomedical Sciences contributes to the diversification of Luxembourg's economy and supports the long term sustainability of Luxembourg's economy. It will attract the highly profitable and high growth biomedical industry, which so far is hesitant to settle in Luxembourg, because of the lack of the required competencies. Research results will curb health costs of the Luxembourg population (e.g. reduce the number of days of sick-leave), increase labour productivity and optimize the efficiency of the health care system.
	C3. Society	High	Public research in this field is of high societal importance, especially in the context of an ageing society. It will improve the services of the health system, enhance health promoting behaviour and accelerate the translation of scientific results into clinical practice.
C4. Accordance with the political agenda in Luxembourg		High	The field is in line with the efforts of the Ministry of Economy and Foreign Commerce (MECO) to set up an action plan to develop the framework for a flourishing biomedical industry in Luxembourg, with the government's program "Vers un Plan National – Alimentation saine et activité physique" and the Health National Plan.

<table>
<tr><td rowspan="4">Feasibility</td><td>C5. Public and political acceptance</td><td>Mixed</td><td>Research in this field is highly welcome by the public as society and businesses alike will benefit from improved health care and new business opportunities. Only one sub-field of regenerative medicine (stem cell research) is highly controversial for ethical reasons.
The legal environment could be improved by the legal framework planned by the Ministry of Economy and Foreign Commerce. There are likely to be some legal problems as well as ethical concerns when establishing a tissue bank and when collecting or merging datasets.</td></tr>
<tr><td>C6. Private sector activities in Luxembourg</td><td>Low</td><td>The level of private sector activities is low, even though some steps are being taken by the MECO (esp. for translational medicine).</td></tr>
<tr><td>C7. Public research capacity in Luxembourg</td><td>Medium</td><td>Public research on age-related diseases is strong in Luxembourg (esp. within the BIOSAN and PROVIE programmes of the FNR), but research on regenerative medicine in general is weak. Research is also scarce in translational medicine even though it can draw on existing capacities for the diseases it is envisioned for, and research is surprisingly scarce in public health.</td></tr>
<tr><td>C8. Infrastructure / Critical Mass</td><td colspan="2"><table><tr><td>Critical mass (researchers)</td><td>About 120-130</td></tr><tr><td>Infrastructure and Equipment</td><td>Expensive laboratory equipment, Biomedical Technology Platforms (Tissue bank)</td></tr></table>
Given already existing competences within the BIOSAN and PROVIE programmes and the CRPs, critical mass can be achieved with 120-130 additional researchers. All three sub-priorities need small research teams of 4-10 people around a top scientist and, especially for translational medicine, need to establish interdisciplinary networks.
Currently, there are no research programmes in other countries that cover the same range of topics, so international comparison and assessment is not possible.</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">The field Biomedical Research is in line with the FP7.
International competition is very strong in this emerging field. Regenerative medicine’s promise of revolutionary curative treatments has been recognized by many countries in the world, and many neighbouring countries are conducting research in public health and translational medicine. But in order to address specific domestic needs it will be important for Luxembourg to develop its own domestic research capacities.</td></tr>
<tr><td colspan="2">C10. Contribution to national competences, scientific excellence and international reputation</td><td>Medium</td><td>Overall, scientific excellence can be reached under certain conditions: Especially tissue engineering for therapies of age-related diseases appears to be a promising issue for future public research in Luxembourg, if top scientists are recruited, research capacities are increased, the existing competences in age-related diseases are involved and the legal framework is reformed to create a favourable environment for biotechnology and biomedical industry. Due to Luxembourg’s small size that allows for exhaustive data collection, data collecting and monitoring for</td></tr>
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		Public Health research can be an advantage to reach international visibility. Research in translational medicine will help Luxembourg to keep up with the developments in biomedical research.

C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities identified	Fostering the economic and legal environment for innovation	Research aiming at "Fostering the economic and legal environment for innovation" should therefore take ethical and legal aspects of biomedical research into account, especially the commercialization of research results, and contribute to overcoming current legal hurdles in order to avoid that the development of a future competitive biotechnological industry in Luxembourg fails due to the lack of an adequate legal framework.
	Information Security and Trust Management	Research in information security and trust management should aim at ensuring the protection of data privacy so as to contribute to increasing the public acceptance of new e-Health solutions and biobanks.
	New Functional and intelligent Materials and surfaces, and New Sensing Applications	Combining research in Regenerative Medicine and tissue engineering and research in "New Functional and intelligent Materials and Surfaces" can lead to the development of novel materials for bio-devices (cardio-vascular and other prostheses, encapsulation devices for cells or bioactive molecules, etc.) as well as new diagnostic tools for translational medicine, and may lay the ground for a Luxembourg medical devices and diagnostic tools industry, in line with the MECO strategy. Applications of research focusing on New Sensing Applications can lead to new medical diagnostic tools, portable and low-cost sensing devices controlling physiological functions.
	Biobanks / Tissue Bank	For biomedical research in Luxembourg to be successful it is essential that Luxembourg research has access to large biobanks in Luxembourg and/or on the possibility for Luxembourg researchers to have access to biobank samples in other countries.
	Other Technology Platforms	The development of competencies (research infrastructure, researchers) in genomics, proteomics, coupled to bioinformatics and data analysis is essential for providing the ground for successful research in regenerative medicine and for personalized medicine. Furthermore, research in tissue engineering requires high competencies in three dimensional imaging technologies (confocal fluorescence microscopy, ultrasound…).

7.4.1 Regenerative Medicine in Age-related Diseases

Criteria		**Assessment**	**Justification**
Socio-economic	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.

contribution	C2. Economy	Medium	Since regenerative medicine and tissue engineering have the potential to develop therapies for previously untreatable diseases and conditions, as well as to improve or replace existing pharmaceutical treatments, market estimations for this field are very high. Tissue engineering in combination with the development of novel materials for bio-devices and analytical tools offers interesting economic opportunities for highly specialised spin-offs and start-ups; it can contribute to the diversification of Luxembourg's economy and – last but not least – also create economic benefit by curbing health costs (e. g. for age-related diseases, in particular neuro-degenerative diseases). Public research in regenerative medicine and tissue engineering can foster the development of a biotechnology industry in Luxembourg, by attracting biotechnology companies and renowned experts to Luxembourg. Taking into account, that life sciences and the biomedical field are considered as one of the most important industries of the 21st century, research in this domain may decisively support the long term sustainability and competitiveness of Luxembourg's economy.
	C3. Society	High	The social impact of public research in regenerative medicine - deemed as a "revolutionary approach that focuses on curing conditions as opposed to treating them" - can be very high as this technology has the potential to develop therapies for previously untreatable diseases and conditions, ranging from diabetes to cancer. In particular, regenerative medicine offers the prospect of extended healthy lifespans, as it may help repairing some of the damage caused by ageing, for instance by replacing tissues and organs to treat degenerative diseases and injury resulting from strokes, Alzheimer's and Parkinson's diseases and cardiovascular diseases. Public research in this domain is therefore of high societal importance in the context of an ageing population and the associated increase of age-related diseases; however, even if scientific progress in this research area is expected in the next 5-10 years, the translation of research results into clinical practice might require a longer timeframe.
C4. Accordance with the political agenda in Luxembourg		High	Since research in regenerative medicine and tissue engineering could contribute to lay the ground for the development of a competitive biotechnology and biomedical industry in Luxembourg, this priority is in line with the efforts currently carried out by the Ministry of Economy and Foreign Commerce (MECO) to set up an action plan to develop the framework for a flourishing biomedical industry in Luxembourg, basing on a recent study on the strengths, weaknesses, opportunities and threats for biotechnologies in Luxembourg. [Source: Biotechnology and Biomedicine in Luxembourg: The Strengths and Weaknesses, Ministry of Economic Affairs and Foreign Trade, 2006. In print.]

Feasibility	C5. Public and political acceptance	Mixed	On the one hand, tissue engineering offers prospects of a longer and healthier life. Research in this domain is therefore sure to be highly welcome by the public. Likewise, businesses will welcome the opportunity to engage in regenerative medicine projects as the expected revenues are likely to be high. On the other hand, one sub-field of regenerative medicine (stem cell research) is highly controversial for ethical reasons. The legal environment for research in biotechnology could be improved by the legal framework planned by the Ministry of Economy and Foreign Commerce. There are likely to be some legal problems as well as ethical concerns when establishing a tissue bank.
	C6. Private sector activities in Luxembourg	Low	Since regenerative medicine is a very young field of research, the level of private sector activities is low. Only Advanced Biological Laboratories and Cellon are active in the field of red biotechnology. There are some private laboratories (e.g. Laboratoire de Biologie Moléculaire et Cellulaire du Cancer (LBMCC)) working in the field of age-related diseases which are in the focus of this domain. Accumalux and International Supplier for Orthopedical Surgery - ISOS are interested in starting activities related to this domain.
	C7. Public research capacity in Luxembourg	Medium	Research in regenerative medicine as such actually doesn't play a role in Luxembourg at the moment and there are currently no research capacities in this specific domain[295]. However, given the fact that this priority aims at developing regenerative medicine in the specific case of age-related diseases, it should be noted that research in this domain is strong in Luxembourg, compared to other research domains, but limited compared to capacities abroad. About 120 people carry out research in the fields of oncology, cardiovascular diseases and neurodegenerative diseases alone, mainly at the CRP Santé. The UL has a Life Sciences Research Unit conducting extensive research on different subjects. Research on proteomics is conducted at the CRP Lippmann. With the BIOSAN and the PROVIE programmes, two important life sciences research programmes of the FNR address ageing and age-related diseases.

[295] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

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<td>C8. Infrastructure / Critical Mass</td>
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<table>
<tr><td>Critical mass (researchers)</td><td>About 60</td></tr>
<tr><td>Infrastructure and Equipment</td><td>Expensive laboratory equipment, Biomedical Technology Platforms (Tissue bank)</td></tr>
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With the BIOSAN and the PROVIE programmes, age-related diseases are already an established field of research in Luxembourg with about 40 researchers. This field is to be systematically expanded with a focus on regenerative medicine. During the workshop, four to five additional groups of 10 to15 people around a top scientist with an annual budget of 2 to 3 M€ per group were stated as a good scale to develop internationally competitive research – totalling to about 10 to 15 M€ p.a. This figure seems to be adequate in international comparison.
Regenerative medicine is internationally a rapidly developing and highly competitive field with increasing public research budgets. At Leipzig, a Fraunhofer-Institute for Cell Therapy and Immunology has been founded in 2005 with an investment of 60 M€ to which recently a Translational Centre for Regenerative Medicine has been added (another 20 M€). The Manchester Stem Cell Network (at Manchester University) has 29 senior researchers as members (mostly chairs).
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<td colspan="2">C9. International research context</td>
<td>International competition is very strong in this emerging field. Regenerative medicine's promise of revolutionary curative treatments has been recognized by many countries in the world: the USA, Great Britain (with the Manchester/Liverpool Tissue Engineering Centre), Germany (where important research programmes are running on rare diseases, handicaps and regenerative medicine), Sweden, Japan (Cell therapy and regenerative medicine research are one of the key components of the Kobe Medical Industry Development program), China (China has committed a $1 billion initial investment towards establishing regenerative medicine research), Singapore (a funding programme to promote quality research in human pluripotent stem cells), and Australia have all begun making strong national commitments with hopes of achieving their own advances in regenerative medicine technology. [Source: WTEC Panel Report on Tissue Engineering Research, International Technology Research Institute, 2002. http://www.wtec.org/loyola/te/final/te_final.pdf]
This research area is also already an important research field in EU research policy (with about 17 research centres engaged in the field) and will receive even more budget in FP7. 13 institutions from 4 EU Member States are represented in the Top 50 of public institutions with most authors occurring in scientific publications related to tissue engineering research. [Source: Bock, A. K. et al. (2003) ESTO/IPTS Report "Human tissue-engineered products - Today's markets and future prospects"]
As presented in the German High-Tech Strategy, in addition to its leading role in medical technology, Germany is also striving for a top position in the area of regenerative medicine.
[Source: Federal Ministry of Education and Research, The High-Tech Strategy for Germany, 2006]. In this context, the recent conference Regenerative Medicine in Germany and France – State of the Art and Future Perspectives (25.04.07) brought together experts from Germany and France.</td>
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		In France, the Competitivness Cluster "Atlantic Biotherapies" supports research related to cell and gene therapy, tissue and cell engineering.	
C10. Contribution to national competences, scientific excellence and international reputation		Medium	While the international competition in regenerative medicine is very high, there is practically no expertise in this domain and only a very low level of private sector activities in red biotechnology at the moment in Luxembourg. However, especially tissue engineering for therapies of age-related diseases appear to be a promising issue for future public research in Luxembourg, if top scientists are recruited, research capacities are increased, the existing competences in age-related diseases are involved and the legal framework is reformed to create a favourable environment for biotechnology and biomedical industry.
C11. Cross-linkages with other Priorities identified		Justification	
C11. Cross-linkages with other Priorities identified	Fostering the economic and legal environment for innovation	Regenerative medicine and tissue engineering research offer the potential for laying the ground for a flourishing biomedical industry in Luxembourg, providing the right and adequate legal framework can be developed in Luxembourg. Research aiming at "Fostering the economic and legal environment for innovation" should therefore take ethical and legal aspects of research in regenerative medicine and especially of the commercialization of research results *explicitly* into account and contribute to overcoming current legal hurdles in order to avoid that the development of a future competitive biotechnological industry in Luxembourg fails due to the lack of an adequate legal framework.	
	New Functional and intelligent Materials and surfaces, and New Sensing Applications	Combining research in Regenerative Medicine and tissue engineering and research in "New Functional and intelligent Materials and Surfaces" can lead to the development of novel materials for bio-devices (cardio-vascular and other prostheses, encapsulation devices for cells or bioactive molecules, etc.) and may lay the ground for a Luxembourg medical devices and diagnostic tools industry.	
	Public and Environmental Health	One of the most important challenges to be faced in Western countries in the near future by public health policies and public health research is the ageing of the population. Research in Public Health should therefore take scientific and technological progress in regenerative medicine into account, as regenerative medicine offers the promise of revolutionizing the way to address age-related diseases.	
	Translational Biomedical Research	Translational research will help to transfer the results of research in regenerative medicine and tissue engineering into clinical practice and therefore contribute to increase the impact of research in regenerative medicine on society and economy.	
	Biobanks / Tissue Bank	For research in regenerative medicine and tissue engineering in Luxembourg to be successful and competitive - especially given the very high international competition in this domain - it is essential that Luxembourg researchers have access to biomaterials, pluripotent cells, etc. and therefore research in regenerative medicine is highly dependent on the availability of large biobanks in Luxembourg and/or on the possibility for Luxembourg researchers to have access to biobank samples in other countries.	

	Other Technology Platforms	The development of competencies (research infrastructure, researchers) in genomics, proteomics, coupled to bioinformatics and data analysis is essential for providing the ground for successful research in regenerative medicine and tissue engineering. The other way around, the development of these technology platforms will therefore benefit from an increased funding in the future and is expected to boost research in regenerative medicine. Furthermore, research in tissue engineering requires high competencies in three dimensional imaging technologies (confocal fluorescence microscopy, ultrasound…).

7.4.2 Public and Environmental Health

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	Low	The majority of research aspects in the domain of public health do not have any relevance for environmental aspects, but environmental health is certainly related to the environment. However, environmental health research and policies primarily aim to improve human health via the environment, and are not focused on protection of ecosystems per se. Still, measures taken to reduce human risk can have a purely environmental benefit, improving ecosystem functioning as a result of the measures taken to improve human health.
	C2. Economy	Medium	Research in Public and Environmental Health produces direct and indirect economic benefits for companies and for Luxembourg's economy as a whole. The successful implementation of research results into public health policies increases the efficiency of the health care system, reduces health care costs and lessens therefore the burden of social security; it contributes also to reducing the number of days of sick-leave and to increasing labour productivity. Research in Public Health is furthermore of high importance to reduce the additional health care costs due to an ageing population. Rather the same applies to research on Environmental Health. It should be emphasized that the economic cost of remediating the disease burden attributable to environmental factors is very high (estimated 2 to 3% of the GDP in Europe). A better understanding of cause-effect relations can help reducing these losses. In addition, there is the cost to society in lost productivity over the lifetime of the affected individual.

	C3. Society	High	Research in Public Health will directly contribute to guarantee a high quality of health services and improve population's health by developing and implementing a proactive approach to health and by fostering the economic viability of the health system. One specific aim is to raise the awareness among citizens on health issues and to enhance health promoting behaviours - especially regarding the prevention of life-style diseases (e. g. cardiovascular diseases and other diseases related to obesity). In the long run, it may additionally increase the education level of the whole population (as children with better health and nutrition achieve higher educational attainment). Research in environmental health, especially regarding the impact of air pollution indoors and outdoors on human health will provide the knowledge base and concrete measures by which environment and health research results will be fed into policy-making promoting the population's health.
C4. Accordance with the political agenda in Luxembourg		High	The research issues identified (Health information and promotion, Assessment and equity of the health care system) are in line with the government's programme presented in August 2004, the objectives presented in the document "Vers un Plan National - Alimentation saine et activité physique" set up by the Luxembourg Ministry of Health - and therefore with the objectives of the future Health National Plan - as well as with the activities of the Ministry of Health in order to provide health information directly to the citizens; optimisation of health care services through the use of ICT tools - "Healthnet project"; environmental health activities, etc.) [Sources: "Vers un Plan National - Alimentation saine et activité physique", Ministry of Health; Rapport d'activités, Ministry of Health, 2005]
Feasibility	C5. Public and political acceptance	Favourable	Research in Public and Environmental Health is highly welcome by the general public as direct benefits for personal health and wellbeing are obvious. Improving the health and stress resistance of employees is also of interest to businesses. There may be legal problems when collecting or merging datasets; legal problems and ethical concerns may arise when establishing a biobank of living people supplementing the existing biobank of deceased people.
	C6. Private sector activities in Luxembourg	Low	There are some private sector activities related to public and environmental health issues. E.g. Luxcontrol has expertise in Environmental and Health & Safety analyses. Advanced Biological Laboratories is conducting research on infectious diseases.

	C7. Public research capacity in Luxembourg	Medium	According to a recent survey[296], about 22 FTE researchers are currently carrying out public health research in Luxembourg - the overwhelming majority of them at the CRP Santé, but there are also some competencies at the CEPS/INSTEAD. In contrast, public research capacities in environmental health are quite scarce: only 2 FTE researchers at the Laboratoire National de Santé are involved in research in this domain. Research on public health is conducted mainly in the range of epidemiology (cf. for instance the research group SETT- Epidemiology and Technology Transfer Service at the CRP Santé). There are few activities in the other research issues envisioned (health information and promotion, assessment of the health care system), e.g. minor data collection programmes at the Laboratory of Health and the CRP Santé. Other existing databases to which access is needed in order to conduct public health studies are not sufficiently utilised or interlinked.

[296] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

C8. Infrastructure / Critical Mass

Critical mass (researchers)	About 50
Infrastructure and Equipment	Biomedical Technology Platforms (e. g. biobanks)

Public health as defined during the foresight exercise is a broad interdisciplinary field, in fact an umbrella for research on determinants for public health, on epidemiology, on economic aspects of the health system, on efficient prevention, etc., including longitudinal studies (e. g. on the relation between exposure and effect). Workshop participants estimated that environmental health, taken alone, needs a team of about 30 researchers as critical mass. All topics of public health research require additionally sound scientific Biomedical Technology Platforms: state of the art bio-banking and bioinformatics, versatile laboratories (genomics, proteomics, analytical chemistry) using up-to-date analytical tools and tools for biomedical nanotechnology. Two researchers for each platform, as estimated in the workshop, seems to be rather the lower limit, even taking into account that human and technical resources already exist.
There are different international models for comparison: from the very large RIVM – Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Health and Environment) in the Netherlands (http://www.rivm.nl/en/aboutrivm) to institutes specialised in certain questions about health economy or medical care research like the Interdisciplinary Centre for Public Health of University Erlangen-Nürnberg (http://www.public-health.med.uni-erlangen.de/) with 24 senior scientists as members and a staff of 12 junior researchers or the rather small Department for Public Health at Hamburg University of Applied Sciences with 11 senior and junior researcher (http://www.public-health-forschung.de/mitarbeiter.html/).

C9. International research context

This research priority is in line with the European research objectives for FP7, where health policy driven research will be strongly reinforced. One of the main FP7 Health-related activities aims at improving the health of European citizens and preventing and treating major diseases. The area "Enhanced health promotion and disease prevention" research of FP7 will look into developing evidence for effective public health interventions addressing wider determinants of health (such as stress, diet or environmental factors) at both the individual and community level.[297] The following research topics will be addressed by the second FP7 call on health: Promoting healthy behaviour in children and adolescents (HEALTH-2007-3.3-1), Interventions addressing the gradient of health inequalities (HEALTH-2007-3.3-2), Public health interventions addressing the abuse of alcohol (HEALTH-2007-3.3-3), Evaluation of suicide prevention strategies across and within European countries (HEALTH-2007-3.3-4), Improve vaccination coverage (HEALTH-2007-3.3-5).
FP7 will also fund research projects aiming at assessing the quality, efficiency and solidarity of health care systems including transitional health systems. The following topics will be addressed by the second FP7 call on health: Evaluation of disease

[297] [Source: http://cordis.europa.eu/fp7/cooperation/health_en.html]. Further information: Presentation of «Health research in the 7th Framework Programme» at FP7 launch, Jan. 2007. Cf. also the FP6-project "Strengthening Public Health research in Europe".

	management programmes (HEALTH-2007-3.2-1), Health systems and long term care of the elderly (HEALTH-2007-3.2-2), Mobility of health professionals (HEALTH-2007-3.2-3), Health care human resource planning in nursing (HEALTH-2007-3.2-4), Clinician working time and patient safety (HEALTH-2007-3.2-5), Health outcome measures and population ageing (HEALTH-2007-3.2-6), Trends of population health (HEALTH-2007-3.2-7). [Source: European Commission, WORK PROGRAMME 2007, COOPERATION - THEME 1 HEALTH] *Regarding the specific aspects of Environmental Health:* The European Commission developed a Environment and Health Action Plan 2004-2010, presented at the Fourth Ministerial Conference on Environment & Health in Budapest in June 2004, designed to give the EU the scientifically grounded information needed to help all 25 EU Member States to reduce the adverse health impacts of certain environmental factors and to endorse better cooperation between actors in the environment, health and research fields. [Source: Communication from the Commission to the Council, the European Parliament, the European Economic and Social Comittee: "The European Environment & Health Action Plan 2004-2010", Brussels, 9.6.2004 COM(2004) 416 final, http://ec.europa.eu/environment/health/pdf/com2004416.pdf] Typically, many countries are supporting public health research adapted to domestic needs. For instance, the German High-Tech Strategy will bundle individual campaigns and projects for introducing new medical technologies. Modern information technologies such as the electronic health card will improve medical care for the individual. [Source: Federal Ministry of Education and Research, The High-Tech Strategy for Germany, 2006]. Also Luxembourg has an interest in promoting domestic research in public health - regardless of potential high international competition in this field - in order to tackle Luxembourg specific needs and obligations. Regarding research on environmental health, there might be opportunities for researchers to collaborate with the "Laboratoire Écotoxicité et Santé Environnementale" of the University of Metz and the University of Nancy.	
C10. Contribution to national competences, scientific excellence and international reputation	High	Luxembourg should build up a solid research capacity in this domain in order to provide an innovative and efficient health care system for its people and to cope with ever increasing environmental health issues. Many innovative approaches in this field are based on intense data collecting and monitoring of health data and environmental parameters. Here, Luxembourg's small size allows for quasi exhaustive data collection and can thus be an advantage to reach international visibility in this field.
C11. Cross-linkages with other Priorities identified	Justification	

C11. Cross-linkages with other Priorities	Innovations in Services	At a European level, research focusing on new innovative health-related services, and especially on e-Health services (telemedicine, etc.) is deemed as very promising in order to improve the efficacy of Public Health policies and should therefore be addressed jointly with public health researchers.
	Business Service Design and Innovation	As research in "Business Service Design and Innovation" also covers e-Health applications - seen as very promising for future Public Health policies and actions, there will obviously be some overlaps between research in "Business Service Design and Innovation" and Public Health research.

	Information Security and Trust Management	Research in Public Health related to e-Health applications should take progress in research in "Information Security and Trust Management" into account, since implementing the best secure IT solutions available will contribute to increasing the acceptance of new e-Health solutions.
	Telecommunications and Multimedia	At a European level, ICT applications to health, like e-Health and telemedicine, are deemed as an important future instrument of public health policies, providing tools for improving people's access to healthcare and health information services. Therefore synergies between the two domains "Public Health" and "Telecommunications and Multimedia" should be exploited in future research programmes in order for Luxembourg to exploit fully the potential of new ICT technologies for improving Public Health.
	Understanding Ecosystems and Biodiversity	Although environmental health research and policies primarily aim to improve human health via the environment, and are not focused on the protection of ecosystems per se, the measures taken to reduce human risk can have a purely environmental benefit, improving ecosystem functioning as a result of the measures taken to improve human health.[298] The potential synergies between the priorities "Environmental Health" and "Biodiversity and Ecosystem Functions" should therefore be exploited to the full when implementing future research programmes.
	Sustainable Agro-Systems Management	There are obvious links between nutritional aspects of Public Health research and research issues related to food production in the priority domain "Sustainable Agro-Systems Management". Of course, environmental health issues are also linked to the domain "Sustainable Agro-Systems Management".
	Spatial and Urban Development	Research in Public Health should aim at bridging the rural-urban health care divide and should therefore take aspects related to spatial and urban development into account.
	Identities, Diversity and Integration	One of the important objectives of Public Health policies and Public health research should be to bridge the healthcare divide in society and to improve access to healthcare and health prevention services for socially deprived population groups/ high risk groups, contributing therefore to improving social cohesion and social inclusion.
	Labour Market, Educational requirements and Social Protection	Public Health research should include aspects regarding the quality of employment (e.g. jobs compatible with skills and expectations, matching reward and effort, control of work, exposure to risk and unsafe working conditions, job security, job turnover, flexibility, and social dialogue, amongst other things) as one of the important determinants of good health and well-being (e.g. SHARE, 2005; "Health and Quality in Work", 2005; WHO European Health Report 2002). Research aiming at adapting work practices and working conditions – e.g. ending discrimination, creating barrier-free workplaces and promoting flexibility for employees – will help workers maintain their health. [Source: COMMISSION STAFF WORKING DOCUMENT, Joint Report on Social Protection and Social Inclusion, SUPPORTING DOCUMENT, Brussels, 6.3.2007 SEC(2007) 329]

[298] Commission Staff Working Document, Communication From The Commission To The Council, The European Parliament, The European Economic And Social Committee "The European Environment & Health Action Plan 2004-2010", Extended Impact Assessment {COM(2004) 416 final, Brussels, 9.6.2004, SEC(2004) 729

	New Functional and intelligent Materials and surfaces, and New Sensing Applications	Applications of research focusing on New Sensing Applications can lead to new medical diagnostic tools, portable and low-cost sensing devices controlling physiological functions, therefore contributing to allow the development of telemedicine applications, deemed at European Level as important tools for improving people's access to healthcare and health information services. Further applications could be the monitoring of working and living conditions (safety at workplace, temperature and air circulation quality control in households, etc.).
	Regenerative Medicine in Age-related Diseases	One of the most important challenges faced or to be faced in Western countries in the near future by public health policies and public health research is the ageing of the population. Research in Public Health should therefore take scientific and technological progress in regenerative medicine into account, as regenerative medicine offers the promise of revolutionizing the way to address age-related diseases.
	Translational Biomedical Research	The priority domain "Translational Biomedical Research" is obviously related to Public Health research and the Public Health sector as the transfer of research results from the laboratory to the hospital and public health services (generating applicability) will provide new impulses for improving public health measures, clinical procedures and cures. There are also linkages between translational research and research in Environmental Health as research results in this last field have also to be implemented into practice to reduce the negative effects of the environment on human health.
	Biobanks / Tissue Bank	Databases and biobanks are the necessary precondition of epidemiology and of public health decision making and research and policy-makers should be aware of the necessity to develop biobanks - insufficiently available or insufficiently interlinked in Luxembourg at the moment - and research in Public Health in parallel. Luxembourg research in Public Health could highly benefit from setting up a surveillance system: taking Luxembourg's size into account, it should be possible to uniformly collect medical records and to efficiently access and link data.
	Other Technology Platforms	Research in Public Health and epidemiology requires developing new biomarkers and validating existing ones. There are a lot of biomarkers available at the moment for different diseases and different infectious agents but most of them still need to be validated and tested. Furthermore, high-throughput technologies available today have made it easier to develop new biomarkers.

7.4.3 Translational Biomedical Research

Criteria		Assessment	Justification
Socio-economic contribution	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.
	C2. Economy	Medium	Translational Biomedical Research is generally defined as a multidisciplinary research activity which is focussed on translating basic research findings into a useful therapeutic drug candidate or diagnostic tool. This is being achieved by using disease relevant animal models and a select small patient population to establish a proof -of - concept for a given experimental drug candidate or diagnostic tool. It will therefore by its nature create the competencies necessary to attract high profile innovative clinical studies to the hospitals in Luxembourg and more importantly create the basis to attract the highly profitable and high growth biomedical industry to Luxembourg, which so far has been hesitating to settle in Luxembourg, because of the lack of the required competencies. Translational Biomedical Research will furthermore contribute to reducing the health costs by increasing the efficiency of health care delivery; it contributes also to reducing the number of days of sick-leave and to some degree to increasing labour productivity. In view of expected rising health costs due to an ageing population, successful translational research – in particular in chronic and age-related diseases – will be an asset for Luxembourg. Taking into account, that life sciences are considered as one of the most important industries of the 21st century, research in this domain may even support the long term sustainability of Luxembourg's economy.
	C3. Society	High	The building of competencies in translational research should attract innovative biomedical development programs to Luxembourg and as such should give better access to the most innovative medicines be it devices, diagnostics or therapeutics to the local people. These programs should also increase public awareness of the tremendous efforts happening in the biomedical research worldwide. The specific research issues identified during the FNR Foresight and to be addressed by future public research in Luxembourg - personalized medicine, the control of antiviral and antimicrobial drug resistance and especially the translation of clinical research into clinical practice for the treatment of cardiovascular, neurological and infectious diseases and cancer - are projected to allow improved treatment efficacies and better diagnostic tools, which will benefit the patient.
C4. Accordance with the political agenda in Luxembourg		High	Since translational research is expected to lay the ground for the development of a medical devices industry (e.g. diagnostic tools, etc.) in Luxembourg, this priority is in line with the efforts currently carried out by the Ministry of Economy and Foreign Commerce (MECO) to set up an action plan to develop the (legal)

			framework for a flourishing biomedical industry in Luxembourg, basing on a recent study on the strengths, weaknesses, opportunities and threats for biotechnologies in Luxembourg. [Source: Biotechnology and Biomedicine in Luxembourg: The Strengths and Weaknesses, Ministry of Economic Affairs and Foreign Trade, 2006. In print.]
Feasibility	C5. Public and political acceptance	Favourable	By its practical and tangible nature, public acceptance of this research domain is high. Being a highly regulated discipline worldwide according to strict ethical standards, a legal framework must exist or must be adapted for Luxembourg. For example accessing human tissue banks require specific regulatory and legal frameworks which may have to be put into place prior to establishing a program.
	C6. Private sector activities in Luxembourg	Low	This sector is not yet developed in Luxembourg, however first steps are being taken by the Ministry of Economy and Foreign Commerce.
	C7. Public research capacity in Luxembourg	Low	According to a recent survey[299], there are no researchers actually involved in translational research at the moment in Luxembourg and only few activities (e.g. some aspects of the activities of the Epidemiology and Technology Transfer Service at the CRP Santé) in translational research in Luxembourg. However, as an interdisciplinary research domain, Translational Biomedical Research draws on existing competences and renommée in medical research, mainly at the CRP Santé and the UL, which covers most of the specific groups of diseases envisioned for research: according to the study cited above, there are at the CRP Santé 10.5 FTE researchers involved in research related to cardiovascular diseases, 7.25 FTE researchers involved in research related to neurological diseases, and 44 FTE researchers in oncology.

[299] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

<table>
<tr><td></td><td>C8. Infrastructure / Critical Mass</td><td>
<table>
<tr><td>Critical mass (researchers)</td><td>About 10 to 20</td></tr>
<tr><td>Infrastructure and Equipment</td><td>Some equipment, Biomedical Technology Platforms</td></tr>
</table>
Translational research is aimed at improving the interfaces between fundamental research, clinical application and public health and technology transfer. It requires therefore small, but well networked interdisciplinary teams related to the most important groups of diseases. Taking into account, that there is already an established research base for different groups of diseases, 2 to 4 teams of 5 to 10 researchers seem adequate.
For comparison: The DTCB (Danish Centre for Translational Breast Cancer Research) has a research unit of 7 researchers (http://www.dctb.org/site/75/493/). The Translational Research Group at the Institute Curie, specialised in different kinds of cancer, also has a staff of 7 (http://www.curie.fr/recherche/themes/equipe_histoire.cfm/id_equipe/37/lang/_gb.htm).
</td></tr>
<tr><td colspan="2">C9. International research context</td><td>The specific diseases to be addressed by Luxembourg research are in line with the FP7 objectives: Translational research - already supported within the 6th Framework Programme[300] - is emphasized in the 7th Framework Programme where research activities addressing translational research related to cancer, cardiovascular diseases, diabetes / obesity but also rare and chronic diseases as well as infectious diseases will be funded in order to confront major threats to public health.
[Source: http://www.technion.ac.il/~liaison/fp7/health.html#2]
There are, at an international level, many research activities in this field: for instance, in the USA (e.g. Center for Clinical and Translational Sciences (CCTS) of the University of Texas, Irving Institute for Clinical and Translational Research of the Columbia University, etc.[301]), in Japan (Kobe Translational research centre), in the UK[302], France, Italy - to name but a few. Improving the efficiency of the translation of medical research results into practice is one of the aims of the Roadmap for Medical Research set up by the US-National Health Institutes in 2006[303] and translational research is also highlighted in the new “High-tech Strategy for Germany”[304] which foresees the set up of “Translational research clusters” with the aim of accelerating the translation of research findings into public health and practice. However, as for public health research, it might be important for Luxembourg to develop domestic research capacities – despite of a high competition in this research domain - in order to address specific needs.</td></tr>
</table>

300 http://ec.europa.eu/research/fp6/index_en.cfm?p=1. The total EC contribution committed to discovery and translational research activities for PRD under FP6 is more than 255M euros. http://ec.europa.eu/research/health/poverty-diseases/fp6projects_en.html

301 A list of translational research activities funded by the National Institutes of Health in the USA can be found on: http://nihroadmap.nih.gov/clinicalresearch/fundedresearch.asp.

302 In the UK, the importance of translational research has been highlighted for instance in the ‘Science & Innovation Investment Framework 2004-2014: next steps’ has a stated objective – ‘*to ensure the delivery of high-quality translational health research to deliver real economic, as well as health, benefits, from the UK’s excellent science base*’ (2006).

303 http://nihroadmap.nih.gov/clinicalresearch/index.asp

304 http://www.bmbf.de/pub/bmbf_hts_lang.pdf

C10. Contribution to national competences, scientific excellence and international reputation	Medium	Translational Biomedical Research is a promising and innovative approach for accelerating the transition of research findings into public health and clinical practice. Luxembourg should therefore aim at building up capacities in this domain in order to keep up with the developments in biomedical research. However, international competitiveness might only be reached if Luxembourg's researchers focus on specific aspects and diseases where already some competencies exist.
C11. Cross-linkages with other Priorities identified	Justification	
C11. Cross-linkages with other Priorities identified	Fostering the economic and legal environment for innovation	Given the right legal framework, translational research may promote biomedical spin-offs capitalizing on patents derived from research results and therefore help laying the ground for a new biomedical industry in Luxembourg. Hence, given this important economic potential of translational research, research aiming at "Fostering the economic and legal environment for innovation" should take the requirements of translational research - regarding patenting, commercializing or research results, etc. - *explicitly* into account and contribute to overcoming current legal hurdles.
	Information Security and Trust Management	The necessity of the availability of tissue banks and biobanks for the successful development of translational research poses new challenges to research in information security: research in this domain should aim at ensuring the protection of data privacy so as to overcome some ethical problems related to biobanks and increase the public acceptance of biobanks.
	New Functional and intelligent Materials and Surfaces, and New Sensing Applications	Specific aspects of the research domain "New Functional and intelligent Materials and Surfaces, and new sensing applications" could lead to new medical devices and diagnostic tools, and therefore in combination with Translational research help the development of a new diagnostic industry in Luxembourg. This is in line with the strategy of the Ministry of Economy and Foreign Commerce (MECO). Applications of research focusing on New Sensing Applications can lead to new medical diagnostic tools, portable and low-cost sensing devices controlling physiological functions.
	Regenerative Medicine in Age-related Diseases	Translational research will help to transfer the results of research in regenerative medicine and tissue engineering into clinical practice and therefore contribute to increase the impact of research in regenerative medicine on society and economy.
	Public and Environmental Health	The priority domain "Translational Biomedical Research" is obviously related to Public Health research and the Public Health sector as the transfer of research results from the laboratory to the hospital and public health services (generating applicability) will provide new impulses for improving public health measures, clinical procedures and cures. There are also linkages between translational research and research in Environmental Health as research results in the latter field have also to be implemented into practice to reduce the negative effects of the environment on human health.
	Biobanks / Tissue Bank	Given an adequate legal framework for biomedical research, translational research would benefit from the set up of a tissue bank and a pathogen bank as well as from the set up of a clinical investigation centre carrying out applied clinical research - which would also be of benefit to new public health research and policies.
	Other Technology Platforms	The development of competencies (technical infrastructure, researchers) in genomics and proteomics is a sine qua non for furthering research aiming at developing personalized medicine and therapies, as these Technology Platforms allow tailoring the most suitable pharmacotherapy for the each patient, based on individual profiling.

7.5 Labour Market, Educational Requirements and Social Protection

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.
	C2. Economy	High	Research addressing Labour Market, Educational Requirements and Social Protection is highly important as it concerns the long-term sustainability of the whole social and economic system. Although Luxembourg has the highest living standard and one of the lowest unemployment rates in Europe, unemployment and – as a main cause of it – the gaps between labour supply and labour demand pose a real challenge. Improving the match would have tremendous positive effects both for the economy and the social security system. Public research focused on these issues could aim at developing new or better incentives for work participation (i.e. new retirement schemes) and diversifying Luxembourg's economy while maintaining social cohesion, stability and security. New and/or more flexible work models – adapted to a knowledge economy and combined with life-long learning and work-life balancing – could play an important role here. Research that fosters the development of new work models and that improves the match between labour demand and labour supply would also help to avoid "brain drain", to attract high skills to Luxembourg and to increase competitiveness.
	C3. Society	High	Research in the domain "Labour Market, Educational requirements and Social Protection" will aim to stem the rising unemployment in Luxembourg, to increase the match between labour supply and labour demand, to adapt the educational system to a modern knowledge society, to increase social cohesion and stability by addressing aspects like social inclusion, gender issues, migration issues, etc., and last but not least, to assure the long-term sustainability of the Luxembourg social security system by reducing the negative impact of demographic ageing.
C4. Accordance with the political agenda in Luxembourg		High	This research priority is in line with the government's programme presented in August 2004, the guidelines for employment policies developed in the National Action Plan for Innovation and Full Employment and with the objectives of the government, as announced by Luxembourg's Prime Minister Jean-Claude Juncker on 9 May 2007 on the occasion of the traditional declaration on the social, economic and financial situation of the country related to: improving the match between labour supply and labour demand through better education, promoting the social inclusion in the labour market. Issues related to the ageing workforce (life long learning tools, work models and working conditions, educational requirements for the labour force, the social inclusion in the labour market, gender equity on the labour market, etc. - identified as promising research issues for this priority - were also already addressed in the National Action Plan for Employment, set up in 2004.

			[Sources: Jean-Claude Juncker, Déclaration du gouvernement sur la situation économique, sociale et financière du pays 2007, 09.05.2007, http://www.gouvernement.lu/salle_presse/actualite/2007/05/09etatnation/index.html#8; Plan National d'Action pour l'Emploi, 2004; National Action Plan for Innovation and Full Employment, 2006].
Feasibility	C5. Public and political acceptance	Mixed	Luxembourg data protection laws prohibit the merging of datasets from different sources (e.g. "Administration de l'Emploi" or "Inspection Generale de la Securite Sociale") which poses significant problems for some of the research envisioned in this domain. Public acceptance is high as research will improve the economic success and welfare of Luxembourg.
	C6. Private sector activities in Luxembourg	Medium	There are several consulting firms in Luxembourg with competencies in recruitment and human resources (e.g. Deloitte, Hudson/DeWitte&Morel, Schneider Consulting) capable of conducting research in this domain. Insurance companies (e.g. AXA, La Luxembourgeoise, Euresa-Life) may be potential partners for projects related to social protection.
	C7. Public research capacity in Luxembourg	Medium	Established expertise and public research activities on the labour market in Luxembourg are existing at the STATEC (demographic statistics), the CEPS/INSTEAD (e. g. social security modelisation; according to a recent survey[305] 10 FTE researchers are involved in research focusing on the social and economic aspects of this priority domain), the CITI - Centre d'Innovation par les Technologies de l'Information, CRP Tudor (according to the survey cited above, about 10 FTE researchers are involved in research focusing on the social and economic aspects and 10 FTE researchers involved in research focusing on the educational aspects of this priority domain) and the UL (e. g. educational measurement and applied cognitive science, language learning, unemployment, socio-economic change (INSIDE); new competences will be developed at the UL (3 chairs)). The FNR VIVRE programme has funded some research on the labour market, too. Studies are carried out on the macro level (national economy level) as well as on the micro level, but there seems to be a need for more research on the micro level, e. g. addressing career trajectories ("transitional labour markets") and long-term projects.

[305] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

<table>
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A specific unit at a public research institution is needed to carry out more basic, long-term research. This unit (or Centre of Competence) should also include positions for visiting scientists. Internationally, one could e. g. draw a comparison with the European Foundation for the Improvement of Living and Working Conditions in Dublin (www.eurofound.europa.eu), which has research teams of 8 persons for each specific topic. Three or four groups of that size could make up the necessary critical mass for the research priority.</td></tr>
<tr><td colspan="2">C9. International research context</td><td colspan="2">Luxembourg's labour market has many specific and intriguing features, which make this domain scientifically attractive for researchers. As a small economy with a large proportion of immigrants and cross-border workers in the working population, Luxembourg has a quite peculiar labour market. For this reason, research results stemming from other countries can not simply be "translated" for Luxembourg; there is a need for domestic research in this domain. Considering the size of the Luxembourg research community, international cooperation, first of all within the Greater Region, is not an option but a necessity. The 7th Framework Program explicitly invites cooperation on "growth, employment and competitiveness in a knowledge society" (with the topics of "innovation, competitiveness and labour market policies"; "education and life-long learning"; "economic structures and productivity"). [Source: http://cordis.europa.eu/fp7/cooperation/socio-economic_en.html]
Within the Greater Region, there might be opportunities for researchers to collaborate with the "Institut für Arbeitsrecht und Arbeitsbeziehungen in der EG (IAAEG)" of the University of Trier, with the "Trierer Arbeitsgemeinschaft für Umwelt-, Regional- und Strukturforschung e.V. (TAURUS)", the "Laboratoire Interuniversitaire des Sciences de l'Education et de la Communication" of the University of Nancy.</td></tr>
<tr><td colspan="2">C10. Contribution to national competences, scientific excellence and international reputation</td><td>Medium</td><td>Due to the many specific and intriguing features of Luxembourg's labour market, research results from other countries can not be simply translated for Luxembourg and domestic research in Luxembourg is needed in this domain. On the other hand, the small size of the Luxembourg research community in this field make an international cooperation (within the Greater Region) a necessity. International visibility can only be achieved if Luxembourg's researchers engage in more fundamental questions in this research domain, go beyond applying existing methodologies and consider longer time horizons.</td></tr>
<tr><td colspan="2">C11. Cross-linkages with other Priorities identified</td><td colspan="2">Justification</td></tr>
</table>

C11. Cross-linkages with other Priorities identified	Innovations in Services	Since employment in services accounts for about 75 % of total employment in Luxembourg, there will clearly be some overlaps between research related to “Innovation in services” and research related to “Labour Market, Educational requirements and social protection”. In particular, the trend towards knowledge-based and information intensive services has had an influence on the educational requirements, qualifications and skills needed on the labour market. For instance, specific issues regarding to life-long learning and specific work skills required in the information society should therefore be addressed in multidisciplinary research projects.
	Business Service Design and Innovation	Applications of research in “Business Service Design and Innovation” leading to new e-learning tools and services, adapted to the requirements of a new knowledge economy, are of course, strongly linked to the priority “Labour Market, Educational requirements and Social Protection”.
	Fostering the economic and legal environment for innovation	Research aiming at “Fostering the economic and legal framework for innovation” should take aspects related to education, work qualifications, ageing workforce (is an ageing workforce less innovative?), etc. into account.
	Performance and Development of Financial Systems	There are links between some research topics in “Performance and Development of Financial Systems” related to retirement funds and retirement planning or financial education and corresponding issues in the domain “Labour Market, Educational requirements and Social Protection”.
	Telecommunications and Multimedia	Research in “Multimedia” could lead to multilingual multimedia applications and especially to life-long learning tools or multilingual translation tools, which would also be of interest for the research priority “Labour Market, Educational requirements and Social Protection”, contributing to strengthening social inclusion in the labour market (especially against the background of an ageing workforce).
	Spatial and Urban Development	There are clear linkages between the priorities “Labour Market, Educational requirements and Social Protection” and “Spatial and Urban Development” related, for instance, to cross-border labour markets and the related transport/mobility/housing issues.
	Identities, Diversity and Integration	There are clear overlaps between the research priorities “Labour Market, Educational requirements and Social Protection” and “Identities, Diversity and Integration” – related, for instance, to inclusion in the labour market of different social groups, education and work skills required in the labour market, new work models in the knowledge society or in the context of an ageing workforce and the related consequences on the individual/society, etc.
	Public and Environmental Health	Public Health research should include aspects regarding the quality of employment (e.g. jobs compatible with skills and expectations, matching reward and effort, control of work, exposure to risk and unsafe working conditions, job security, job turnover, flexibility, and social dialogue) as one of the important determinants of good health and well-being (e.g. SHARE, 2005; "Health and Quality in Work", 2005; WHO European Health Report 2002). Research aiming at adapting work practices and working conditions – e.g. ending discrimination, creating barrier-free workplaces and promoting flexibility for employees – will help workers maintain their health. [Source: COMMISSION STAFF WORKING DOCUMENT, Joint Report on Social Protection and Social Inclusion, SUPPORTING DOCUMENT, Brussels, 6.3.2007 SEC(2007) 329]
	Technology Platform Modelling and Simulations	As the success of research in “Labour Market, Educational Requirements and Social Protection” will depend on the availability of a well managed database infrastructure including data on the macro level as well as data on the micro level of the individual, this research priority will benefit from the development of Modelling and Simulation competencies and facilities.

7.6 Identities, Diversity and Integration

Criteria		**Assessment**	**Justification**
Socio-economic contribution	C1. Environment	No Impact	There is no direct or indirect impact of research in this domain on environmental aspects.
	C2. Economy	Low	Although not primarily oriented towards economic interests, research about Identities, Diversity and Integration will have an indirect economic relevance, generally speaking, through the enhancement of a modernisation of society and in particular through a better integration of the immigrant workforce, rising educational and training standards and better social cohesion. In a knowledge economy, cultural diversity is an asset also from an economic point of view, and research on this topic contributes to a better utilisation of this asset. A point in case is multilingualism and the opportunities it offers e. g. for companies (and other organizations) active on a European level. Research on identity, ethnic, cultural, and language diversity and integration addresses factors which distinguish Luxembourg from its neighbours making it a test bed of European integration. Such research may contribute to increase the attractiveness of the country for companies and workforce.
	C3. Society	High	Research in this domain informs political decision making and responds to the need of the Luxembourg society to reflect upon itself in order to understand the current very important societal transitions - especially against the background of immigration and migration flows - and is therefore obviously of high societal importance. Public research focusing on Identities, Diversity and Integration, in the specific context of the multicultural and multilingual Luxembourg society, will aim at a better mutual understanding of the different population groups within the society and therefore at strengthening social cohesion - furthering the construction of a specific Luxembourg identity - as well as social, political and work participation.
C4. Accordance with the political agenda in Luxembourg		High	This research priority is in line with the objectives of social cohesion of the Lisbon agenda as well as with government's objectives as presented by Luxembourg's Prime Minister Jean-Claude Juncker announced on 9 May 2007 on the occasion of the traditional declaration on the social, economic and financial situation of the country - related to: managing the heterogeneity of the population at school; new societal challenges due to population ageing; migration, the integration of immigrants and the strengthening of social cohesion. [Source: Jean-Claude Juncker, Déclaration du gouvernement sur la situation économique, sociale et financière du pays 2007, 09.05.2007, http://www.gouvernement.lu/salle_presse/actualite/2007/05/09etatnation/index.html#8]

Feasibility	C5. Public and political acceptance	Favourable	In a multicultural and multilingual society the topics identity, diversity and integration are of strong public interest and research on these issues is highly welcome as it will foster social cohesion and integration. Some legal problems may arise with data collection, as there are privacy protection measures restricting the use of certain data sets.
	C6. Private sector activities in Luxembourg	Low	Research in this domain is, in general, dominated by the public sector (not only in Luxembourg). Some of the ICT companies present in Luxembourg could be partners in ICT projects related to multilinguality. Semantica is active in the field of human language technology.
	C7. Public research capacity in Luxembourg	Medium	Some aspects of the topic have been addressed within the scope of FNR's "VIVRE" programme. "Luxembourg studies" is a priority research axis at the University of Luxembourg within the research unit IPSE - according to a recent survey[306], there are about 4 FTE researchers involved in research on identities and languages) and the FLSHASE conducts research on Luxembourg language and history as well as sociolinguistics. CEPS/INSTEAD has important data collections that may be further analysed and carries out studies in the research domain (according to the survey cited above, 3 FTE researchers are involved in research focusing on identities, migration and democracy and political participation/integeration). Other resources are available in the national and local museums and Archives, the Centre National de Littérature, the Bibliothèque Nationale and the Centre National de l'Audiovisuel. The recently created Humanités Associées – the network of young researchers in the social sciences and humanities in Luxembourg - is a first step to foster cooperation within this multidisciplinary field of research. There is, however, little advanced research on the socio-cultural aspects of migration. Likewise, comprehensive databases on diversity, integration and multilingualism, free of ideological bias, do not exist yet, but are essential prerequisites for conducting research in this domain.

[306] This information is based on a competencies survey carried out in spring 2007 by FNR. All Luxembourg research institutions were asked for their competencies and staff involved in the research domains identified during the FNR Foresight exercise. However, since the responses obtained do not cover all research institutions in Luxembourg (data could be obtained from the following institutions: CEPS/Instead, Departments : Population & Emploi, Entreprises, EURES, GEODE and ERDI; Departments LTI and CITI of the CRP-HT; Administration des Eaux et Forêts ; LNS/CRP-Santé/CHL ; University of Luxembourg UR IPSE Etudes Luxembourgeoises ; CRP-GL; CRTE), the figures presented here can not be exhaustive; it can also not be excluded that some researchers are counted twice; however, these figures gives a flavour of the current research public research capacities in Luxembourg.

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<td>C8. Infrastructure / Critical Mass</td>
<td>
<table>
<tr><td>Critical mass (researchers)</td><td>About 40</td></tr>
<tr><td>Infrastructure and Equipment</td><td>No major infrastructure needed</td></tr>
</table>
The working group recommended that a small research institute structure should be build up with long-term basic funding. Such an institute may consider implementing a graduate school on the culture and society of Luxembourg to foster a productive and attractive environment for doctoral and post-doctoral students. The multi-disciplinary core group could consist of 15 senior and junior researchers plus a slightly larger number of project personnel and visiting scientists. It should closely cooperate with projects on multilingual multimedia content (Priority 2.1.5.9 Telecommunications and Multimedia).
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<tr>
<td colspan="2">C9. International research context</td>
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This research priority is in line with the research domains to be funded by FP7: Major trends in society and their implications - demographic change, reconciling family and work, health and quality of life, youth policies, social exclusion and discrimination; The citizen in the European Union - political participation, citizenship and rights, democracy and accountability, the media, cultural diversity and heritage, religions, attitudes and values. [Source: http://cordis.europa.eu/fp7/cooperation/socio-economic_en.html]
In particular, within FP7, research projects related to the following aspects will be funded - in accordance with the specific research issues identified for research in “Identities, Diversity and Integration” in the FNR Foresight process:
- Analysing, comparing and evaluating the various societal models in a medium- to long-term perspective (SSH-2007-2.1.1)
- Migration (SSH-2007-3.1.3) with the aim to better understand the factors and conditions determining migration flows and the diverse experiences of migrants, as well as the implications for demographic changes and social, economic and cultural policies in Europe.
- Cultural interactions and multiculturalism in European societies (SSH-2007-3.3.1) with the aim to analyse how European Union societies are addressing issues of multiculturalism, diversities and traditions in view of policies which can lead to constructive, positive and peaceful societies and a constructive dialogue of cultures.
- Youth and social exclusion (SSH-2007-3.2.1) with the aim to achieve a comprehensive and integrated approach and provide policy recommendations to dealing effectively with the social exclusion of young people in terms of causes, processes, changes and prospects.
- Democratic "ownership" and participation (SSH-2007-5.1.1) with the aim to achieve a comprehensive knowledge of why and how participation and democratic "ownership" develop or are hampered.
- Histories and Identities – articulating national and European identities (SSH-2007-5.2.1) with the aim to better understand the way in which European cultures and identities are formed; the relationship between national and European identities, feelings of belonging, traditions, convictions and languages.
- Creativity, Culture and Democracy (SSH-2007-5.2.2) with the aim to explore the origins, role and societal impact of creativity, especially in the context of literature and the Arts.
Whereas research on national and regional identities is performed by many universities and institutes throughout Europe (A point in
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	case is the programme "Identities and Social Action", a five year research programme funded by the UK Economic and Social Research Council and running until December 2008. It is a £4 million public investment in social scientific research on identities and identity issues). Within the Greater Region, there might be opportunities for researchers to collaborate with the Exzellenzcluster "Gesellschaftliche Abhängigkeiten und soziale Netzwerke" of the University of Trier, the "Centre d'Études Germaniques Interculturelles de Lorraine" and the "Laboratoire Lorrain de Sciences Sociales" of the Universities of Metz/Nancy.	
C10. Contribution to national competences, scientific excellence and international reputation	High	As the subject of this research domain is the Luxembourg society with its socio-cultural specifics and historical aspects, Luxembourg itself must build up high quality research capacities in the country to conduct this research. Results on aspects of integration or a genuine multicultural and multilingual society may also be interesting on an international level and could contribute to Luxembourg's international reputation.

C11. Cross-linkages with other Priorities identified		Justification
C11. Cross-linkages with other Priorities identified	Business Service Design and Innovation	Some aspects of research in "Business Service Design and Innovation" leading to e-Health, e-administration, e-government or e-voting applications are clearly linked to research related to social inclusion and political participation.
	Telecommunications and Multimedia	Research in the domain "Telecommunications and Multimedia" contributing to building the Information and Knowledge society will bring deep changes in our way of working and living. There are therefore overlaps with the priority "Identities, Diversity and Integration" (e.g. how to bridge the digital divide in society?). Specifically in the Luxembourg context, the development of new multilingual, multimedia applications can contribute to consolidate the visibility of Luxembourg's culture and language on the web, promote a specific Luxembourg's identity and make the Luxembourg cultural heritage available to more people - and have therefore a high social impact furthering for instance social cohesion and inclusion.
	Spatial and Urban Development	The linkage between these domains becomes even more obvious when considering so-called „immaterial spaces"(Luxembourg consists not only of a political space defined by physical borders, it can also be described as a linguistic, living and working space and most of these spaces go beyond the mere geographical space Luxembourg occupies).
	Labour Market, Educational requirements and Social Protection	There are clear overlaps between the research priorities "Labour Market, Educational requirements and Social Protection" and "Identities, Diversity and Integration" – related for instance to inclusion in the labour market of different social groups, education and work skills required in the labour market, new work models in the knowledge society or in the context of an ageing workforce and the related consequences on the individual/ society, etc.
	Public and Environmental Health	One of the important objectives of Public Health policies and Public health research should be to bridge the healthcare divide in society and to improve the access to healthcare and health prevention services of socially deprived population groups/ high risk groups, contributing therefore to improving social cohesion and social inclusion.

	Technology Platform Information Infrastructure supporting research	Databases free of an ideological bias are important prerequisites for the proposed lines of research. In addition to a better use of available databases, new ones have to be built up and to be managed in a professional way. Apart from databases, well equipped and well managed archives and libraries are basic infrastructural requirements for this research priority. Regarding information infrastructure, there might be opportunities for researchers to collaborate with the "Kompetenzzentrum für elektronische Erschließungs- und Publikationsverfahren in den Geisteswissenschaften" of the University of Trier.

7.7 Cross-linkages between the research priorities

The following table summarizes the cross-linkages identified between the research priorities. It allows to highlight possible synergies to be exploited when implementing future research projects. In particular, the table underlines that Technology Platforms requirements may be common to several priorities. Therefore, the development of these platforms, allowing "economies of scale" and the bundling of competencies, will be an asset for future research.

Cross-linkages with other priorities	Innovation in Services (Umbrella priority)	Business Service Design and Innovation	Fostering the Economic and Legal Environment for Innovation	Performance and Development of the Financial Systems	Information Security and Trust Management	Telecommunications and Multimedia	Sustainable Resource Management in Luxembourg (Umbrella priority)	Managing Sustainable Development	Understanding Ecosystems and Biodiversity	Sustainable Management of Water Resources	Sustainable Uses and Sources of Energy	Sustainable Agro-Systems Management	Spatial and Urban Development	New Functional and Intelligent Materials and Surfaces, and New Sensing Applications	Biomedical Sciences (Umbrella Priority)	Regenerative Medicine in Age-related Diseases	Public Health and Environmental Health	Translational Biomedical Research	Labour Market, Educational Requirements and Social Protection	Identities, Diversity and Integration	Technology Platform Modelling and Simulations	Technology Platform Information Infrastructure supporting research	Biobanks / Tissue Bank	Other Technology Platforms

Innovation in Services (Umbrella priority)																	X		X					
Business Service Design and Innovation			X	X	X	X											X		X	X				
Fostering the Economic and Legal Environment for Innovation		X		X	X	X									X	X		X	X					
Performance and Development of the Financial Systems		X	X		X														X		X			
Information Security and Trust Management		X	X	X		X									X		X	X						
Telecommunications and Multimedia		X	X		X												X		X	X				
Sustainable Resource Management in Luxembourg (Umbrella priority)														X							X			
Managing Sustainable Development									X	X	X	X	X								X			
Understanding Ecosystems and Biodiversity								X		X	X	X	X	X			X				X			
Sustainable Management of Water Resources								X	X			X	X	X							X			
Sustainable Uses and Sources of Energy								X	X			X	X	X										
Sustainable Agro-Systems Management								X	X	X	X		X	X			X				X			
Spatial and Urban Development								X	X	X	X	X					X		X	X	X			
New Functional and Intelligent Materials, and New Sensing Applications							X		X	X	X	X			X	X	X	X			X			
Biomedical Sciences (Umbrella priority)			X		X									X									X	X
Regenerative Medicine in Age-related Diseases			X											X			X	X					X	X
Public Health and Environmental Health	X	X			X	X			X			X	X	X		X		X	X	X			X	X
Translational Biomedical Research			X		X									X		X	X						X	X
Labour Market, Educational requirements and Social Protection	X	X	X	X		X							X				X			X	X			
Identities, Diversity and Integration		X				X							X				X		X			X		

7.8 Overall comparison of the assessment for all priorities

The following table allows for an overall comparison of the assessment of all priorities along the 8 quantitative criteria presented in Chapter 2.4. However, it should be emphasized that this table provides no absolute assessment of the priorities and that it can only be used sensibly in combination with the in-depth analysis of the priorities as presented in Chapter 6.

Priorities	**Socio-economic Contribution**				Feasibility						
	C1. Environment	C2. Economy	C3. Society	C4. Accordance with the political agenda in Luxembourg	C5. Overall Framework Public acceptance and legal framework	C6. Private sector activities in Luxembourg	C7. Public sector capacity in Luxembourg	C8. Infrastructure / Critical Mass	C9. International research context	C10. Contribution to national competences, scientific excellence and international reputation	C11. Cross-linkages with other priorities
Innovation in Services (Umbrella priority)	No Impact	High	High	High	Favourable	High	High			High	
Business Service Design and Innovation	No Impact	High	Medium	High	Favourable	High	High			High	
Fostering the Economic and Legal Environment for Innovation	Low	High	Medium	High	Favourable	High	Medium			Medium	
Performance and Development of the Financial Systems	No Impact	High	High	High	Favourable	High	Low			Medium	
Information Security and Trust Management	No Impact	High	Medium	High	Mixed	High	High			High	
Telecommunications and Multimedia	No Impact	Medium	High	High	Favourable	High	High			High	
Sustainable Resource Management in Luxembourg (Umbrella priority)	High	Medium	Medium	High	Favourable	Low	Medium			Medium	
Managing Sustainable Development	High	Medium	Medium	High	Mixed	Low	Low			High	

Understanding Ecosystems and Biodiversity	High	Low	Medium	High	Mixed	Low	Medium			Medium	
Sustainable Management of Water Resources	High	Medium	Medium	High	Favourable	Low	High			Medium	
Sustainable Uses and Sources of Energy	High	High	Medium	High	Favourable	Medium	Medium			Medium	
Sustainable Agro-Systems Management	High	Low	Medium	High	Favourable	Low	Medium			Medium	
Spatial and Urban Development	High	Medium	High	High	Favourable	Low	Low			Medium	
New Functional and intelligent Materials and surfaces, and New Sensing Applications	Medium	High	Low	High	Favourable	High	High			Medium	
Biomedical Sciences (Umbrella Priority)	Low	Medium	High	High	Mixed	Low	Medium			Medium	
Regenerative Medicine in Age-related Diseases	No Impact	Medium	High	High	Mixed	Low	Medium			Medium	
Public Health and Environmental Health	Low	Medium	High	High	Favourable	Low	Medium			High	
Translational Biomedical Research	No Impact	Medium	High	High	Favourable	Low	Low			Medium	
Labour Market, Educational Requirements and Social Protection	No Impact	High	High	High	Mixed	Medium	Medium			Medium	
Identities, Diversity and Integration	No Impact	Low	High	High	Favourable	Low	Medium			High	

8. Conclusion

The FNR Foresight exercise was the first exercise of this kind in Luxembourg's public research sector. One major aim of the Foresight exercise was to promote a foresight culture in Luxembourg through the involvement of many participants from different backgrounds at all stages of the process and the familiarisation of the stakeholders with Foresight methodologies. In general, the exercise was welcomed as a 'refreshing' new approach and in recent surveys amongst the participants at the thematic workshops more than 80% of the respondents expressed a positive opinion of the exercise.

Over the course of the Foresight, the scope and available timescale were modified because of the rapidly evolving political agenda in R&D policy making. Whereas the timescale was limited to a year, the scope was enlarged from FNR programmes to national research priorities. Some aspects of the Luxembourg R&D system, related mostly to its small size and its youthfulness, have left their mark on the shape and scope of FNR Foresight. The dearth of statistical and analytical data is characteristic of the system's novelty. Even though the exercise took account of this, some data remain missing. Increased effort needs to be put on data collection and analysis in the future to ensure the validity of baseline and benchmarking data and to set policy making on a firm data basis. Additional attention should also be given to the deliberative processes which fell somewhat short of what was required.

As Luxembourg has only a small number of researchers, the validity of their views is often questioned and parochial concerns were widespread. Because of this, efforts have been made to include international participants as far as possible, both as a validation of and as a complement to the views of Luxembourg-based researchers. At the end, the identification of R&D spending priorities was done through a more forward-looking and participative process than would normally be used in priority-setting.

A national research priority (NRP), by definition, should address the challenges of the Luxembourg society, economy, and environment through research and lay the foundation for new innovative products and processes, but also contribute to creating an environment and an international visibility making Luxembourg an attractive location for companies to establish themselves and to remain for years to come. In addition, research has the obligation to inform the public administration and decision making on environmental and societal issues. In all cases however, a NRP should account for emerging trends on the international level, and should thus ensure that public research in Luxembourg finds overlap with international research activities and allow for sustained development of this line of research in Luxembourg.

The feasibility of a NRP to take root in Luxembourg and to address the issues described above depends largely on existing assets given in Luxembourg at the time of embarking in the particular direction. The implementation period for the NRP is – in line with the time horizon of the foresight exercise – 10 years and hence the research in the NRP needs to be able to reach critical mass within this timeframe. An existing scientific base (researchers in public and private sector) and an economic base (companies' interest in the research domain, serving also as regional partners for immediate collaboration and recruitment of research personnel) form these assets.

From the point of view of sustaining attractiveness and continuity in future program definitions, a NRP should be neither to narrow (specific) nor to broad (unspecific) in scope. On the one hand a NRP should have a clear focus, so that a critical mass of research can be built up and attractiveness in term of visibility and competitiveness can be guaranteed. But on the other hand this focus should have sufficient scope for interdisciplinary cooperation, and it should allow sufficient liberty to follow new emerging research questions and reduce the risk of sticking to dead ends or jumping from one narrow niche to the other.

Taking all these aspects into account, research priorities should fulfil the following criteria:

- Attractiveness
  - Social impact/ relevance
  - Economic impact/ relevance
  - Environmental impact/ relevance
  - Scientific attractiveness (emerging trend, intriguing)
- Feasibility
  - Critical mass can be reached within 10 years
  - International competitiveness can be reached within 10 years
- Focus (Granularity)
  - Sufficient focus, but not too restrictive

The future priorities for public research in Luxembourg were identified based on data on the Luxembourg context, the expertise on the subject matter of the researchers and stakeholders involved in the FNR Foresight process, as well as the consideration of research and technology trends on the international level.

Starting from a "long-list" of 56 possible research areas for Luxembourg with about 250 issues set up in the first phase of the Foresight exercise and based on the criteria described above, the FNR Foresight exercise identified in the second phase 6 priorities for public research in Luxembourg.

Although the subject of technological platforms was not explicitly addressed, certain platform requirements where highlighted in the Foresight exercise as a necessary condition for specific research priorities. The following platforms were deemed necessary:

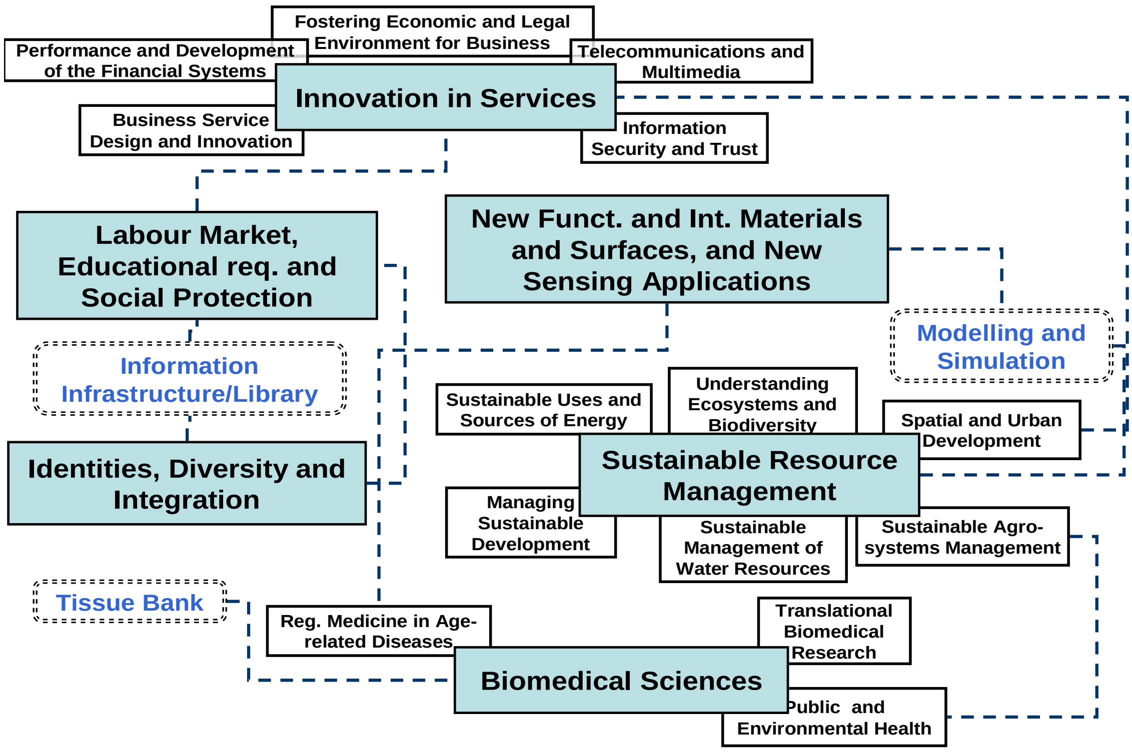
- *Modelling and Simulation*
- *Information Infrastructure supporting Research*
- *Tissue Bank*
- *Other Technology Platforms like proteomics, genomics, etc.*

The figure below presents the research priorities and their interrelationships. It attempts to summarise the portfolio of research priorities (shown in blue boxes) and research platforms highlighted in the exercise by indicating the main sub-issues for each priority. In addition, the figure shows some of the interlinkages and interdependencies that exist between the various research topics. The figure should demonstrate that potential future research projects may cover more than one research priority. In fact such projects would deal effectively with one of the main national constraints of there being a relatively small number of researchers in Luxembourg. Such projects would be of an interdisciplinary nature and would involve researchers from different areas to address common issues that were identified by stakeholders of the Luxembourg society (see chapter 4).

Thus, the challenges and opportunities facing Luxembourg concerning *Transportation and Logistics* could be approached with the knowledge gained in *Service Sciences* (by providing new ICT technologies in logistic services) on the one hand and *Spatial and Urban Development* on the other. Mixing Material Sciences and regenerative medicine may provide new ways of looking at biomaterials and prosthesis. Combining the knowledge in the various disciplines touching the use of resources could lead to a better understanding of the interdependencies of material and energy flows.

This multidimensional approach was seen as particularly useful to provide science based solutions that support human well-being and the sustainable use of resources. The approach advocated by the participants of the environmental sciences workshop would constitute a change in paradigm from a *uni*-disciplinary view to a new holistic 'Luxembourg model'.

Many of the Foresight participants recognized the importance of interdisciplinary research. This view is shared by the scientific community in general as stated in the National Academies[307] report, *Facilitating Interdisciplinary Research,* published in 2004. Much progress in scientific fields has emerged from working across several disciplines.



[307] http://www.nap.edu/

The report shows that academia in the US has taken some steps to embrace interdisciplinary research. One case in point presented is the Harvard University Center for the Environment programme where complex problems facing the environment are approached by collaborative investigation by scholars versed in different disciplines. The greatest driver of interdisciplinarity is perhaps the sheer complexity of nature, and the need to draw on and interface various disciplines, and forge partnerships of researchers with different backgrounds to provide effective solutions to complex questions.

The report shows that interdisciplinary research comes in various shapes or forms. It also shows, however, that it often faces discouraging barriers largely rooting from the fact that academic systems are based on 'classic' scientific disciplines. In addition, working across disciplines requires not only depth of knowledge but also a holistic understanding of complex systems, a view also supported by experts in the Foresight exercise. They stressed that one needs to have strong sectorial knowledge but that the real benefits could only be achieved if the sectorial knowledge is bundled in a 'centre of competence'.

The central problem facing interdisciplinary research in Luxembourg is finding ways to remove the barriers detailed in the National Academies report. Perhaps Luxembourg can draw on its strengths highlighted in chapter 5, and exploit the opportunities that present themselves. The young research environment, the planning of the City of Science and the Government's dedication to strengthen the research landscape in Luxembourg provide an optimal starting point to set the framework for interdisciplinary research.

In view of some of the more tangible synergies between the research domains highlighted by the experts in the Foresight process, the administrative and scientific boards of the FNR have proposed to regroup some of the domains identified in the Foresight process under single headings (described in Chapter 6) giving the domains a clearer orientation.

The research priorities put forward by the FNR are thus:

- **Innovation in Services**
- **Sustainable Resource Management in Luxembourg**
- **New Functional and Intelligent Materials and Surfaces, and New Sensing Applications**
- **Biomedical Sciences**
- **Labour Market, Educational Requirements and Social Protection**
- **Identities, Diversity and Integration**

Although the general headings appear to be very broad, the priorities are precisely defined and delineated through their subdomains and the reseach axes detailed for each subdomain.

The priorities listed above are all of high importance for Luxembourg and constitute a well-balanced research portfolio allowing to tackle major socio-economic and environmental challenges faced by Luxembourg over the next 10 years.

Nevertheless there are distinctions in the impacts of the different research priorities on the economy, society, the environment, in their budgetary requirements, etc. A further prioritization of these research domains by the government, in order to be as objective and transparent as possible, should be based on clear criteria. These criteria can, for instance, allow to take into account the scientific potential of the research domains (state-of-the art in Luxembourg, possibility for Luxembourg research to become internationally competitive within the next ten years, etc.) as well as socio-economic and ecological interests or priorities and the potential for the research domains to meet these demands. The assessment of the priorities identified in this FNR Foresight process along a set of specific criteria, as carried out in the final phase of the Foresight exercise, prepare the ground for such a national priority setting.

How these new promising areas will be taken up needs to be further developed. It is recognised that increasing spending on R&D will not, on its own, deliver desirable outcomes. In this regard, both the implementation of the FNR Foresight results and the Luxembourg research system in general face some major challenges for the future – challenges which need to be carefully addressed to make public R&D policy a success. Amongst these are the following sorts of issues:

- How to absorb the significant spending increases effectively and with the maximum leverage?
- How to build capacity in the priority domains, even if some human resources and infrastructures already exist, never mind a situation where little capacity might currently exist?
- How to improve the attractiveness of the Luxembourg research environment and to become a magnet for excellent young and senior researchers?
- How to improve the legal framework for research?
- How to allow for the development of interdisciplinary research?
- How to inform and take into account developments at the University of Luxembourg and the new City of Science?
- How to increase international networking of public research?
- How to ensure critical mass whilst maintaining sufficient variety for new opportunities to emerge?
- How to leave space for high risk research and novel ideas outside of the research priorities?

We thoroughly recommend the decision makers to include national and international experts in the planning of the implementation of the results. The Foresight exercise has generated so far a number of high potential research domains but careful attention needs to be given to the specificities, the needs and the different current situations of the various domains.

There appears to be a strong commitment from policy makers to build a more forward-looking and strategic culture across the public research base to address the issues highlighted. Whilst foresight can point to areas of potential interest, this does not mean that policy makers can abdicate their responsibilities for decision-making. Many difficult decisions will still need to be taken in light of the FNR Foresight's findings. The present Foresight however has provided a solid basis for decision making, by compiling relevant data and involving many stakeholders of the research environment to ensure an in-depth expert analysis.

The FNR Foresight has also built networks between the public and private sector, Luxembourg based and foreign researchers, and research actors and public administrators which form the basis for future dialogue about the above mentioned issues and the scaffold for the possible institutionalisation of these platforms. These types of dialogue platforms are needed to best implement the conclusions of the foresight exercise, especially in the fields where we start from scratch. The actors mostly impacted by the decisions have largely been actively involved in the exercise, thus preparing these decisions; all of which will help to legitimise the decision making and importantly also the implementation process.

Although the foresight provides the general directions for the next 10 years, fine-tuning will still need to be done and the themes have to be revisited during the course of the next decade in order to ensure alignment with unforeseen trends. We therefore see the Foresight process far from completed and recourse to expert advice and discourse will still be necessary in the future. We foresee the need for the continuation of the process in view of preparing implementation decisions and to reassess the research directions at various stages in the coming years. Foresight is set to remain an accompanying steering element for public research in the long term.

Annexes

A1 General definitions of the research priorities

Priority Domain	Definition
Business Service Design and Innovation	The domain **Business Service Design and Innovation** is a very large domain covering many different applications and e-services of different levels of granularity: business related e-services (e-business, administration-to-business services, same processes in e-administration and internal e-solutions of a company…), e-government (including e-voting), e-governance, e-administration, but also services related to e-health, e-learning, etc. "**Services science**, [is] a discipline concerned with finding ways to increase productivity and innovation in services-related industries and tasks by applying scientific means and methods.[…] Services science is a multidisciplinary field that seeks to bring together knowledge from diverse areas to improve the service industry's operations, performance, and innovation." [Source: Linda Dailey Paulson, Services Science: A New Field for Today's Economy, IEEE Computer, August 2006, p18-21]
Fostering the Economic and Legal Environment for Innovation	This domain, recognizing innovation as the key-driving force of economic growth, addresses the economic and legal means to develop and increase an innovation-friendly environment in Luxembourg. It encompasses all **innovation** activities, i. e. the "creation of new products and/or services" [Source: www.investorwords.com, WebFinance, Inc.].
Performance and Development of Financial Systems	**This domain addresses research issues and tools (financial engineering, etc.) focusing on performance and development of all financial systems (macro-economic financial system as well as subsystems).** **Finance** = 1. A branch of economics concerned with resource allocation as well as resource management, acquisition and investment. Simply, finance deals with matters related to money and the markets. 2. To raise money through the issuance and sale of debt and/or equity. [Source: www.investorwords.com, WebFinance, Inc.] **Banking** = In general terms, the business activity of accepting and safeguarding money owned by other individuals and entities, and then lending out this money in order to earn a profit. [Source: www.investorwords.com, WebFinance, Inc.] **Financial Engineering** = Financial engineering is the application of science-based mathematical models to decisions about saving, investing, borrowing, lending, and managing

	risk. The term financial engineering came into use after the discovery of the Black-Scholes-Merton option pricing model in the early 1970s. Their scientific breakthrough led to a new way to solve practical financial problems by designing custom contracts and replicating them dynamically using instruments traded in markets. In recent years the rise of many new organized markets for futures and swaps and innovations in telecommunications and computer technology have dramatically reduced the cost of trading standardized financial instruments. This has vastly increased the scope of financial engineering. As a result it has become possible to produce at reasonable cost customized financial contracts that address a broad range of investment and risk management needs faced by firms, governments, and households around the world. [Source: Z. Bodie, Professor of Finance and Economics at Boston University School of Management, http://www.fenews.com/what-is-fe/what-is-fe.html]
Managing Sustainable Development	Research in this domain aims at maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend on the other.
Understanding Ecosystems and Biodiversity	"**Biodiversity** is the totality of genes, species, and ecosystems in a region. [...] Biodiversity can be divided into three hierarchical categories—genes, species, and ecosystems—that describe quite different aspects of living systems and that scientists measure in different ways-. • **Genetic diversity** refers to the variation of genes within species. This covers distinct populations of the same species (such as the thousands of traditional rice varieties in India) or genetic variation within a population (which is very high among Indian rhinos, for example, and very low among cheetahs). [...] • **Species diversity** refers to the variety of species within a region. Such diversity can be measured in many ways, and scientists have not settled on a single best method. The number of species in a region—its species "richness"—is one often-used measure, but a more precise measurement, "taxonomic diversity," also considers the relationship of species to each other. For example, an island with two species of birds and one species of lizard has greater taxonomic diversity than an island with three species of birds but no lizards. [...] • **Ecosystem diversity** is harder to measure than species or genetic diversity. Nevertheless, as long as a consistent set of criteria is used to define communities of species and ecosystems, their number and distribution can be measured and parameterised using ecosystems functions. **Ecosystem functions** are the physical, chemical, and biological processes or attributes that

	contribute to the self-maintenance of an ecosystem; in other words, what the ecosystem does. Some examples of ecosystem functions are provision of wildlife habitat, carbon cycling, or the trapping of nutrients. Thus, ecosystems, such as wetlands, forests, or estuaries, can be characterized by the processes, or functions, that occur within them. **Ecosystem services** are the beneficial outcomes, for the natural environment or people that result from ecosystem functions. Some examples of ecosystem services are support of the food chain, harvesting of animals or plants, and the provision of clean water or scenic views. In order for an ecosystem to provide services to humans, some interaction with, or at least some appreciation by, humans is required. Thus, functions of ecosystems are value-neutral, while their services have value to society. Besides ecosystem diversity, many other expressions of biodiversity can be important. These include the relative abundance of species, the age structure of populations, the pattern of communities in a region, changes in community composition and structure over time, and even such ecological processes as predation, parasitism, and mutualism. More generally, to meet specific management or policy goals, it is often important to examine not only compositional diversity—genes, species, and ecosystems—." **Biodiversity Conservation** aims at "supporting sustainable development by protecting and using biological resources in ways that do not diminish the world's variety of genes and species or destroy important habitats and ecosystems". It encompasses saving biodiversity, studying it, and using it sustainably and equitably. • **Saving biodiversity** means taking steps to protect genes, species, habitats, and ecosystems. The best way to maintain species is to maintain their habitats. Saving biodiversity therefore often involves efforts to prevent the degradation of key natural ecosystems and to manage and protect them effectively. But since many of the world's habitats have been modified for such human uses as agriculture, [conservation] programs must include measures to maintain diversity on lands and in waters that have already been disturbed. A third component is restoring lost species to their former habitats and preserving species in genebanks, zoos, botanic gardens, and other off-site *(ex situ)* facilities. • **Studying biodiversity** means documenting its composition, distribution, structure, and function; understanding the roles and functions of genes, species, and ecosystems; grasping the complex links between modified and natural systems; and using this understanding to support sustainable development. It also means building awareness of biodiversity's values, providing opportunities for people to appreciate nature's variety, integrating biodiversity issues into educational curricula, and

	ensuring that the public has access to information on biodiversity, especially on developments that will influence it locally. • **Using biodiversity sustainably and equitably** means husbanding biological resources and ecosystems services so that they last indefinitely, making sure that biodiversity is used to improve the human condition, and seeing that these resources are shared equitably. "Use" does not, however, automatically imply consumption. Often, the best economic use of biodiversity may be to maintain it in its natural state for its ecological or cultural values, as in the cases of forested watersheds or sacred groves. [Sources: - Global Biodiversity Strategy, Guidelines for Action to Save, Study and Use Earth's Biotic Wealth Sustainably and Equitably. (1992). World Resources Institute (WRI), The World Conservation Union (IUCN), United Nations Environment Programme (UNEP), http://pdf.wri.org/globalbiodiversitystrategy_bw.pdf ; - http://www.ecosystemvaluation.org/1-02.htm]
Sustainable Management of Water Resources	**Sustainable Management of Water Resources** is the integrating concept for a number of water sub-sectors such as hydropower, water supply and sanitation, irrigation and drainage, and environment. An integrated water resources perspective ensures that social, economic, environmental and technical dimensions are taken into account in the management and development of water resources. [Source: www.worldbank.org]
Sustainable Uses and Sources of Energy	This domain focuses on **energy efficiency** and **renewable energies**. **Energy efficiency** has a broader sense that what is usually understood with an implicit reference to technological efficiency only: it encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic activity (e.g. the energy used per unit of GDP or value added) or to meet the energy requirements for a given level of comfort. Energy efficiency is associated to economic efficiency and includes technological, behavioural and economic changes. Energy efficiency improvements refer to a reduction in the energy used for a given energy service (heating, lighting...) or level of activity. This reduction in the energy consumption is not necessarily associated to technical changes, since it can also result from a better organisation and management (e.g. domotics) or improved economic efficiency in the sector (e.g. overall gains of productivity). [Source:http://www.worldenergy.org/wec-geis/publications/reports/eepi/introduction/definition.asp]

	"**Renewable energy:** Any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources." [Source: Texas Renewable Energy Industries Association]
Sustainable Agro-Systems Management	Research in this domain aims at a sustainable management of agro-systems, defined as follows: The notion of *agrosystems* is defined as production systems based on the ecological and socioeconomic relations involved in the reproduction of rural societies. Coming from agricultural economics, the term originally stands for local and regional arrangements of land use, livestock, technology, and farm management. By broadening this rather narrow meaning, the concept of agrosystem integrates the whole complex of ecological, economic, political, social and cultural relations relevant for rural production and reproduction. [Source: http://www.univie.ac.at/ruralhistory/agrosystems.htm]
Spatial and Urban Development	This domain addresses research exploring the conceptual construction, organisation and practical use of space, including material aspects (geography and land use, e. g. for buildings, transportation and other infrastructures, industry, agriculture, tourism...) as well as immaterial ones (culture, social relations, participation...), in order to foster sustainable territorial development in urban as well as rural areas.
Information Security and Trust Management	**Information security** aims at the protection of information against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional. In network management, security management refers to the set of functions (a) that protects telecommunications networks and systems from unauthorized access by persons, acts, or influences and (b) that includes many subfunctions, such as creating, deleting, and controlling security services and mechanisms; distributing security-relevant information; reporting security-relevant events; controlling the distribution of cryptographic keying material; and authorizing subscriber access, rights, and privileges. [Sources: ANSI approved Telecom Glossary 2000, prepared by ATIS Committee T1A1]: http://www.atis.org/tg2k/] D. Artz and Y. Gil, A Survey of Trust in Computer Science and the Semantic Web, Information Sciences Institute, University of Southern California, Feb. 2006] **Trust** is in cryptology and cryptosystems the characteristic allowing one entity to assume that

	a second entity will behave exactly as the first entity expects. Note: Trust may apply only for some specific function. The critical role of trust in the authentication framework is to describe the relationship between an authenticating entity and a certification authority; an authenticating entity must be certain that it can trust the certification authority to create only valid and reliable certificates. [After X.509] [Source: ANSI approved Telecom Glossary 2000, prepared by ATIS Committee T1A1]: http://www.atis.org/tg2k/]
Telecommunications and Multimedia	**Telecommunication** is defined as any transmission, emission or reception of signs, signals, writing, images, sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems. [Source: Glossary of Frequently Used Telecommunications Terms, Federal Communications Commission (www.fcc.gov): http://www.fcc.gov/connectglobe/glossary.html] **Multimedia** is defined as the combination of various forms of media (texts, graphics, animation, audio, etc.) to communicate information. The term also refers to information products that include text, audio, and visual content. [Source: Glossary of Frequently Used Telecommunications Terms, Federal Communications Commission (www.fcc.gov): http://www.fcc.gov/connectglobe/glossary.html] Multimedia also refers to computer data storage devices, especially those used to store multimedia content. As the information is presented in various formats, multimedia enhances user experience and makes it easier and faster to grasp information. Presenting information in various formats is nothing new, but multimedia generally implies presenting information in various digital formats. It is also used in visual arts to describe works created using more than one medium. [Source: Griffith University, http://132.234.250.210/cis/p_cat/program/bitrelatedcourses.html]
Identities, Diversity and Integration	This domain addresses social cohesion as a whole, encompassing the aspects of identity, diversity and integration and including all elements contributing to the construction of identities, the whole field of ethnic and cultural diversity and all aspects of integration or participation in social and political life, in work etc.
Labour Market, Educational Requirements and Social Protection	This domain addresses Labour Market, the transition from the education system to Labour Market and the educational requirements associated. It also deals with social protection and the aspects of social cohesion related to labour market. **Labour Market =** A collective term for employment, unemployment, participation rates and wages. [Source: Glossary of the Reserve Bank of Australia,

	http://www.rba.gov.au/Glossary/text_only.asp] **Social protection** is defined as policies and programs to reduce poverty and vulnerability by (i) promoting efficient labor markets, (ii) diminishing exposure to risks, and (iii) enhancing capacity to protect against hazards/loss of income. [Source: http://www.asiandevbank.org/] **Social Cohesion =** A social cohesive society can be described as a society preventing social exclusion: "Social cohesion comes in to describe a society which offers opportunities to all its members within a framework of accepted values and institutions. Such a society is therefore one of inclusion. People belong; they are not allowed to be excluded" (Dahrendorf et al., 1995). Social Cohesion incorporates mainly two societal goal dimensions which can be analytically distinguished: (1) Reduction of disparities, inequalities, and social exclusion; (Inequality Dimension) (2) Strengthening of social relations, interactions and ties. (Social Capital dimension) **Social Cohesion in the domain of Labour Market and Working Conditions:** **Inequality dimension**. Inequalities in the labour market concern: • regional disparities in employment opportunities and in unemployment risks • inequalities in the employment conditions of various population groups: unequal opportunities for women and men, inequalities between young and old workers, disadvantages for disabled people and for foreigners. **Social Capital Dimension**. The domain of labour market and working conditions also comprises various aspects which refer to the goal of strengthening the social capital of a society: • participation in the area of working life: rate of membership in labour unions and in professional organisations, rate of employees represented by a workers' council, etc. • quality of societal institutions: perceived quality of labour unions, labour offices and labour courts, trust in labour unions, etc. • quality of social relations at the workplace: between colleagues and between superiors and employees, etc. • connections between European countries in the working life: employment of people from other European Countries, contacts to employed people from other European Countries, attitudes towards a European labour market. [Sources: Berger-Schmitt, R.: Social Cohesion as an Aspect of the Quality of Societies: Concept and Measurement. EuReporting Working Paper No. 14, Subproject "European System of Social Indicators". Mannheim: Centre for Survey Research and Methodology (ZUMA), Social Indicators Department, 2000.

	Dahrendorf, R. et al.: Report on Wealth Creation and Social Cohesion in a Free Society. - London: 1995]
New functional and intelligent materials and surfaces, and New Sensing Applications	The definition of functional materials reflects the ability of a material to perform a certain "function" under a determined stimulus. In this general definition a wide spectrum of materials can be included together with an ample range of material properties and applications. The group of functional materials mainly includes dielectrics, pyroelectrics, piezoelectrics, ferroelectrics, ferroelectrics relaxors, incipient ferroelectrics, semiconductors, ionic conductors, superconductors, electro-optics, and magnetic materials. [Source: Czuber, J., Czekaj, D. Functional properties of ferroelectric thin films, Contribution to the 36 Winter School on Wave and Quantum Acoustics, 2007, Polish Acoustical Society]. **Intelligent or Smart Materials or surfaces are** "systems containing multifunctional parts that can perform sensing, control, and actuation; they are a primitive analogue of a biological body. Smart materials are used to construct these smart structures, which can perform both sensing and actuation functions. The 'I.Q.' of smart materials is measured in terms of their 'responsiveness' to environmental stimuli and their 'agility.' The first criterion requires a large amplitude change, whereas the second assigns faster response materials with higher 'I.Q.' Commonly encountered smart materials and structures can be categorized into three different levels: (*i*) single-phase materials, (*ii*) composite materials, and (*iii*) smart structures. Many ferroic materials and those with one or more large anomalies associated with phase-transition phenomena belong to the first category. Functional composites are generally designed to use nonfunctional materials to enhance functional materials or to combine several functional materials to make a multifunctional composite. The third category is an integration of sensors, actuators, and a control system that mimics the biological body in performing many desirable functions, such as synchronization with environmental changes, self-repair of damages, etc. These three levels cover the general definition of smart materials and structures." [Source: Wenwu, C., Cudney, H. H., Waser, R. Smart Materials and Structures, PNAS, Vol. 96, Issue 15, 8330-8331, July 20, 1999] Sensors can be defined in several ways. According to McGee et al. (1999) sensors can be defined as "systems" that refine and extend the human facilities of "sensing" and "perception" In other words, sensors are human-made elements embedded within human-machine systems which help humans to acquire information, by the process of sensing, and to handle data, by performing information handling operations.

	Furthermore, Kretschmer & Kohlhoff (1997) characterise a sensor is a signalprocessing system with two features: • A primary feature aiming at measuring physical, chemical or biological units/dimensions following according to a specified principle • A secondary feature of signal translation, which through one or several steps appears as exit signal. In this study, we have chosen to use the following definition: Sensors and sensor systems perform a diversity of sensing functions allowing the acquisition, capture, communication processing, and distribution of information about the states of the physical systems. This may be chemical composition, texture and morphology, large-scale structure, position, and also dynamics. It is a characteristic feature of that the device is tailored to the environment in which it is to operate. [Sources: Andersen, P. D., Jørgensen, B. H., Rasmussen, B. (2001) Sensor Technology Foresight, Risø National Laboratory, Roskilde, Denmark Kretschmer, T., Kohlhoff, J. (1997). *Sensorik: Überblick und Trends*, Frauenhofer Institut Naturwissenschaftlich-Technische Trendanalysen. McGhee, J., Henderson, I.A., Sydenham, P.H. (1999). *Sensor science - essentials for instrumentation and measurement technology*, Measurement, **25**, 89-113.]
Regenerative Medicine in Age-related Diseases	This domain encompasses **all applications of regenerative medicine/tissue engineering in therapies of age-related diseases, with focus on cancer, vascular biology and neurodegeneration**. Tissue engineering / regenerative medicine is an emerging multidisciplinary field involving biology, medicine, and engineering that is likely to revolutionize the ways we improve the health and quality of life for millions of people worldwide by restoring, maintaining, or enhancing tissue and organ function. In addition to having a therapeutic application, where the tissue is either grown in a patient or outside the patient and transplanted, tissue engineering can have diagnostic applications where the tissue is made in vitro and used for testing drug metabolism and uptake, toxicity, and pathogenicity. The foundation of tissue engineering/regenerative medicine for either therapeutic or diagnostic applications is the ability to exploit living cells in a variety of ways. Tissue engineering research includes the following areas: 1) Biomaterials: including novel biomaterials that are designed to direct the organization,

	growth, and differentiation of cells in the process of forming functional tissue by providing both physical and chemical cues. 2) Cells: including enabling methodologies for the proliferation and differentiation of cells, acquiring the appropriate source of cells such as autologous cells, allogeneic cells, xenogeneic cells, stem cells, genetically engineered cells, and immunological manipulation. 3) Biomolecules: including angiogenic factors, growth factors, differentiation factors and bone morphogenic proteins 4) Engineering Design Aspects: including 2-d cell expansion, 3-d tissue growth, bioreactors, vascularization, cell and tissue storage and shipping (biological packaging). 5) Biomechanical Aspects of Design: including properties of native tissues, identification of minimum properties required of engineered tissues, mechanical signals regulating engineered tissues, and efficacy and safety of engineered tissues. 6) Informatics to support tissue engineering: gene and protein sequencing, gene expression analysis, protein expression and interaction analysis, quantitative cellular image analysis, quantitative tissue analysis, in silico tissue and cell modeling, digital tissue manufacturing, automated quality assurance systems, data mining tools, and clinical informatics interfaces. [Source: http://www.tissue-engineering.net/index.php?seite=whatiste]
Public Health	**Public Health** is the effort organized by society to protect, promote, and restore the people's health. It is the combination of sciences, skills, and beliefs that is directed to the maintenance and improvement of health through collective or social actions. The programs, services, and institutions of public health emphasize the prevention of disease and the health needs of the population as a whole. Additional goals include the reduction of the amount of disease, premature death, disability, and discomfort in the population. The basic sciences of public health include epidemiology and vital statistics, which measure health status and assess health trends in the population. Epidemiology is also a powerful research method, used to identify causes and calculate risks of acquiring or dying of many conditions. Many sciences, including toxicology and microbiology, are applied to detect, monitor, and correct physical, chemical, and biological hazards in the environment. Such applications are being used to address concerns about a deteriorating global environment. The social and behavioral sciences have become more prominent in public health since the recognition that such factors as indolence, loneliness, personality type, and addiction to tobacco contribute to the risk of premature death and chronic disabling diseases. [Source: http://www.healthresources.mumbaipage.com/aboutus.htm]
Environmental Health	**Environmental health** science is the study of how the environment and environmental agents

	affect human health. This includes preventing, intervening in, and treating human disease associated with the environment. [Source: http://www.ehsc.orst.edu/outreach/whatisehs.html]
Translational biomedical research	**Translational Biomedical Research"** or **"translational research"** transforms scientific discoveries arising from laboratory, clinical, or population studies into clinical applications and refers therefore to research at the interface between fundamental research and clinical application. [Source: adapted from the Definition of Translational Research by the National Cancer Institute of the US National Institutes of Health. http://www.cancer.gov/trwg/TRWG-definition-and-TR-continuum]
Technology Platforms	Technology Platforms allow the concentration of expensive equipment and avoid duplication (cost-effective), guarantee that tasks are performed by experts, and foster collaborations. Most technology Platforms technologies are not simply services to projects, but involve fundamental and innovative research to keep the technologies up-to-date or advance them to new grounds. Technology Platforms are ideal to form centres of expertise with international recognition and might eventually even draw customers from industry and abroad, i.e., also have an economic impact. This domain encompasses Modelling and Simulation technologies, the Information infrastructure supporting research, Biobanks and Tissue Banks, as well as proteomics, genomics, bioinformatics, etc.

A2 Technology Platforms

Although the subject of technological platforms was not explicitly addressed in the workshops, certain platform requirements were highlighted in the Foresight exercise as a necessary condition for specific research priorities.

In general, Technology Platforms allow for the concentration of expensive equipment and avoid duplication (cost-effective), they guarantee that tasks are performed by experts, and they foster collaborations. Most Technology Platforms are not simply services to projects, but involve fundamental and innovative research to keep the technologies up-to-date or advance them to new grounds. Technology Platforms are ideal to form centres of expertise with international recognition and might eventually even draw customers from industry and abroad, i.e., also have an economic impact.

A2.1 Modelling and Simulations

The utilization of computational modelling and simulation techniques as well as the organisation of scientific data in complex databases are essential parts of scientific work in practically all modern research domains. Many research findings, technological developments and innovations would simply be impossible without state-of-the-art simulations performed on high-performance computer systems. Scientific computing is needed in all disciplines and it is a productive and powerful tool for a growing scientific community in Luxembourg. It is therefore mandatory for Luxembourg to provide researchers in all research domains with continuously evolving high-power computational capacities and support. This can be achieved by establishing a Platform for Modelling and Simulations as a central facility of high competence in scientific computing in Luxembourg. The platform should act as an "intelligent service provider" and should develop expertise in applying existing software as well as developing and adapting software for specific research problems. The focus should not so much be on the development of new computational methods but predominantly on the adaptation of existing ones. Furthermore, the platform should not be regarded as a simple service provider but rather as a support facility that does not only provide a sophisticated computational infrastructure, but also actively advises, trains and educates the potential users.

During this foresight exercise strong demands for scientific computing capacities were expressed in several research fields. The areas with the highest demand for a Modelling and Simulations Platform were the domains related to material sciences, environmental sciences and life sciences. Their needs for support in scientific computing can be outlined as follows.

In the field of New Functional and Intelligent Materials and Surfaces, and New Sensing Applications (see chapter 6.3) the application of computational material science methods contributes to develop new software tools for modelling the properties and behaviour of materials. These simulations should be run on high-performance supercomputer systems. The combination of Computational Fluid Dynamics (CFD) with simulations of solid materials behaviour is seen as an upcoming technique that demands high expertise in scientific computing and a powerful computation infrastructure.

Researchers of the domain Managing Sustainable Development (see chapter 6.2.1) aim at developing mathematical models for regional sustainability and a comprehensive analysis of the sustainable development of Luxembourg. This includes designing adequate computational tools and modifying existing ones like GIS tools (Geographical Information System tools) to make them adequate for environmental analysis. The question of how to organise knowledge about environmental management and issues so as to capitalise on existing currently fragmented environmental data should also be addressed by researchers of the field in collaboration with the Modelling and Simulations Platform.

Climate change is a transversal issue with interdisciplinary relevance for all fields in the sustainable resource management domain (see chapter 6.2). Future activities in the management of water and energy resources, agro-systems and ecosystems have to be seen in the context of Luxembourg's adaptation to the predicted global climate changes. The success of sustainable resource management will strongly depend on how effectively the uncertainties in the climatic parameters can be constrained by numerical modelling. Global climate change scenarios are built on a regular basis and published in the framework of the Intergovernmental Panel on Climate Change (IPCC).[308] Since these climate simulations are based on grid calculations covering thousands of km^2, it is necessary to down-scale the impacts on Luxembourg. This task, which is a fundamental prerequisite for all environmental research activities in Luxembourg, should be executed by a dedicated working group or department in the Modelling and Simulations Platform, building on the existing expertise in climate model down-scaling.

The demands from the research areas described above should be used for guidance when it comes to the implementation of the platform. This approach should not only imply the implementation of computer hardware and the selection and development of software. Also an adequate structuring and selection of human resources will help to adapt the platform to existing needs and to optimize the interface between the centralized facility and the research groups from the different domains. Competence guaranteed by computational scientists with cutting-edge knowledge should be mixed with specific expertise of computational research experts stemming from the main research backgrounds involved. Physical models of materials, complex ecosystems or biochemical structures require deep fundamental understanding of the scientific basis and can only be developed within a multi-disciplinary environment.

In general, the structure of the platform should be open for demands from all fields of research. In fact, the need for modelling and simulation services is expected to increase, in part, due to the mere existence of the platform and the availability of computational support, which helps researchers to identify strategies to solve problems in their field by using computational modelling. The Modelling and Simulations Platform will also be highly attractive for several industrial sectors in Luxembourg. Therefore, the dialogue between this public computational research centre and private sector research and development should be encouraged. Collaborations with industrial partners and computational services provided to business are seen as potential sources of additional financing.

Careful and well-informed planning prior to the actual implementation of the platform is crucial for its success and usability. Care should be taken when aligning public funding on the platform to current research demands as expressed by the actors in the various fields involved. These

[308] http://www.ipcc.ch/

needs are likely to be underestimated. The true needs can only be expressed by a scientific community that is sufficiently knowledgeable about the possibilities of computation means put at their disposal. The necessity of keeping the infrastructure continuously up-to-date has to be included in financial planning. The hardware should consist of scalable systems that can grow with increasing demands and technological progress. An appropriate facility is needed that can easily house growing computer systems including air conditioning and space. A nucleus of highly educated permanent staff should be established in order to guarantee a high level of expertise for running the platform and adapting the systems to the needs of research groups from all disciplines. In order to enable researchers in Luxembourg to exploit the computing capacities provided by the platform, specialized courses, e.g. on parallel computing, should be offered.

Due to Luxembourg's size it is possible to handle the scientific computing demands from all disciplines in one central facility. The economic advantages of such a centralisation of capacities are obvious. Substantial savings can be expected in hardware, software, licensing, and system maintenance. However, the bundling of competencies and capacities in a platform will also increase the level of expertise and computing power that is available for each research field compared to "stand-alone" solutions. Research groups in Luxembourg will greatly benefit from the advantage of having local support by expertise in scientific computing. As a consequence a boost of scientific progress in various fields can be expected.

A2.2 Information infrastructure supporting research

During the Foresight exercise it became clear that an excellent national information infrastructure is an absolute prerequisite for research. Such an infrastructure is built on three pillars:

1. *A national consortium as a service and access provider to scientific information*

Due to the small size of Luxembourg it is most cost-efficient to rely on a single service and access provider. The services would consist mainly in: negotiating access licences from publishers, running and maintaining a single access portal, providing added-value services to make the available information easier to access and manageable for the final users, e.g. linking services, meta-search services, personalisation, alerting services, etc.

Most of these services are already operational in the shape and form of the National Library's and the University's Information portal at http://www.portail.bnu.lu. This portal and the existing bilateral consortium BNL-University should be extended to other public research organisations. Access is already available for members of the public from the place of their choice for most of the licensed content (>15k eJournals, >200 databases). In view of the EU Commission's i2010 goal, this strategic goal of giving access to as much information as reasonably possible to the largest number of people is crucial to support the evolution into an innovative knowledge society.

2. *A repository for the national scientific production (digital-born and digitised)*

A national repository for thesis, “mémoires”, pre-prints, post-prints, published articles (possibly subject to publisher embargoes) is needed. Such a repository will allow the long-term measurement of the quantity and impact of the national scientific production.

It should be noted that this repository will not preclude any scientists from publishing their findings in a journal of their choice. Also, there will be no preference for either the “author-pays” (Open Access) or the “reader-pays” (Subscription) model. The only funding pre-requisite that is retained is that funding mechanisms should include any publishing costs, so that authors actually have the possibility to opt for the « author-pays » model, as recommended by the European Commission[309].

The National Library’s mission is to guarantee the long-term archiving of digital born material, therefore the repository service should be based on a close cooperation between the National Library, the University and public research organisations.

3. *A national service for digitising scientifically relevant publications (paper-based)*

It was noted several times that there is a large body of Luxembourg content and Luxembourgensia which would benefit public research enormously if it were available under digital form. There are substantial benefits to digitisation: from guaranteeing access to fragile material to better searchability due to advanced meta-data.

The National Library should act nationally as a coordinator and dissemination partner to ensure that digitisation efforts from all the concerned partners follow the most-widely used standards to ensure interoperability on a European and global scale.

A2.3 Biobanks / Tissue Bank

The understanding of pathologies and the confirmation of results obtained with cell and animal models for disease is critically dependent on the availability of human material that can be used in research projects. Thus, one of the main difficulties and limiting factors to bio-medical research and partly also to public health research (not just in Luxembourg) consists in the limited access to biobanks[310] samples in general, and tissue samples from patients and healthy persons in particular and the associated expense. In Luxembourg, initiatives for collecting human material are fragmented and sample quality is frequently not adequate for modern genomic analyses (e.g. microarray analysis of mRNA) or information about patients’ data is lacking. The rationale of biobanking for the researchers is to establish or facilitate future research opportunities that could not or only with much greater difficulties be fulfilled at the current time, when the biobanking takes place. There are typically two sets of reasons:

- One is that methods, technology, logistics, finances, and not least pertinent information about the biological samples stored or the subjects they were drawn from, for example emergence of

[309] http://ec.europa.eu/research/science-society/document_library/pdf_06/communication-022007_en.pdf

[310] Biobanks can be defined as systematic collections of biological samples of tissue, cells or body fluids, from human beings combined with a parallel systematic collection of information belonging to each sample about pertinent characteristics of the human subjects donating the samples and/or the circumstances under which the donation has taken place. [Source: Braun, A; Rijkers-Defrasne, S.; Deschênes, M.; Scerri, C. A.; Laage-Hellman, J. (2006) ESTO/IPTS Report "Biobanks in Europe: Prospects for Harmonization and Net-working". Seville: IPTS- Institute for Prospective Technological Studies.]

future diseases, may be lacking at the current time. When these prerequisites are met, then the samples or subsets of the samples will be taken out of the biobank and investigated.

- The other set of reasons has to do with the nature of research: it always implies an appreciation that the future may bring ideas, questions, or problems that are not foreseen at the current time. In order to be prepared for research that address such ideas, questions or problems, biological samples are stored in a biobank. It is suggested that the latter reason is in fact predominating in most biobanking activities as they have been and currently are being conducted.[311]

Since legal aspects and high associated costs often restrain the possibility for researchers to access biosamples from abroad, a tissue bank in Luxembourg was seen as a 'platform' that could have tremendous benefit to the whole of bio-medical research and a developing private biotechnology sector. Well catalogued healthy reference material would be an invaluable asset for many research projects in the domains of Public Health, and Translational research as well as Regenerative Medicine. A central resource centre for biological material with well-established state-of-the-art protocols for collecting, conditioning and storing biological material, guarantying its traceability could increase the attractiveness of Luxembourg as a partner in European research networks.

The importance for future research of tissue banks and of biobanks in general is underlined by FP7 activities aiming at furthering and networking biobanks initiatives across Europe and developing European standards and norms for human sample biobanks[312]. The collection of all kinds of samples would need to be well documented and the access efficiently regulated. Given an appropriate technological and regulative framework, still lacking at the moment[313], a tissue bank could be a great asset. However, as ethical concerns are still important obstacles and the public debate in Luxembourg has been very limited so far, Luxembourg still needs to start confronting the issue of tissue banks, and more generally of biobanks, on the ethical and social level. More generally, the success of such an action will critically rely on the concerted interaction of clinicians, anatomo-pathologists, scientists, lawyers and governmental institutions.

A2.4 Other Platforms

Additional platforms where highlighted particularly for the Life sciences where some biomedical Technology Platforms (e.g. genomic and proteomic platforms) are already in existence in Luxembourg. To a large extent existing competences are still in development and department barriers are low and an integrated view prevails. Therefore flexibility is needed to

[311] Source: Braun, A. et al. (2006) ESTO/IPTS Report "Biobanks in Europe: Prospects for Harmonization and Net-working"]

[312] Presentation of «Health research in the 7th Framework Programme» at FP7 launch, Jan. 2007. http://www.forschungsrahmenprogramm.de/_media/WS-Gesundheit_1_Quintana.ppt#1

For information on the future role of biobanks for research, as emerged in international foresight studies, see: [Source: Braun, A. et al. (2006) ESTO/IPTS Report "Biobanks in Europe: Prospects for Harmonization and Net-working"]

[313] In 2005 a law on the use of human tissues and cells for therapeutical purposes - transposing the European Directive 2004/23 on setting standards of quality and safety for the donation, procurement, testing, processing, preservation, storage and distribution of human tissues and cells - was released; it has still to be transposed into Luxembourg's legislation. [Source: Braun, A. et al. (2006) ESTO/IPTS Report "Biobanks in Europe: Prospects for Harmonization and Net-working"]

closely link and interconnect the platforms to provide tools and services to be used in a broad variety of medical applications and to help address scientific questions emerging from the key research areas.[314] In an initial step, these exiting competences need to be identified and further developed and interlinked (e. g. proteomics, genomics, coupled to bioinformatics and data analysis) to form a competence basis for new platforms. The usual difficulties in understanding across disciplinary boundaries need to be overcome to create and optimally exploit these platforms in the frame of inter-institutional cooperation agreements.

Building on the insights gained through traditional approaches of genomics and proteomics, new multi-faceted platforms can be built (e.g. systems biology and metabolomics). However, to be efficient and cost-effective, building new plat-forms requires coordination at a national level.

In case of the research field tissue engineering, three dimensional imaging technologies (confocal fluorescence microscopy, ultrasound…) were seen as a requirement. In principle, platform technology services could be imported in some areas. Experiences with animal experimentation and cultured cells show, however, that competence in image analysis is needed in Luxembourg and one cannot solely rely on services located abroad.

Besides all forms of analytics, imaging, spectroscopic techniques, etc., the establishment of supplier platforms (e.g., for expression vectors, proteins, special chemicals and biochemicals) could be of interest. For instance, the need of developing new biomarkers and validating existing ones for research in public health and epidemiology was highlighted. There are a lot of biomarkers available at the moment for different diseases and different infectious agents but most of them still need to be validated and tested. Furthermore, high-throughput technologies available today have made it easier to develop new biomarkers.

[314] Some examples: Proteomics used to identify novel therapeutic targets, genetic engineering of cells and tissues for therapeutic purposes, development of small molecules, including engineered antibodies, service-oriented biotechnologies, e.g. sequencing, antibody / active protein production, molecular screening.

A3 Fiches

1. Innovation in Services
Challenges in the national context
Luxembourg's impressive economic growth since the 1980s - compared to neighbouring countries - has been due to the performance of the services sector which developed at an accelerating pace in the last decade of the 20th century. Today, the services sector is Luxembourg most important economic sector: by 2001, services as a whole (commerce, financial services, property and business services, other services like public administration, education, and community services) contributed more than 80 % of the total value added and employment in services accounts for about 75 % of total employment in Luxembourg. The services sector is driven by the outstanding performance of the financial services (financial intermediation, insurance and financial auxiliaries) which contributed, between 1996 and 2000, for more than 25% to the total growth of gross value added. The development of financial services has also had favourable repercussions on such sectors as hotels, catering, air transport, business services (consulting, advertising, legal services, cleaning, security) and IT services and the impact on growth of these sectors should not be underestimated. The employment in business services practically quintupled from 1985 to 2002 (from 7000 people to more than 35 000) and represented approximately 13% of total employment in the Luxembourg economy in 2002. The share of business services in total value added grew from 3.1% in 1985 to 6.3% in 2002.
Research Issues
1.1 Business Service Design and Innovation 1.2 Fostering the Economic and Legal Environment for Innovation 1.3 Performance and Development of the Financial Systems 1.4 Information Security and Trust Management
Research objectives
It is of highest importance for Luxembourg, on the one hand to consolidate the competitiveness of its most important economic sector, and on the other hand to strengthen the innovation capacity in all sectors in order to diversify the economy and therefore minimize the risks associated with a strong dependency of the economy on one sector (the finance sector). Hence, public research in the three domains Business Service Design and Innovation, Fostering the Economic and Legal Framework for Innovation, and Performance and Development of the Financial Systems is of extremely high socio-economic relevance for Luxembourg.

1.1 Business Service Design and Innovation

Challenges in the national context

Luxembourg's economy is largely based on the service sector and this dominance is even expected to rise in the future whereas the manufacturing industry will correspondingly lose its share in the Luxembourg economy. IT activities, comprising consulting in information technology systems, software services production, data processing, database activities, etc., currently constitute the most dynamic sector of the economy in terms of employment and value added. Additionally customers of e-services are mainly located outside of Luxembourg (e.g. finance and broadcasting industry), the market potential and thus the economic impact is enormous in comparison to the size of the country. Hence, it will be important to develop tools that facilitate and aid the development and improvement of high-value added products and services for both business and the general public in Luxembourg. Research in *Business Service Design and innovation* is based on an interdisciplinary approach guaranteeing the alignment of technologies, business processes and strategies as well as human skills. Within the Luxembourgish context, it might be also interesting to take care of an additional dimension regarding the research related to and needed for the alignment with the regulatory and legal framework. Research may cover many different applications and e-services of different levels of granularity: business related e-services (business to-business, administration-to-business services, same processes in e-administration and internal e-solutions of a company…), e-government (including e-voting), e-governance, e-administration, but also services related to e-health, e-learning, etc.

Research Issues

The most promising research issues

- Seamless service architecture
- Incentive systems
- Business-IT alignment
- service disintegration
- enterprise architecture
- adaptivity, interoperability
- simulation and optimization
- service level agreements

deal with the three business/IT alignment situations:

1. business model innovation
2. business process efficiency and flexibility
3. business service regulation compliance

Research objectives

Within the next 10 years, Luxembourg public research should aim at:

- providing knowledge and direct support to industry and SMEs for the development of more productive services;
- fostering innovation and creating added value for the banking sector but also in other sectors e.g. broadcasting sector, transport and logistics;

- achieving a sort of "clearing house" functionality for information exchange in various sectors (e.g. health services for cross-border workers, clearing house between national standards) between businesses, financial institutions and government to make it easy to create, share and use knowledge in business, scientific and societal applications;
- developing a university course/degree on services science and become a hub/reference point for services science in order to increase Luxembourg's scientific reputation in this domain and attract talents.

1.2 Fostering the Economic and Legal Environment for Innovation
Challenges in the national context
Boosting innovation is at the core of the Lisbon Strategy as well as the "National Plan for Innovation and Full Employment" of the Luxembourg government since it is a key determinant of the ability of an enterprise, sector, region or country to remain competitive. Despite its good general economic performance, Luxembourg performs less well in innovation. The EIS indicators in 2004 highlighted many areas related to innovation where Luxembourg is below the EU25 average. In terms of innovation drivers and knowledge creation, Luxembourg ranks low and its performance in applications ranges from very poor for new-to-market product sales and for employment in medium-high and high tech manufacturing, to far above the EU average for high tech exports. The improvement of Luxembourg’s innovation capacity in SMEs and large companies should be one of the priorities of public research in view of increasing Luxembourg’s competitiveness, diversifying the economy and minimizing the risks associated with Luxembourg’s specialization in financial services. As innovative regulatory frameworks in Luxembourg have created new opportunities and fostered innovation - especially in the financial sector so far-, it is important to build on this competitive strength. Where and how regulations facilitate innovation and what the best innovative-friendly regulatory framework for Luxembourg’s companies in the next 5-10 years should look like - given the context of European harmonisation- should remain fields of research. In that regard, the regulatory framework can be seen as an enabler for innovation in the whole services sector.
Research Issues
▪ Analysis of legal framework to improve economic competitiveness and innovation ▪ European harmonisation / EU directives and regulations vs. national statutes ▪ Impact of globalisation, supra-nationalisation and European integration on governance ▪ Regulatory competition between member states (in areas like banking, security, company law, retirement funds) ▪ Business Law ▪ Corporate governance and shareholder protection ▪ Entrepreneurship ▪ Efficient administration – innovation funding mechanisms for SMEs ▪ Intellectual Property Rights ▪ Employment protection legislation / labour market ▪ Tax incentives / Tax law
Research objectives
In general, public research should determine the right balance between European harmonisation and intergovernmental competition in order to consolidate the legislative advantages already existing in Luxembourg, to address existing legal constraints or create new sovereignty niches supporting economic development, as well as to modernise Luxembourg’s legislation. Public research should not reduce itself to being a mere supplier of tools for businesses but should focus on general issues such as e.g. understanding links between regulation and innovation as well as the development of appropriate methodologies for evaluating political measures within market economies.

Luxembourg could for instance become a leader in the area of company law in the EU (and the opportunities that arise due to company law harmonisation). This could be a substitute for the current habit of importing law from neighbouring countries, a practice by which legal constraints are imported as well.

1.3 Performance and Development of the Financial Systems

Challenges in the national context

The financial sector underpinned Luxembourg high economic growth during the period 1985-2005 and can therefore be rightly considered as the *heart of the Luxembourg economy.* Today, the Luxembourg economy is growing by around 4-4.5% p.a. and the financial sector, which has recovered from the bursting of the stock market bubble and benefited from the return of investors' confidence in capital and equity markets, currently accounts for 31% of economic activity thus making Luxembourg economy very dependent on the performance of the financial sector. Research related to Performance and Development of the Financial Systems is of high importance to maintain the international competitive position of Luxembourg as financial market place. Even if the estimated trend growth rate of the national economy remains high by international comparison, it has nevertheless slowed considerably and may weaken further due to factors such as financial market liberalisation and harmonisation. Research will contribute to ensuring the long-term sustainability of the whole Luxembourg economy, as the financial sector has an important "multiplier" effect on the rest of the economy.

Research Issues

Public research should focus on research topics which cannot be easily addressed by companies and therefore contribute to leveraging the capacities of companies involved in the field.

For public research to be relevant for the financial sector, research should focus on the main drivers on the demand and supply side of Luxembourg's most interesting financial areas - in terms of revenue generation and job creation -, namely the Investment fund industry and Private Banking:

- the *Investment Fund industry*, where Luxembourg has managed to develop into a global player in administration and cross-border distribution. The main challenge is not the administration of funds anymore, but innovation in the distribution of funds, especially considering tomorrow's new markets: Asia, Russia, the Middle East, and Latin America.
- the *traditional Private Banking activity*, with its services offering constantly adjustments to the changes in the regulatory and tax framework and hence the needs of the client.

Because of the financial sector's predominant role in the economy, research on financial systems, should not only focus on the macro-economic financial system but also on all kind of financial subsystems, appears as a "natural" national research priority.
Other possible interesting research areas might be: Portfolio Management, Behavioural Finance, Socially Responsible Investment including Microfinance, Risk Management and forecasting financial risks, Venture Capital, Retirement Planning and Financing, Financial Education, etc.

Nevertheless, given Luxembourg's very young and small research and innovation system, a too strong narrowing down of the priorities within research in finance at this stage might be counterproductive and hamper the development of an internationally visible and successful critical mass of researchers.

Research objectives
Public research in "Performance and Development of the Financial Systems" would increase or strengthen the attractiveness and competitiveness of Luxembourg as a business-friendly environment in general and Luxembourg's financial sector in particular - especially in the context of European harmonisation ("switch from sovereignty niches to excellence niches"). In particular, research should help to cope with the most important challenges and opportunities faced by the banking market at the moment: the quality of services provided to the client, the development of new products and services and the managing of distribution channels. The set up of Public-Private-Partnerships would allow for a dialogue between the researchers and the main users of research and as such for a quick implementation of the results by all social and economic stakeholders.

1.4 Information Security and Trust Management

Challenges in the national context

IT activities, comprising consulting in information technology systems, software production, data processing, database activities, etc., currently constitute the most dynamic sector of the economy in terms of employment and value added e.g. E-commerce opens doors to the international market as it allows a wider range of potential customers to be reached without taking account of the limitation of space. "Information Security and Trust Management" is a "transversal" research domain of central and ever-growing importance not only for the banking industry, but for nearly all other ICT applications and e-services (e.g. health applications and applications in critical infrastructures like water and energy infrastructures). Information security research in Luxembourg should concentrate on the needs of Luxembourg as a market place. As the financial sector is the heart of Luxembourg's economy, research should contribute to consolidate Luxembourg's reputation as a safe harbour for information. Research areas like identity management and privacy - areas that should benefit the banking industry - have top priority. The public and the private sector are particularly interested in risk management and security issues.

Research Issues

- Trust, Information security and Risk management
- Identity and Privacy Management, including Digital Rights Management
- Reliability and Resilience
- Legal framework for trust
- Security protocols and Cryptology
  - Pseudo-anonymity
  - Formal proofs / Verification / Validation
  - Secret key algorithms cryptanalysis and design
  - Public key algorithms and protocols design
- Security of implementation of cryptographic algorithms

Research objectives

Luxembourg should set the objective of becoming a leader in all aspects of trust and security in order to attract new business to Luxembourg and to further develop the economy based on services and finance. Besides its obvious impact on the financial and the broadcasting sectors, public research in this domain will be also profitable for SMEs, as information security and trust are enablers for other business activities. However it is of importance not to develop security applications on its own, but research should be rather steered towards the development of secure (IT-based) applications considering the interdisciplinary character of growth sectors e.g. telecommunications. Apart from the technical side, the legislation frameworks sometimes limit the use and implementation of new security solutions. Luxembourg should therefore aim at achieving a clear and appropriate legal framework adapted to security issues as this could be of high relevance for companies and a competitive advantage over other countries. Public research in this domain should therefore be carried out in an interdisciplinary way involving ICT experts, users of security solutions, business law researchers and public decision makers.

1.5 Telecommunications and Multimedia

Challenges in the national context

The domain "Telecommunications and Multimedia" encompasses the development of technical infrastructures for the distribution of content as well as the development of new multimedia applications.

The development of technical infrastructures for the distribution of content was seen to be very important for Luxembourg. Research in this area should be media and telecommunications-neutral, addressing therefore satellite as well as terrestrial transmission. Regarding satellite distribution of content, the ESA membership provides new opportunities for collaborations with experts and industries abroad and for influencing the development of new telecommunications standards.

The presence in Luxembourg of a satellite-based communication operator (SES) and a number of content providers seems to offer some opportunities for Luxembourg in positioning new services regarding interactive TV and/or interactive internet content.

Research Issues

- Aggregation and distribution of content
  - Distribution/Personalization of content
  - Location based services, contextual based services (using satellite-based solutions)
  - IP based, on demand, interactively, very diverse
  - Multimedia
- Distributed, Mobile, and Self organising networks
  - Seamless connectivity/interoperability/networking (security, handover, QoS,...)
  - Sensor networks
  - Wireless access
  - Engineering of distributed applications
  - Network support (testing, operation, management...)
  - Mobility and Interoperability / Interfacing between systems
  - Radio frequency systems
  - Next generation networks
  - Mobility governance
  - Pervasiveness
  - IP-based converged networks
- Crisis management
  - Early warning systems
  - Data back-up

Research objectives

Research in telecommunications should focus on the distribution and personalisation of satellite signals and build on the existing competencies in the private sector, especially in the ground segment. Crisis and disaster management could significantly profit from advanced ICT architecture, regarding monitoring and early warning-systems as well as integrated "alarm" chains. The study of intelligent, self-organised and dynamic networks for improving seamless applications/hand-over has been assessed as very promising for public research, especially because of a lack of a strong international R&D on that issue so far.
Public research activities related to multimedia applications should be promoted, with the view to develop a Pan European platform for aggregation, distribution and delivery of content. Important research issues for the next years concern the management of

multimedia content; the convergence of different media contents and of distribution of media content; search engines and cross-format data retrieval; the semantic web (semantic tools); geolocalisation and location-based services.
Another important aspect was seen in multilingual content management i.e. in applications that allow multilingual content generation, data retrieval and tools that enable „barrier-free"-communication by being accessible in multiple languages. Such applications could provide an interesting niche for Luxembourg research and business responding to needs that can not be addressed by monolingual societies.

2. Sustainable Resource Management in Luxembourg
Challenges in the national context
Sustainable development is maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend on the other. According to The World Commission on Environment and Development, it is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. As Luxembourg's ecological footprint[315] ranks among the highest worldwide research priorities in Environmental Sciences should be chosen so as to promote a more sustainable use of resources and a sustainable way of living in Luxembourg.
Research Issues
2.1 Managing Sustainable Development 2.2 Understanding Ecosystems and Biodiversity 2.3 Sustainable Management of Water Resources 2.4 Sustainable Uses and Sources of Energy 2.5 Sustainable Agro-Systems Management 2.6 Spatial and Urban Development
Research Objectives
The domain "Sustainable Resource Management in Luxembourg" encompasses all research areas related to environmental sciences that were assessed as important for Luxembourg in this foresight process. Besides the obvious fact that these domains have points of contact where they are interlinked with each other, it is of outmost importance for research to contribute successfully to a sustainable management of resources in Luxembourg to overcome disciplinary hurdles and develop a more holistic approach by combining results from various research activities.

[315] The Ecological Footprint (EF) measures the extent to which humanity is using nature's resources faster than they can regenerate. [Source: Ecological Footprint and Biocapacity, European Commission, 2006, http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-AU-06-001/EN/KS-AU-06-001-EN.PDF]

2.1 Managing Sustainable Development

Challenges in the national context

In order to achieve sustainability for the Luxembourg society, it is of importance to consider the correlations between the different constituents of the environment, e.g. agriculture, energy, waste treatment, water management etc., and to gain an integrative understanding of the energy and material flows in Luxembourg. This understanding of the current use of environmental resources will contribute to optimize resource use (water, energy, raw materials) in the future. The environmental situation in Luxembourg has to be analysed and broken down to territorial levels, at which solutions and optimisation strategies could be implemented requiring comprehensive monitoring and analysis tools for e.g. the water and soil quality, air pollution, etc. Such analysis tools do partly exist already but only for certain resources. A comprehensive model for the use and management of all natural resources and their relations, however, is still missing.

Research Issues

- Development and application of tools and methods for the sustainable use of resources
- Data collection and scenario development, including the setting up of an information base for decision-makers
- Multi-criterial assessment of processes, scenarios, technologies, products…
- Analysis and optimization of material and energy flows on a local, regional and national level
- Assessment of existing and development of new governmental support systems and financial tools; micro-finance; contracting tools; development of business opportunities for SMEs
- Development and analysis of indicators
- Integrative approach between the Plan National de Développement Durable, the National Plan for Rural Development and the National Plan for Environmental Protection, as well as the Implementation of the EU Water Directive

Research objectives

This research priority is seen as an innovative approach to generate a systematic knowledge of the Luxembourg environment and to improve the quality and coordination of research efforts in the various environmental research domains. The approach should include economic as well as ecological goals in the different fields of interest.

To be able to achieve sustainable development goals for the whole Luxembourg society, all relevant public and private actors should choose strategies that focus on ecotechnologies, clean technologies, integrating technologies and highly efficient technologies regarding to resources use and pollution. However, the question is not so much to provide and develop ecotechnological solutions "made in Luxembourg" but to have a consistent approach on and implementation of existing and emerging technologies for sustainable resource use. The objective is to constantly monitor and feed an existing action plan in order to facilitate an informed decision-making and to find long-lasting solutions with the vision of making Luxembourg a showcase for regional sustainability. Luxembourg has, due to its size, a unique chance to set up a systematic, transdisciplinary research approach in order to govern upcoming ecological challenges in a proactive manner.

2.2 Understanding Ecosystems and Biodiversity

Challenges in the national context

In order to achieve an adequate management of natural resources, a thorough understanding of the intimate functioning of the ecosystems needs to be elaborated. Research on biodiversity and ecosystem functions is of great importance for Luxembourg due to the social-environmental benefits associated with it. The preservation of biodiversity is, in general, a fundamental component of any sustainable development. Recent research reveals that loss of biodiversity can impact the functioning of both natural and managed ecosystems. These results raise concerns about the capacity of impoverished ecosystems to deliver ecological goods and services which are essential to human well-being. Some examples of ecosystem services are support of the food chain, harvesting of animals or plants, regulation of water, air and climate or the provision of scenic views. In order to reverse the trend of ongoing loss of biodiversity and to ensure the achievement of long-term sustainability goals, research in this field should be integrated into the concept of sustainable development in Luxembourg in the near future.

Research Issues

- Evaluation and Monitoring of Biodiversity
  - Taxonomy
  - Status evaluation
  - Monitoring
- Understanding of ecosystems
  - Population dynamics
  - Invasive and introduced species
  - Human biodiversity interactions
  - Impact of climate change and pollution
  - Dissemination of genes in space and time including habitat corridors
  - Socio-economic evaluation of BD and ESF
  - Climate Change related issues:
    - Climate change and its effects on environment and society in Luxembourg:
    - Climate change cause and effects
    - Analyse Climate Feedbacks and Sensitivity to natural and Human-induced environmental changes
- Management and conservation
  - Restoration ecology
  - Sustainable management of natural resources including agriculture, forestry,…
  - Management of human/BD interactions
  - Strategies for public awareness

Research objectives

The objective of research in this domain is to preserve the ecosystems and the biodiversity as a fundamental pillar of a sustainable development of Luxembourg society. Beyond the mere understanding of biodiversity and ecosystems and their environmental implications, the economic relevance for Luxembourg of these two issues is often underestimated. Although there exist many ecosystem services with high socio-economic benefits for present and future generations, research activities in this field are often regarded to be of minor economic importance not only by the public but also by policy-makers. One major objective of public research in this domain should, therefore, be to tackle this acceptance problem by a systematic assessment of ecosystem services in order to properly ascertain the socio-economic benefit of biodiversity which is practically unvalued so far. The approach to this task should be to identify opportunities for economic benefit by emphasising the potential sources of economic growth through conservation of biodiversity.

2.3 Sustainable Management of Water Resources

Challenges in the national context

The fundamental resource water in form of ground water, surface water and urban water and the water cycle as an interlinking mechanism is a highly complex system which is very sensitive to climatic changes and other anthropogenic influences. For instance, excessive abstraction of water from ground water and surface water can have a negative impact on the hydraulic regime of Luxembourg's rivers. The need for an efficient and sustainable management of water resources in Luxembourg is obvious in the light of the potential threats arising from water pollution, water scarcity, risk of floods and other hazards. Luxembourg is already spending large amounts of money in water processing, waste water treatment etc. thus making it necessary to provide intelligent and innovative technologies and to find more efficient solutions in this field.

Research Issues

- Water pollution by emerging substances, incl. removal by innovative processes
- Water availability/ scarcity
- Flood risk
- Protection of groundwater and of other water bodies
- Hydrological functioning of groundwater, interaction in the hydrological cycle
- Chemical and microbiological risk assessment
- Biological indicators
- Risk assessment and management
- Climate change and impact on the water cycle in Luxembourg
- Remediation of polluted ground water / risk assessment of accidental pollution scenarios
- Demand of irrigation in agriculture in drought phases
- Water issues related to biomass farming
- Resource management
- Online measurement and monitoring

Research objectives

The further development of the current research competences in the water is certainly in the national interest of Luxembourg in order to develop an integrated water resources perspective ensuring that social, economic, environmental and technical dimensions are taken into account in the management and development of water resources.
An important challenge is to develop water management tools to cope with the influence of global climate change and human activities (agricultural practices, biomass farming, altered pollutant fluxes, and modified energy balances) on e.g. the scarcity of high quality water for human consumption and flood risks. Additionally there is a strong need for new technologies for measuring the state of pollution of all water bodies by emerging substances (chemical and microbiological) and also for the removal of identified contaminants. A major goal is the implementation of an online measuring and monitoring system for all water bodies. Besides these technological aspects the development of risk assessment and management tools is demanded in order to prevent water pollution hazards and to reduce the number of water analyses needed to guarantee high water quality standards. The socio-economic impacts and conditions of sustainable water resources management should also be investigated.

2.4 Sustainable Uses and Sources of Energy
Challenges in the national context
Providing the country with sufficient energy is seen as the most important task for Luxembourg in the future, given the high per capita energy consumption rate and the existence of a number of energy-intensive industries. The fact that the majority of Luxembourg's gross energy consumption has to be imported leads to an enormous economic dependency of Luxembourg on oil and gas exporting countries, including high uncertainties in pricing and long-term availability. Considering the climatic impacts and the generally limited availability of fossil energies, it is of high importance for Luxembourg to increase energy efficiency as well as the share of regenerative and renewable energy sources and to develop competencies in these fields. However, the motivation for research activities in the energy sector not only environmental but is strongly influenced by economic issues. In addition to the economic aim of reducing Luxembourg's energy dependency, there is a high potential of exporting energy related technologies developed in Luxembourg. Both applied and basic energy research hold high potential to produce high value added, as the market for energy- and environmental technologies is continuously increasing.
Research Issues

• Energy efficiency
  o Recovery of waste-energy and co-generation in industrial processes
  o Energy efficiency in private, commercial and public buildings (including research on construction materials, installed technology, integrated planning)
• Bioenergies
  o Biomass, biogas and biofuel, including biological conversion and thermochemical conversion
  o Sociological, technical and economical evaluation
  o Storage and distribution of novel biofuels
  o Biofuels for aviation
  o Linocellulosic resources
  o Wind energy
• Hydrogen as energy vector in combination with bioenergies
  o Embarked storage and security of hydrogen
  o Transport and distribution of hydrogen

Research objectives
On the subject of energy efficiency, several objectives for public sector research were highlighted: • Reduction of energy consumption in domestic, commercial and public buildings by innovative construction materials, installed technology and integrated planning, thus taking the whole life cycle of buildings into account. • Increasing the rate of recovery and co-generation from waste energy in industry. • Achieved energy savings in transportation and logistics, including the development of innovative fuels and encouraging different kinds of mobility. Besides the fundamental and applied technological questions it should be emphasized that the reduction of energy consumption has also a behavioural and pedagogical aspect which needs to be taken into account by common efforts with researchers from the social sciences. Concerning renewable energy research topics, the following objectives were mentioned:

- Research in Luxembourg should focus on a deeper understanding of the conversion processes involved (e.g. biomass to liquid, biogas production etc.) in order to decide which of these technologies are relevant and feasible for Luxembourg.
- The agricultural production of biomass for energy generation has important socio-economic consequences that have to be considered.

An important research objective will be the sociological, technical and economical evaluation of the impacts of all above mentioned research issues.

2.5 Sustainable Agro-Systems Management

Challenges in the national context

The production, transformation, consumption and conservation of agro-food products is an essential pillar of a sustainable and competitive society which effectively addresses consumer needs on food quality and safety, environmental protection and animal welfare. Research in the domain Sustainable Agro-systems Management may contribute to modernize the agro-industrial sector by providing a deeper understanding of e.g. the energy consumption during food production, the impact of food production on biodiversity and the assessment of pest damage versus the economical and environmental cost of preventive actions. Additionally animal health could be improved by encouraging the natural immunological defense of the animal as well as the selection of appropriate breeds and animal welfare friendly husbandry and feeding systems.

Results in this domain are also of social relevance, since a more healthy nutrition will have positive effects on human well-being and the health care system. The economic relevance should not be neglected, since fostering sustainable food production or energy production from biomass can create new economic activities in Luxembourg.

Research Issues

- Issues of sustainable farming
  - Food quality and authenticity, food safety, food security, food technology
  - Animal health and sustainable livestock production systems
  - Plant health and pest management
- Biodiversity and preservation and development of local genetic resources (livestock, plant species)
- Water protection
- Soil protection
  - Erosion and compaction
  - Soil quality and fertility
  - Climate relevance of farming and food production systems
  - Monitoring tools
- Renewable resources
  - Impact on ecosystems
  - Valorization of by-products
- Nutrition and food
- Consumer education and behaviour

Research objectives

The main objective of research in this domain is to facilitate an informed and evidence-based governance of the Luxembourg agricultural sector and to adapt Luxembourg's agricultural sector to the climate changes and to EU regulations. The short decision paths in Luxembourg are seen as a unique opportunity to facilitate a fast transfer of knowledge. In order to achieve progress in the domain Sustainable Agro-systems Management it is necessary to bundle the sectoral knowledge and expertise of other domains in joint projects following an integrative approach. This could constitute a change of thinking in Luxembourg and truly help to modernize the agro-industrial sector.

As a concrete example one could state the governmenbt's wish to dedicate 20% of the agricultural land to the production of Biomass by the year 2020. The impact of this change, especially the introduction of non-native plants for the production of biomass on the ecosystems in Luxembourg needs to be investigated.

2.6 Spatial and Urban Development

Challenges in the national context

On the European level, territorial development and therefore research on territorial issues have gained in the last decade crucial relevance with the enlargement of the EU, the subsequent reframing of structural funds and the necessary redefinition of regional policy. Luxembourg is likewise facing a number of challenges with an important territorial dimension that have to be addressed by spatial planning and development:

- *Environmental problems*: impacts and risks of climate change; sustainable land use.
- *Economic challenges*: reinforce the attractiveness of a country through living quality, efficiency of the transport system and a high level infrastructure.
- *Social issues*: New ways of living and social exclusion.
- *Urbanisation*: Increasing population and transformation from an industrial to a knowledge society.

Despite a strong European research tradition in spatial development, Luxembourg has to engage on its own in this field. Finding answers to the question of how Luxembourg can foster economic development, provide a liveable habitat for its population and protect its natural environment is crucial to the future quality of life within the country – and this "search process" can only be successfully organized within Luxembourg itself in combining research with stakeholder participation.

Research Issues

- **Integrated spatial and, urban development at different scales**
  - Processes of urbanization : urban sprawl, urban density
  - Processes of metropolization : polarization of streams and activities, centralization and concentration of activities, specialization of space
  - Processes of (spatial) exclusion : social inequalities and segregation, functional specialization
  - Urban living quality, urban comfort
  - Infrastructures
- **Environmental health and ecological aspects of urban development (pollution, noise …)**
- **Transport, mobility, migration and accessibility**
  - Relation between residential and daily mobility
  - Labour market daily flows, trans-border working flows
  - Transport systems and flows
  - Perception of mobility and behavior
  - Virtual space and its impact on mobility (telework, e-trade, etc.)
- **Evaluation of existing and development of new policy instruments on local, regional, national and transnational levels**
  - New forms of governance and cooperation with other cities and regions
  - Citizen participation
  - Planning policies
- **Modeling and simulation of urban growth and spatial development (scenario and prospective approach)**

Research objectives

The main objective of research in spatial or territorial planning and development is to explore the conceptual construction, organisation and practical use of space (geography and land use, e. g. for buildings, transportation and other infrastructures, industry, agriculture, tourism...), in order to foster sustainable territorial development in urban as well as rural areas. It is a highly cross-sectoral and interdisciplinary research domain, which includes geographical, demographic, social, psychological, political, economical, ecological as well as technological aspects.

Research in spatial development in and for Luxembourg will cover a wide set of research issues and will have to adapt, improve on or even invent methodologies and tools to investigate, model, and forecast territorial development within the country and the Greater Region. Within this research domain monitoring and simulation tools have to be employed or to be developed. This includes geographical information systems but also empirical surveys and data bases on e.g. the mobility and habitat behaviour of people within and around Luxembourg, qualitative studies on their intrinsic motivations and basic research on how processes of metropolization and polarization can be described and explained. Luxembourg has wide reaching urban effects over the national borders: it attracts people and concentrates wealth and material flows from a much larger area.

3. New functional and intelligent materials and surfaces, and New sensing applications
Challenges in the national context
On a national basis, there are many R&D activities on materials and surfaces in the industrial sector with existing activities on polymers, on composites and multicomposites, new materials in automotive supplier industry, ceramics etc and research in the domain 'New functional and intelligent materials and surfaces, and new sensing applications' is offering a wide range of technological, scientific, and economic opportunities. The main objective of this research domain is to investigate and to develop novel materials with new or improved functions (e.g. surfaces with no corrosion, catalysers, absorbers) and also basic materials for applications in new sensors (e.g Environmental monitoring, energy efficiency, safety at workplace, domestic sensors, medical diagnostic tools, automotive sector and traceability for logistics *etc*) In many cases the functionality of a material arises from its surface properties, i.e. from the interaction between the surface and the environment, which is why technologies for surface functionalisation (Nanostructural surfaces, nanocoating) are a major focus of this domain. However, also bulk properties and effects of materials can be exploited in various applications and should not be generally neglected. It should also be considered that the technologies of modification and processing and also of analysis are strongly coupled to a specific material class and are completely different from one material class to another. Process knowledge is a critical factor for developing novel materials. Therefore, studying and optimising such processes, including their modelling and simulation, the synthesis at laboratory scale as well as the scale-up and the production of new materials at industrial scale should be investigated.
Research Issues
▪ Surface and interface engineering ▪ Intelligent materials and materials combination (related to surfaces and bulk) ▪ High added-value materials ▪ Sustainable synthesis and production processes ▪ Nanoelectronics, nanooptics, nanomagnetism ▪ Nanobiosciences ▪ Nanostructural surfaces, nanocoating
Research objectives
Publicly funded research in this field plays the role of an enabler for new economic activities (spin-offs, start-ups, licensing). An additional objective of this domain is to exploit various technologies for the development of new sensing devices for various applications as listed above. Therefore, the approach of research activities in this domain should be highly application-orientated. Major progress and applicable results can only be achieved by intense collaborations between the public and the private research sector and by establishing efficient channels for technology transfer. Critical mass can only be reached by attracting excellent researchers and by joint efforts in the public and industrial research sector. Research in this field is to a great extent based on computational models of the studied

materials at a molecular level in order to understand (and predict) their properties and interactions with the environment. Therefore, projects in this research domain should be strongly supported by scientific computation activities based on the Modelling and Simulations Platform.
Research and education in this domain should be accompanied by efforts to improve the public understanding of nanosciences and nanotechnology as their applications may arise new challenges in the safety, regulatory or ethical domains that will require societal debate. In this context nano-risks need to be addressed in a proactive way.

4. Biomedical Sciences
Challenges in the national context
Biomedical Sciences is a research field of utmost importance for individual and public health issues and for improving quality of life. In order to cope with the health challenges to be faced in the next 10 years and especially with the structural problems of the health care system as well as increasing health costs partly due to the increase of chronic and age-related diseases, future research in Biomedical Sciences in Luxembourg should aim, on the one hand, at improving public health. Research addressing health information and promotion, environmental health aspects, as well as the assessment and improvement of the healthcare system is of high socio-economic importance for Luxembourg. Such research will provide information to policy makers and help translate research results into policy-making with the overall objective of contributing to guarantee high quality health services and reducing the burden on the social security system, as well as improving the quality of life. On the other hand, highest priority should be given to research activities on age-related diseases in a select number of major pathologies like cancer, cardiovascular diseases and neurodegeneration, with high medical need and where significant progress is expected in the next decade. In particular, research on regenerative medicine and tissue engineering is a promising new area of research expected to significantly improve the therapeutic arsenal of so far untreated severe diseases and therefore to help contribute to reduce the additional health care costs due to an ageing population. Tissue engineering in combination with the development of novel materials for bio-devices may furthermore foster the development of a flourishing biomedical industry in Luxembourg. Last but not least, it is necessary to establish translational biomedical research programs consisting of multidisciplinary teams which foster the collaboration between scientists, engineers and clinicians and hence accelerate the basic research concepts towards clinical application.
Research Issues
o **Regenerative Medicine in Age-related Diseases** o **Public and Environmental Health** o **Translational biomedical research**
Research objectives
Overall the national research priority “Biomedical Sciences” should aim at increasing critical mass and rendering Luxembourg research in life sciences internationally competitive as well as stimulating the establishment of a biomedical industry in Luxembourg over the next 5-10-years.

4.1. Regenerative Medicine in Age-related Diseases
Challenges in the national context
Regenerative medicine and especially tissue engineering for therapies of age-related diseases appear to be a promising issue for future public research in Luxembourg - despite of a very strong international competition in this area. Regenerative medicine is an applied field of tissue engineering that holds the realistic promise of regenerating damaged tissues in vivo (in the living body) and externally creating "tissues for life" available for implantation. Tissue engineering applications in regenerative medicine for age-related diseases is an interesting opportunity for Luxembourg and significant developments and progress in this research area is expected in the next 5-10 years. Research in tissue engineering is from a scientific point of view very attractive and there seems to be a lot of entry points, such as for instance the development of tissue and cell engineering in combination with the development of novel materials for bio-devices (cardio-vascular and other prostheses, encapsulation devices for cells or bioactive molecules etc.). Furthermore, tissue engineering has the potential of replacing some existing pharmaceutical treatments provided the costs of (future) tissue engineering based therapies are competitive.
Research Issues
• **Tissue and cell therapy** - tissue engineering - biomaterials - development of appropriate modelling and imaging tools **Age-related medical indications:** • Cardio-vascular Diseases • Oncology ▪ Neurodegenerative Diseases
Research objectives
In order to achieve internationally recognized scientific excellence in regenerative medicine and tissue engineering it is of high importance to increase the number of high-qualified researchers in the field (e.g. build on the FNR-funded programme ATTRACT). Four to five groups of 10-15 people with an overall budget per group of 2-3 Mio Eur p.a. were stated as a good scale to develop internationally competitive research. Given the high international competition and the limited human resources in public research in Luxembourg, Luxembourg should concentrate its efforts on some sub-domains and build on existing competencies in order to be able to achieve critical mass for internationally recognised research. International visibility - as in all research fields - should be reached through publications in top scientific journals. Future research programs should furthermore allow for and support interdisciplinary collaboration (an asset for small groups) between the scientific and medical community in Luxembourg and between the public and private sector as well as international research collaboration. Finally, these programs should foster start-up companies in a five years time frame. This

requires also developing competencies in intellectual property filing and management to support researchers.

The increased budget for public research - and the strengthening of Technology Platforms - as well as reforms of the legal framework were necessary to create a favourable environment for biotechnology and biomedical industry in Luxembourg will provide the ground for developing a critical mass for research and related industrial applications in regenerative medicine.

4.2 Public and Environmental Health
Challenges in the national context
Public health, defined as the approach to medicine concerned with the health of the community as a whole. Luxembourg Public Health research should focus on issues related to health information and promotion, the impact of behavioural and environmental factors on public health and the assessment and improvement of the health care system. Analysis of the impact of dissemination of health-related information and the promotion of health behaviour education on the reduction of health care cost brought is one field of study. Especially pertinent to the Luxembourg society are the effects of obesity and stress on public health and the rise in life style diseases and cardio-vascular diseases. Further important research issues relate to mental illnesses, as depression is expected to be in a few years the disease group with the second heaviest toll globally and addressing related issues could be highly relevant for Luxembourg having one of the highest suicide rates in the EU-15. Additional issues relate to the exposure of the individuals to environmental factors. Environmental Health policy, combining monitoring/traceability technologies and risk reduction strategies on the level of the exposed individuals, is high on the agenda in Europe and naturally also of importance for Luxembourg at national level. Air pollution indoors and outdoors are the environmental factors with the greatest impact on health in Europe but further research issues for Luxembourg concern occupational health (exposure to nano-particles, the reduction of the use of antibiotics, the treatment for environment related diseases like asthma, allergies and possibly also the “chronic fatigue syndrome” as well as the field of preventions, e.g. by providing data for labelling products. Given that a major difficulty within the field of environmental health are combinatory effects (humans are exposed to a multitude of pollutants everyday) Luxembourg has a distinctive advantage: research issues in environmental health are usually of a workable scale for Luxembourg and taking the size of the country into account, quasi exhaustive data collections are feasible. Despite Luxembourg having a high quality health system, continuous monitoring and assessment (regarding e.g. accessibility and equity of health care) of the systems is required to ensure sustained efficiency to cope with rising health costs. In particular, regarding to the ageing population, research should address the evaluation of economic and social effects of home-based health care. ICT applications to health, like e-Health and telemedicine, though not discussed in-depth in this FNR Foresight exercise, are deemed at European level as important tools for improving people’s access to healthcare and health information services and research in this area may be worthwhile for Luxembourg. Luxembourg has an interest in promoting domestic research in public health - regardless of potential high international competition in this field - in order to tackle Luxembourg specific needs and obligations. Such research, providing information to policy makers with the overall objective of contributing to guarantee a high quality of health services and improve

population's health, is obviously of highest social relevance.
Research Issues
• **Health information** - Data bases • **Health promotion** - Disease prevention - Work-related diseases - Improving mental health in occupational settings - Health education / promoting health - Tools to assess health promoting programs • **Health system** - Collective and institutional factors - Health economics - Quality of health care system - Rational drug use in private practice - Optimizing delivery of health care (quality of life, patient security, efficient eHealth) - Assessment of programmes • **Impact of environmental factors on human health** - Pollutants in the environment (occupational health, indoor and outdoor environment) - Atmospheric pollution and health (Feinstaub, nano-particles) - Study of allergens - Study of low-dose long-term effects of industrial and agricultural pollution - Micro-organismic "pollutants" / pathogens • **Monitoring in environmental health** - Biomonitoring, incl. bio indicators and human bio-monitoring (diagnostic devices) - Tools for biomonitoring (exposure markers, effect markers) - Monitoring of medical environment • **Prevention and treatment of environment diseases** - Linking human nutrition (food as a vector of pollutants) & health & environmental needs - Traceability and labelling of industrial products (indoor environment) - Reducing the use of antibiotics
Research objectives
The main objective of Luxembourg's public research should be to establishing the knowledge base and providing concrete measures by which environment and health research results will be fed into policy-making, for analysing and filling the gaps in environment and health activities. Therefore additional high class foreign scientists still need to be attracted to Luxembourg to reach critical mass. study time related effects (longitudinal studies) of environmental factors on the human health Databases, the necessary precondition of epidemiology and of public health decision making, exist but are not sufficiently utilised and interlinked. Improvements are to be made by setting up a surveillance system: taking Luxembourg's size into account, it should be possible to uniformly collect medical records and to efficiently access and link data. The creation of a biobank of living people supplementing the existing biobanks should be supported. To cope with the interdisciplinary complexity of the research issues, multidisciplinarity and PPP involving private laboratories, and the medical sector as a whole should be fostered. Technology Platforms (e.g. genomics, metabolomics, proteomics, nanotechnology tools) may have to be developed to support future research focusing on Public health. Time related effects (longitudinal studies) of environmental factors on the human health

should be studies and multi-annual stable funding schemes should allow for this. On the national level it could be of interest to build up alert systems to inform the public on daily impacts of their outdoor environment.

4.3 Translational biomedical research
Challenges in the national context
Translational biomedical research refers to research at the interface between fundamental research and clinical application. Luxembourg research in this area should aim to bridge the gap between fundamental research, clinical application and public health and technology transfer. Linking Public Health research (providing a macro-view of the population as a whole) and the Public Health sector should improve the transfer of research results from the laboratory to the hospital and public health services generating applicability and providing new impulses for improving public health measures, clinical procedures and cures. Fundamental biomedical research linked to clinical research aims at translating research into treatment on the patient level and can lead to the development of new technology e. g. technology transfer to the diagnostic industry. One promising line where Luxembourg activities in translational research should be focused within translational research could be personalized medicine, in (some of) the disease groups listed below, by harnessing genomics and proteomics technologies for tailoring the most suitable pharmacotherapy for the each patient, based on individual profiling.
Research Issues

• Diagnostics and Personalised medicine
• Control of antiviral and antimicrobial drug resistance
• Specific groups of diseases
    o Cardiology and cardiovascular diseases
    o Infectious Diseases
    o Oncology
    o Neurology
    o Individualised prevention of age-related diseases
    o Molecular pathways & diseases

Research objectives
Translational research is *per se* an interdisciplinary research domain and synergies between this domain and the priorities Public Health, Environmental Health and Technology Platforms should be exploited when designing future research programmes. Future research programmes should build on existing competences in fundamental research on the specific disease groups listed above and the existing technological know-how at the public research institutions. Because it may be difficult for Luxembourg to reach critical mass for internationally recognized research related to all specific diseases listed above, future translational research projects might rather focus on some specific aspects. The list of diseases in itself is not as important as the interface between fundamental research and clinical application. Luxembourg translational research will obviously benefit from activities and existing expertise developed on the Technology Platforms where synergies can be built. Future research should capitalise on the existing renommée of Luxembourg research in medical sciences - compared to other research fields - documented through the solid publication record. Given an adequate legal framework for biomedical research, translational research would profit from the set up of a tissue bank and a pathogen bank as well as from the set up of a clinical investigation centre carrying out applied clinical

research - which would also benefit to new public health research and policies.

5. Labour Market, Educational requirements and Social Protection

Challenges in the national context

Although Luxembourg has the highest living standard and one of the lowest unemployment rates in Europe, unemployment and more generally imbalances of the labour market pose a real challenge.

Improving the match between labour supply and labour demand is a real challenge for Luxembourg – and has implications for education, immigration/cross-border relations, etc. In order to gain a better understanding of the labour market structure, one needs to support research investigating quantitative and qualitative aspects of labour market supply and demand and their influence on a small open economy (see research issues below).

Research addressing the welfare state is also especially important as it concerns the long-term sustainability of the social and economic system.
In addition, it is crucial that Luxembourg provides itself with an adequate evaluation system of competences with the advent of the knowledge society, new educational techniques like tele-learning and new work models.

Research Issues

Analysis and understanding of labour supply in Luxembourg:

- Incentives for work participation
- Immigrants and cross-border workers: Work qualifications and motivations
- Consequences of an ageing population and a shrinking workforce on the labour market
- Maintaining and developing a multicultural and qualified workforce (incl. education and training issues)

Analysis of labour demand:

- Diversification of the economy: Workforce demand for diversification
- Labour demand of private and public organisations
- Hiring behaviour of private and public organisations (in terms of qualification levels, origin, age, gender…)

Analysis of the relation between labour supply and demand / Recruitment problems:

- Structure of the mismatch between labour supply and demand (in terms of qualifications, origin, unemployment replacement rates, shrinking and ageing working population, retirement schemes, high proportion of immigrants and cross-border workers, hiring behaviour of the private and public sectors …)
- Factors leading to this mismatch
- Possible remedies (qualification, regulatory framework, incentives, work models…)

Social system and welfare:

- Impact of cross-border and immigrant workforce on the economy
- Ageing workforce and intergenerational relations
- Population at risk (less qualified, handicapped, elderly persons…)
- Labour market transitions and social security
- New work models
- Gender issues
- Luxembourg welfare state in the larger context (Greater Region and EU internal market / regulation)

Educational issues:

- Determinants of educational achievement / failure
- Individual learning paths and differentiated learning and management of heterogeneity
- Validation of professional experience
- Transition from education system to labour market and issue of life-long learning
- Effectiveness of educational system from an economical point of view

Research objectives

The main objectives of research in the domain is:

6. to gain a better understanding of the functioning of the labour market and the social systems,

7. to provide the government with scientific expertise (data, intervention studies, policy evaluation…) for successful, evidence-based policy making (e.g. adapting educational policy), and
8. to assist developing (involving all stakeholders) new models for work and social protection.

Long term, sustained lines of research are needed to engage in more fundamental questions and to go beyond applying existing methodologies by considering longer time horizons.

On the whole, more high-quality researchers are needed, from short term scholarships or visiting scientists to attracting excellent researchers from abroad with long-term contracts.

6. Identities, Diversity and Integration

Challenges in the national context

The domain *Identities, diversity, integration* responds to the need of the Luxembourg society to reflect upon itself in order to understand the current transitions of the society and the dynamics of change and their impact on society.

Research has to address the construction of identities, cultural diversity and the various aspects of social, political and work participation in a multicultural and multilingual society, social cohesion to provide the scientific understanding for a harmonious 'living together'. This research is by its nature interdisciplinary, capitalizing from many branches of social sciences and humanities – from psychology to empirical social research, from cultural studies to history, from linguistics to educational research.

The second set of research issues is concerned with the benefits and challenges of a **multilingual** society. Since different languages might convey different views, the languages used and spoken are very closely related to the construction of identity. In general, language diversity is seen as important aspect of the cultural richness of a society, but at the same time it poses a lot of problems for integration and social cohesion.

In terms of more fundamental research, a specialisation in cognitive and brain processes for language acquisition may be an interesting alternative, for example by including researchers from the relatively new field of neurosciences in view of testing and developing efficient language teaching methods.

Research Issues

Identities, immigration, cultural transmissions

- Luxembourg history(ies), language(s) and culture(s)
- Concepts and facets of identity and culture:
  - Identity and cultural self-consciousness
  - Dynamics and diversity of identities
  - Role of education and language in identity building
  - Identity in a small country, in the context of the Greater Region, Luxembourg/European identity
  - Family and individual identities in a multicultural society
- Migration flows towards or out of Luxembourg
  - Migration: the concept of 'living together' vs. 'integration'
  - Immigration and social cohesion
- Intergenerational relations
  - Transmission of values and memories
  - Intergenerational solidarity
  - Generations in family and society

Language, identity, education

- Federative multilingualism
  - Managing the heterogeneity of the population at school and in society
  - Language diversity and language policy: Which place and role for Lëtzeburgesch, French, German, English, Portuguese, Italian?
- Education
  - Multicultural didactics
  - Outcome oriented assessment tools for educational achievements;
  - Testing educational reforms;
  - ICT language teaching tools

- o ICT multilingual tools and ICT language services research
- Political participation and representation:
  - o Political culture, citizenship
  - o Influence of EU on the national policies
  - o Decision structures (local, regional, national)

Research objectives

The main objectives of research on *identities, diversity, and integration* are:

- to contribute to understanding the dynamics of change of the Luxembourg society under internal and external influences, and in particular in a context of immigration and migration flows,
- to empirically analyse the present state of society in particular with respect to cultural identities, barriers for political, social and work participation, segregation trends in education, housing etc.
- to support policy making with data, conceptual clarifications, and recommendations.

In order to achieve this a high quality research about the issues above needs to be build up, including systematic, long-term data collection, better use of available and new databases (Private public partnerships could be useful to develop access and retrieval tools), new ways of thinking ("*conceptionalizing*") change, and long-term basic funding to sustain core groups of scientific collaborators over a longer time horizon.

A4 Trends identified in international Foresight exercises

This chapter presents some examples for trends identified in international foresight exercises for all 6 thematic fields addressed in this FNR Foresight exercise, on the basis of the information available from the European Foresight Monitoring Network (www.efmn.eu)[316]. This list is not exhaustive.

Information and Communication Technologies

Name of the Foresight initiative	Trends identified
Danish Foresight - Teknologisk Fremsyn[317]	Areas identified within the ICT panel as being critical for the future include: • Pervasive computing • Health services • Facility management, especially of large building, constructing projects, etc. • Security (digital ID etc) • ICT applications in the Food chain • Entertainment (especially games and film production). Key technologies for the future include: • Communication networks and infrastructure, • Energy saving ICT technology, such as improved batteries and electrical consumption technology, • MEMS - Micro-Electronic-Mechanical Systems, silicon technologies, sensors, micro-mechanical components, etc. • Screen Technologies such as OLED - Organic Light Emitting Diode, LCD and digital paper technologies, etc. • Software technologies.

[316] The EFMN is financed by the European Commission Directorate General for Research as part of a series of initiatives intended to provide a Foresight Knowledge Sharing Platform for foresight practitioners and policy makers in the European Union. More information can be found on www.efmn.eu

[317] The purpose of the Danish technology foresight exercise, carried out 2001-2005 by the Danish Ministry for Science, Technology and Innovation, was to gain insights into, and prepare for future technological developments, market and social needs. It meant to assist government ministries and agencies formulate and develop a framework for new research programmes. [Source: S. Mahroum, Danish Technology Foresight 2015 (2004). EFMN Foresight Brief No. 5, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief05.pdf]

UK Foresight - Cyber Trust and Crime Prevention 2018[318]	The trends identified in the ICT sector are the following: • Move towards pervasive and ubiquitous computing, and as a consequence huge data sets, intelligently mined by autonomous and intelligent software. • Migration from the internet infrastructure to 'utility computing'. These services will not be confined to the home and personal digital environments, but will be created with wearable technology allowing people to be connected at any time and in any place. Applications and their content will be automatically tailored to the user. • Increasing Complexity and hence vulnerability of information systems. Vulnerability will be both in terms of risk of failure of parts of the system and more opportunities for crime. The following elements were deemed as important for enhancing the trustworthiness of complex systems in the future and reducing new types of criminal opportunity associated with ICT: • New digital forensic tools to automatically scan for potential problems and assign provenance in an auditable way. • New language and frameworks are required for a response which can be applied in a quick, flexible way to new challenges as they arrive. One of the delays in responding to risk is often labelling it, getting a common understanding of it and then working out how something new fits in with our current systems of risk management. • Design-out crime but design-in usability. • Continue to build international collaboration to respond to the risks. Cyber crime is a global issue and international cooperation will be needed to address it, with ethical principles guiding the debate. A need to improve international law enforcement cooperation and further develop international standards was identified, including harmonization of international data protection legislation. • Develop a stronger partnership between government and business to improve law enforcement capability. • Develop solutions to improve trust: Identity, security and privacy are all factors that affect how trusting people are. Possible solutions to improve trust include better information for the user about technologies and their risks, together with dialogue between government and business. • Technologies for identification and authentication.

[318] The aim of this Foresight exercise carried out 2003-2004 by the Office of Science and Technology was to take an independent and objective look at the subject of the vulnerability of ICT and using the best knowledge available explore the applications and implications of next-generation technologies on this issue. [Source: J. Jackson, Cyber Trust and Crime Prevention 2018 (2004). EFMN Foresight Brief No. 10, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief10.pdf]

Third Korean Foresight exercise[319]	Among the 21 keys technology areas for the future selected based on their expected impact on quality of life, economic growth and public need, the following ICT key technologies were listed: • Cognitive Science and Humanoid Robot Technology • Culture Content Technology for Immersive Entertainment • Digital Convergence Technology for Augmented Reality • Knowledge and Information Security • Smart Computing for Ultra-high Performance • Ubiquitous Civil Infrastructure Management
South African Benchmark 2020[320]	The following global technology trends in ICT were identified[321]: • Mobile technologies - wireless, wearables, Wi-Fi, ultrawide band, smart phones and location-based services, • Smart networked objects - including technologies like RFID, MEMS, smart dust, digital ink and embedded computing, • Semantic technologies - Semantic Web, XBRL, automatic tagging, affinity profiles and information extraction.
Spanish Media Futures 2018[322]	According to the conclusions of the study, the transformation the communication media will undergo in the next 15 years due to the impact of new technologies on the sector will be determined mainly by five significant trends: • Massive broadband access and permanent online connections

[319] The Third Korean Foresight Exercise entitled 'Future Perspectives and Technology Foresight for Korea – Identifying Challenges and Opportunities for Korea's Economy and Society' carried out 2003-2004 represents the most comprehensive effort to date by the Korean government in the field of S&T foresight. [Source: B. Park, Korea 2030 (2005). EFMN Foresight Brief No. 36, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief36.pdf]

[320] The overall goal of the South African Benchmark 2020 was the identification of global technological trends, which will influence the competitiveness and future development of South African industries over the next 15 years, focussing on innovation areas that hold the potential to reduce industrial dependency on foreign technology. [Source: S. Rijkers-Defrasne, South African Benchmark 2020 (2006). EFMN Foresight Brief No. 63, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief63.pdf]

[321] Starting from these global trends, the following technologies were deemed as having specific importance for the growth and continued development of the South African ICT sector:

- Mobile technologies and devices,
- Wireless network technologies,
- Human Language Technologies (HLT),
- Open Source Software,
- Telemedicine,
- Geomatics
- Manufacturing Technologies – Robotics / Artificial Intelligence,
- Grid computing,
- RFID.

	• Advancement of communication media by replacing the supply driven focus by a demand driven one. • Vertical integration of content creation industry and distribution channels • Possibility to access different media via the same terminal • Stratification and globalisation of audiences
Technology Foresight Slovenia 2020[323]	Information and communication technologies (ICT) rank as the most important among the key technologies because of its dominant role in all manufacturing and service industries. It deserves a continued special attention due to its economic and social relevance not least for innovation. ICT is important for its inherent cross-disciplinary and cross sectoral nature and for its new ways of producing, trading and communicating. The selected technological research fields for Slovenian economy range from intelligence networks, broadband systems to bioelectronics and optoelectronics.
Russian Critical Technologies 2015[324]	In information and telecommunication systems priority will be given to technologies for creating intelligent management systems for complex objects and navigation systems, technologies for transmitting, processing and protecting information, technologies for software development and technologies for computation systems. As a result, it will allow developing within a short period of time such novel products and services as intelligent systems for supporting complex equipment operators and creating automated production facilities; intelligent robots; smart houses and vehicles; systems for a single telecommunications network encompassing the Internet, television, radio, various multimedia and virtual reality systems; automated systems for contacts with government agencies at all levels; standard electronic identification documents; distance education and health care systems, etc. that will have far greater quality and effectiveness than similar products of older generation.
Converging Technologies Enabling the Information	Within the convergent cluster of Cognitive Science + ICT one can perceive the emergence of intelligent devices that mimic cognitive processes of the brain and the mind in: • Sensing, • Perceiving, • Memorizing, • Controlling, • Acting and • Learning. Cognitive neuroscience supported by brain imaging techniques is at the forefront of developments in cognitive science and has strong links with developments

[322] The study carried out by undertaken by Fundación Observatorio de Prospectiva Tecnológica Industrial (OPTI) in collaboration with Fundación EOI and the Instituto Catalán de Tecnología (ICT) in 2003 aimed to determine the evolution of social communication media in Spain within the next 15 years with special attention to the impact of new technologies in this area. [Source: C. Pagel, Communication Media Spain 2018 (2006). EFMN Foresight Brief No. 64, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief64.pdf]

[323] The technology foresight study sponsored by the Ministry for Science and Technology, was conducted as part of the process of preparation for the mid term national R&D Programme 2006-2010 in Slovenia. This was the first national foresight exercise. It had several objectives: to promote the continuous forward thinking practice in society, to foster dialogue among main stakeholders in the innovation process, and to set preliminary R&D priorities for the future research and technology policy. [Source: P. Stanovnik and M. Kos, Technology Foresight Slovenia 2020 (2006). EFMN Foresight Brief No. 71, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief71.pdf]

[324] The Ministry of Education and Science of the Russian Federation conducted a foresight exercise aimed at identifying national S&T priorities and developing the list of critical technologies. The results obtained were used as a background for the Federal Science and Technology Programme. [Source: A. Sokolov, Russian Critical Technologies 2015 (2006). EFMN Foresight Brief No. 79, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief79.pdf]

Society[325]	in neurobiology. Brain-machine interfaces coupled with robotics provide opportunities to create systems that can operate under circumstances that are difficult, dangerous or simply impossible for human beings: • Disaster zones such as earthquake sites, • Deep sea or • Outer space. Cognitive vision systems that enable intelligent monitoring processes, speech and language processing technologies also feature amongst the technological trends within cognitive science and ICT. Within Biotechnology + ICT convergent cluster developments were identified that brought together bio-informatics and computational biology to provide technologies for: • Non-invasive monitoring and diagnosis based on biosensors and biomarkers, • Biological computing and the • Development of virtual environments to manipulate genetic properties of organisms. Within the Nanotechnology + ICT cluster developments were identified within; • Nano-electronics for nano-scale medical diagnosis and treatment, for cleaner, safer and more comfortable transport, and for anti-terrorism and security applications, • Nano-photonics for fiber-optic communication, optical data storage, quantum dots, simulation and modeling techniques as well as image processing and pattern recognition. Finally, new trends within the Material Sciences + ICT convergent cluster show overlaps with other clusters. This is especially true in the terms of the attention given to simulation and modeling, image processing, pattern recognition and neural networks. The overlap with Nanotechnology + ICT is particular strong in the area of electronics. These trends provide opportunities in a variety of fields including: • Diagnosis and treatment in the field of medicine on the basis of markers and sensors, • Brain imaging, deep neural stimulation and robotic surgery, • The application of robotics to the exploration of outer space and deep sea as well as personal care and industrial processes, • New modes of computing based on biological computing and nano-computing paradigms, • New and advanced simulation and modeling techniques, • Pattern recognition techniques based on the application of artificial neural networks in a great range of potential application domains.

[325] The purpose of the project sponsored by the IPTS and carried out in 2005 was to analyse the scientific strengths of the EU compared to the USA and Japan in the field of 'converging technologies' with the aim of informing and influencing the European research agenda. [Source: M. van Lieshout, Converging Technologies Enabling the Information Society (2005). EFMN Foresight Brief No. 40, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief40.pdf]

Physical Sciences

Name of the Foresight initiative	Trends identified
Swedish National Foresight - Teknisk Framsyn[326]	The top 100 fields in which Sweden had the best preconditions were then categorized within 11 areas, of which the following in the field of Physical Sciences and Engineering: **Mechanical systems and structures** and **Functional materials.**
Anticipating Change for Europe's Industries 2020 to 2025[327]	**Automotive Industry** The drivers of change are the following: Increasing global vehicle fleet; Congestion; Changing patterns in vehicle production; Impact on the environment; Reliance on oil; Development of new fuels; New materials, safety, navigation. **Textiles and Leather** The main drivers of change here are international trade relations, organization and structure of the industry, new and emerging technologies, human resources and the enforcement of international rules and conventions.
Danish Foresight - Teknologisk Fremsyn[328]	**Nanotechnology Panel** The following technological areas were identified as being critical for the development of the domain and to have a strong relevance for Danish society and its economy: **Nano-Sensors and Nano-Fluidics** • NEMS (Nano-Electro-Mechanical Systems) for selective detection of specified molecules or cells, measurement of heat or binding energies … • Development of very efficient, distributed sensor systems that combine CMOS and NEMS, that communicate using wireless technology and

[326] Teknisk Framsyn's second foresight study, carried out 2003-2004, aimed to identify the preconditions for sustained technological progress and economic growth for Sweden over a 15-20 year period to 2025. With its intention of inspiring the coming generation of decision-makers who will shape Sweden's future, the project was directed at the private sector as well as government, public sector policies and organizations. [Source: S. Mahroum and C. Blackman, Swedish Technology Foresight 2004 (2004). EFMN Foresight Brief No. 2, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief02.pdf]

[327] Sector Futures - an initiative launched by the European Monitoring Centre of Change (European Foundation for the Improvement of Living and Working Conditions) in 2003 - provides insights at the sectoral level on the future of Europe. The broad objectives of the Sector Futures initiative are to: 1. Understand drivers of change as they apply to specific sectors of the European economy; 2. Highlight possible scenarios and probable futures on a sector by sector basis; 3. Provide information and links to access additional information and data at sectoral level; 4. Identify and highlight topics and issues for debate in relation to the changing futures of sectors, for the companies and individuals who work in them and depend on them. [Source: C. Blackman, Anticipating Change for Europe's Industries 2020 to 2025 (2004). Foresight Brief No. 4, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief04.pdf]

[328] The purpose of the Danish technology foresight exercise, carried out 2001-2005 by the Danish Ministry for Science, Technology and Innovation, was to gain insights into, and prepare for future technological developments, market and social needs. It meant to assist government ministries and agencies formulate and develop a framework for new research programmes.

[Sources: S. Mahroum, Danish Technology Foresight 2015 (2004). EFMN Foresight Brief No. 5, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief05.pdf

B. Rasmussen and P. D. Andersen, Danish Nano-science and Nano-technology for 2025 (2005). EFMN Foresight Brief No. 32, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief32.pdf]

	can be used in applications for environmental monitoring, process control, indoor climate control and traffic safety. • Practical application of "lab-on-a-chip" systems based on nano-optics and nano-fluidic liquid handling systems for point-of-care diagnostics. • Practical application of implanted sensors for monitoring infections … **Polymer Electronics** • Polymer electronics for displays and sensors integrated into packaging, for monitoring the condition and history of goods in transit and storage. • Polymer transistors integrated into single-use equipment for analytical purposes in primary health care. • Multicoloured plastic displays instead of liquid crystal displays. • Polymer FETs or Field Effect Transistors for RFID tags • Polymer electronics and optics for solar cell technology. **Nano-Optics and Nano-Photonics** • Fibres micro-structured in their longitudinal direction for use in highpower lasers for welding, light sources in large displays, supercontinuum-generating units and optical communication systems, • Compact, low-price nano- or micro-structured plane components with integrated optical circuits based on photonic band gaps with application to sensor systems and fibre-to-home technologies. • New sensors and optical switches based on filling the fine structure in optical crystal fibres with liquids, coatings or liquid crystals. • Signal processing based on PBG structures with built-in non-linear optical elements for modulation, wavelength conversion, four-wave mixing and optical conjugation. **Nano-Catalysis, Hydrogen Technology …** • The use of in situ, theoretical and other methods to create tailored catalysts and other functional nano-materials • Chemical approaches to hydrogen storage based on use of methane, methanol or ammonia or in the form of metal hydrides and using new materials that incorporate nano-technology and nano-particles. • New, cheaper, longer life SO and PEM fuel cells. • Development and improvement of catalysts based on natural enzymes, efficient at low temperatures and pressures. • Specific catalytic Nano-systems for the breakdown of pollutants in nature using pre-organisation of reagents, catalysis and product release. **Nano-Materials with New Functional Properties** • Alloys or ceramic materials that crystallise with very small grain size to give high strength and good workability for use in high-value products, from the micro to macro scale, such as implants and sports equipment. • Nano-composites with greater properties than pure polymers for corrosion resistance, sound absorption, and ease of recycling. • Functional products made from woven and non-woven polymer fibres • Coatings with built-in chemical functionality obtained from nanoparticles or a nano-structured topology. • Block co-polymers for self-repairing surfaces. • Nano-porous materials as filters in the food and drink industry. • Thermoelectric materials with radically improved properties for cooling and energy production, based on nano-sized structures.

Foresight Vehicle Technology Roadmap 2020[329]	Five technological areas were identified by the experts as having significant potential to deliver high impact technology solutions to meet the social, economic and environmental goals: Engine and Powertrain Technologies. Hybrid, Electric and Alternatively Fuelled Vehicle Technologies. Advanced Software, Sensor, Electronic and Telematics Technologies. Advanced Structures and Materials Technologies. Design and Manufacturing Process Technologies.
Greek National Technology Foresight 2021[330]	• **Materials:** Through materials science it is expected that sustainable development will be attained. It is expected that through the use of new technologies in particular through the interaction of ICT, biotechnology, environment, energy, agriculture, industry, transport, tourism, culture, health & defense, hybrid technologies with industrial applications will arise and lead to the development of new competitive industrial sectors. • **Industrial Production and Manufacturing:** Industry and more specifically the manufacturing industry currently plays a strategic role in Greece's economy. The main aim is to apply new technologies and promote research in the industrial sector by creating or extending linkages with research centers for the creation of new and innovative products and processes.
The Brazilian Technology Foresight Programme[331]	**Foresight on Production Chains.** The construction exercise focused on the development and commercialization of urban housing. By 2013 the Brazilian housing sector will still be dominated by the use of traditional processes such as asphalt membranes (sistemas moldados in loco) and conventional materials. It is expected that the use of light prefabricated materials and metal structures will increase moderately. **Textile and Garment Manufacturing** Increased internal demand will generate adaptations and new services customised to both individuals and cultural groups. Increased use of fibers based on PTT for differentiated, technologically sophisticated products as well as micro-fibers. Synthetic fibers will dominate the market. **The Transformation of Plastics.** This exercise focused on production chains for plastic packing used in food. Plastics will not be substituted by 2013. Plastic packaging for carbonated beverages and mineral water will dominate the market - where PET is the most used resin and blowing is the most applied process. Although there is a general agreement that supermarkets will maintain their role as main distributors, both private and public sector believe that small retailers will continue to play a role in the sector. Only the public sector has the optimistic view that NAFTA prices will remain the same in 2013.

[329] The Foresight Vehicle Technology Roadmap 2020, organized in 2001-2003 by the British Society of Motor Manufacturers & Traders, had the goal of identifying market and industry trends and drivers for the automotive sector over a 20 year time horizon. In addition, performance measures and targets for the road transport system were defined. The technologies needed to meet these targets and the research required to deliver them were discussed. [Source: S. Mahroum, Foresight Vehicle Technology Roadmap 2020, Technology and Research Directions for Future Road Vehicles (2004). EFMN Foresight Brief No. 6, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief06.pdf]

[330] The National Foresight Programme in Greece carried out in 2001-2003 mainly focused on exploring the future of the Greek economy and society and the potential role of science, research and technology in shaping the future in terms of the development of a knowledge society. [Source: T. Damvakeraki, Greek National Technology Foresight 2021(2004). EFMN Foresight Brief No. 12, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief12.pdf]

[331] The main objectives of the Brazilian Technology Foresight Programme or BTFP organized by the Ministry of Development, Industry and Trade are to increase the competitiveness of economic stakeholders in specific industry sectors and to provide relevant information to public sector actors involved in the formulation of technology policy.

The Chemical Industry in Flanders – Towards 2010[332]	**Promising fields and Anticipated Developments** **Chemical Synthesis with a Focus on Catalysis:** In future: • Catalysts will be customized and put together from single components. • It will be possible to combine the high selectivity of homogeneous catalysis with the robustness of heterogeneous systems by supporting molecular species on the surface of solids such as zeolites and silica. • Mesoporous solids - new robust solids with hollow channels the dimensions of which can be controlled in the molecular assembly process will have many uses including vehicle exhaust cleaning. Chemists will apply natural processes such as these to industrial chemicals and materials to achieve higher efficiency and improved safety. **Materials Technology:** It will be possible to: • Design and predict material properties from the molecular through to the macroscopic level relying on easy-to-use computational tools. • Precisely manipulate materials from the nano- to the macro-scale. • There will be increased acceptance of methods for disassembly and reuse and widespread use of polymer synthesizing processes that use renewable resources instead of conventional petrochemical processes. • Surface coatings will change colour with temperature. • Special polymers are even now being tested for fireproof cushions and panels in aircraft and cars. The emphasis right now is on applications that improve human safety. **Process Science & Engineering Technology:** Process design will be viewed more comprehensively and will focus on the principles of: • Concurrent engineering, • Design from first principle, • Improved energy efficiency, • Protection of human health, safety, and the environment.

The first phase of the BTFP focused on production chains in four key industry sectors – construction, textiles and garments, plastics, wood and furniture. [Source: R. Popper, Production Chains 2016 - The Brazilian Technology Foresight Programme (2005). EFMN Foresight Brief No. 15, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief15.pdf]

[332] The chemical sector in Flanders-Belgium is among the largest in Europe and the petrochemical centre around the port of Antwerp is the second largest in the world. This foresight study carried out in 2002-2003 intends to contribute to maintaining and even strengthening the competitiveness of this sector in the future. The approach was to: Identify and map future scientific and technological developments in the chemical sector from a socio-economical perspective; Offer companies in the chemical sector in particular their R&D managers, a window-of-opportunity through which to gain a long-term perspective on the industry and anticipate their future needs in terms of RTD capacity. [Source: A. Verbeek, The Chemical Industry in Flanders – Towards 2010 (2005). EFMN Foresight Brief No. 25, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief25.pdf]

	Some precise developments include: • Zero Net Life-Cycle Waste, • Intelligent Control Systems, • Model-based failure and mitigation and • Many new commercial processes will use recycled raw materials as feedstock. **Chemical Measurement & Analysis:** Non-specialists in the scientific community will be able to use researchgrade analytical measurement instruments. Some specific improvements include: • All critical process chemistry will be measured accurately on-line in a manufacturing environment. Interfaces, particulates, and aerosols will be accurately and precisely characterised. • Large combinatorial chemicals will be routinely measured and characterized. • Analysis cycle time will be reduced by a factor 10 of what it was in 1990. • Crystallography and resonance spectroscopy will be used routinely to determine macromolecular structures. • Sample preparation will no longer be needed for routine analytical measurements. **Computational Technologies for Engineering:** These will lead to: • Shortened product-process development cycles, • Optimised processes to improve energy efficiency, and • Efficient design of new products and processes. Highly reliable atomic modelling will allow companies to rapidly design new materials that address environment, health and safety issues. Process modelling and optimisation will be an integral part of the development and implementation cycle. Coupling process science and engineering with the basic sciences will ensure rapid development, design, and scale up. Design methods will include sampling thousands of variations of chemistries from a library to find candidates for development.
Third Korean Foresight exercise[333]	Among the 21 keys technology areas for the future selected based on their expected impact on quality of life, economic growth and public need, the **following key technologies were listed** in the domain of Physical Sciences and Engineering: • Nano and Functional Material Technology; • Satellite Technology
Turkish S+T Vision 2023[334]	**Nanotechnology:** This was seen as a revolutionary topic with a wide range of potential applications such as the development of lightweight super-strength materials, the development of new generation computers, enhancement of the human nervous systems, and reduction of environmental pollution. **Mechatronics:** The development and production of integrated human-machine products were seen as a key area to be investigated through

[333] The Third Korean Foresight Exercise entitled ‘Future Perspectives and Technology Foresight for Korea – Identifying Challenges and Opportunities for Korea’s Economy and Society’ carried out 2003-2004 represents the most comprehensive effort to date by the Korean government in the field of S&T foresight. [Source: B. Park, Korea 2030 (2005). EFMN Foresight Brief No. 36, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief36.pdf]

[334] ‘Vision 2023: Strategies for Science and Technology’ is a national project aimed at providing Turkish stakeholders with a vision for the development of science and technology vision in Turkey over a period of 20 years. [Source: O. Saritas, Turkish S+T Vision 2023 (2005). EFMN Foresight Brief No. 39, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief39.pdf]

	research on micro- and nano-electro-mechanic systems and sensors, robotics and automation technologies, and other generic areas including control technologies and algorithms, micro-mechanics, micro-electronics, and embedded software. **Production Processes and Technologies:** These areas were considered important for the sustainability of competitiveness in areas such as automotive engineering, textiles and household goods production. Areas such as flexible production systems, rapid prototyping systems and material shaping systems were identified as priorities for future investigation. **Material Technologies:** The materials sector provides input to all industrial activities including aerospace, communications, defence, automotive and construction. In the exercise a number of specific technologies were identified as important for further development. Turkey holds the largest Boron reserves in the world and so boron technologies are considered important as were composite materials, polymer technologies and smart materials. **Design Technologies:** Design was considered to play a fundamental role in new process and product development and in increasing the productivity of existing processes and products. In order to achieve these goals key areas included virtual reality software and virtual prototyping, simulation and modelling software, grid technologies, parallel and non-parallel computing software development.
European Manufacturing Visions ManVis 2020[335]	Excellent research projects are needed to address the following challenges: **Paving the way for new technologies in manufacturing** • Roadmapping and foresight on manufacturing relevant nano- and (white) bio-technologies • Measurement and workplace safety for nano-technology and bio-technology • Applied basic research for white bio-technology and nano-manufacturing **Industrialising technologies** • Processing and manipulation of new materials • Incorporating smart materials into components for process technologies • Combining new materials incorporating micro electrical mechanical or adaptronic systems • Exploring new knowledge for modelling and high power computing for the simulation of product development, material behaviour and virtual experiments **Exploiting technology advantages** • Micro-systems in machine tools and products • Intelligent mechatronic systems for automation and robotics used for example in self adapting components • New automation technologies using advanced manmachine interaction that accounts for diverse worker capabilities • New ICT-tools for traditional manufacturing sectors **Technologies for customising products/services** • Tagging and labelling technologies

[335] The ManVis project is an SSA or Specific Support Action financed by the European Commission. It was designed to accompany an ongoing process of developing policies to enhance the competitiveness of European manufacturing industries using a Foresight approach that includes the views of a wide range of European manufacturing experts. [Source: H. Armbruster, C. Dreher and P. Jung-Erceg, European Manufacturing Visions ManVis 2020 (2005). EFMN Foresight Brief No. 53, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief53.pdf]

	• Approaches to product customisation using software or electronic components that allow for maximum flexibility and user integration • Technologies and concepts that facilitate user integration into innovation processes • Technologies and concepts that facilitate personalisation and build to order concepts • SME appropriate tools for networks and logistics
South African Benchmark 2020[336]	**Key areas for the South African chemicals industry:** • Extraction of minerals from coal ash and low value slag, • Fluorine generation and fluorinated organic chemical intermediates, • New performance chemicals improving the recovery of minerals in the mining sector such as polymer used in solvent extraction processes, • Technologies decreasing economies of scale for chemical plants and hence enabling smaller production facilities to compete against the mega plants, • Low-cost diagnostics and aroma chemicals production, • Development of biodegradable and high-performance polymers, • Bio-diesel and products from alpha-olefins, • Generic pharmaceuticals for meeting future demand for antibiotics and/or anti-retrovirals. **Key technologies for the Automotive Industry** • Development of lightweight materials, • Development of alternate fuels e.g. fuel cell technology, • Sensors, electronics and telematics, • Improved design and manufacturing processes. **Key technologies for Aerospace** • Development of composite materials, • Development of hyper aero-thermodynamics, • Development of Sensor usage, • Health and Usage Monitoring systems, • Noise Abatement, • Improved manufacturing processes. **Key technologies for the Metals and Minerals Sector** • Light materials extraction, • Alloy technologies, especially in magnesium, • Process improvement.
Russian Critical	In **nano-systems industry and materials** the most important breakthroughs can be expected in the sphere of nanotechnologies and technologies

[336] The overall goal of the South African Benchmark 2020 was the identification of global technological trends, which will influence the competitiveness and future development of South African industries over the next 15 years, focussing on innovation areas that hold the potential to reduce industrial dependency on foreign technology. [Source: S. Rijkers-Defrasne, South African Benchmark 2020 (2006). EFMN Foresight Brief No. 63, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief63.pdf]

Technologies 2015[337]	for Mechatronics and Microsystems equipment development; technologies for creating crystals; developing and processing materials with special qualities, composite and ceramic materials, polymers and elastomers. There is hardly any area in the aviation and space industry, transportation, electrical power industry, oil industry, microelectronics or medicine that can develop without such materials. These critical technologies are also important for resolving the existing ecological problems. Some of the most important innovation products and services in this area, which are likely to have the greatest economic effect, are ceramic and composite materials with functional properties. They could have applications as super ion-conductors, superconductors or magnetic materials.

[337] The Ministry of Education and Science of the Russian Federation conducted a foresight exercise aimed at identifying national S&T priorities and developing the list of critical technologies. The results obtained were used as a background for the Federal Science and Technology Programme. [Source: A. Sokolov, Russian Critical Technologies 2015 (2006). EFMN Foresight Brief No. 79, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief79.pdf]

Environmental Sciences

Name of the Foresight initiative	Trends identified
Swedish National Foresight - Teknisk Framsyn[338]	Global **climate change** is deepening, and the longterm exhaustion of non-renewable energy sources will create new conditions and challenges. The prevention of climatic change will become more and more important as a steering factor and boundary condition. Climatic issues are especially linked with energy production, energy conservation and energy policy in general. Climate change poses a severe threat to the infrastructure and lifestyle. At the same time, it serves as a driving force for technological development and a potential for development of products and systems to reduce and manage the impact of humans on climate. The top 100 fields in which Sweden had the best preconditions were then categorized within 11 areas, of which the following in the field of Environmental Sciences / Energy: **Environmental and life cycle technology, Mobile energy supply and Fixed energy systems**.
Danish Foresight - Teknologisk Fremsyn[339]	**The Environment Panel** This panel identified the following critical areas for the future: • **Biological resources – water,** • **Biological resources – spatial planning,** • **Consumption of mineral resources,** • **Consumption and spreading of chemicals.** It concludes that the following technologies are required to address these critical issues: • **Flexible energy systems using wind power**: Flexible systems for electricity and heat product ion are the core in increasing the usage of wind energy, and Denmark is working on a broad front in developing hardware and software. • **Systematic optimization of energy consumption in buildings:** Denmark has major potential for achieving energy savings by further developing integrated systems and concepts, especially with opportunities existing in new and smart buildings. Denmark has a competitive advantage in energy savings buildings, new materials, building components, insulation, etc. • **More environmentally-friendly agricultural production:** The perspectives of targeting precision intensive and enable the targeting of high value crops.

338 Teknisk Framsyn's second foresight study, carried out 2003-2004, aimed to identify the preconditions for sustained technological progress and economic growth for Sweden over a 15-20 year period to 2025. With its intention of inspiring the coming generation of decision-makers who will shape Sweden's future, the project was directed at the private sector as well as government, public sector policies and organizations. [Source: S. Mahroum and C. Blackman, Swedish Technology Foresight 2004 (2004). EFMN Foresight Brief No. 2, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief02.pdf]

339 The purpose of the Danish technology foresight exercise, carried out 2001-2005 by the Danish Ministry for Science, Technology and Innovation, was to gain insights into, and prepare for future technological developments, market and social needs. It meant to assist government ministries and agencies formulate and develop a framework for new research programmes.
[Source: S. Mahroum, Danish Technology Foresight 2015 (2004). EFMN Foresight Brief No. 5, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief05.pdf]

	Precision agriculture combines IT, remote sensor and robot technology together with further development of traditional agricultural machinery. Organic farming is based on the idea that farming should be part of a natural biological cycle with main aims are to avoid pollution, to maintain/ increase fertility of the soil and work on more closed substance cycles. • **Design of green materials and products:** Denmark is at the forefront of the development of green products based on environmentally- friendly materials and processes – i.e. green design.
Nordic Hydrogen Energy Foresight 2030[340]	At the Scenario Workshop, external scenarios were developed for Nordic hydrogen energy introduction. On the basis of brainstorming and group discussions, a matrix of three first period scenarios (2003—2015) set against three second-period scenarios (2015—30) was constructed. The general rationale for considering external scenarios is that many conditions of great importance to Nordic H2 energy introduction are beyond the control of Nordic decision-makers: **B – Business:** global economy dominated by US multinationals and US big business-oriented policy approach. Major physical investments are not particularly helped by the prevailing quarter-to-quarter capitalism. **There is very little interest for global environmental issues.** Oil prices are moderate. **However, H2 energy is still believed to be a likely component in future energy systems.** **E – Energy Entrepreneurs and Smart Policies:** global economy dominated by entrepreneurs and venture capitalists, and with policy actors apt at harnessing the power of innovation for societal purposes. **The energy sector is characterized by a tendency towards decentralization. There is some interest for global environmental issues.** Oil prices are moderate. **P – Primacy of Politics** is a Europe-centric economy characterized by co-operation between governments and big business and with a great interest in large-scale investments in, for example, energy and transport systems. **There is some interest for global environmental issues.** Oil prices are high due to security-of-supply problems and **the high oil price is an important driver for energy sector change.** The 9 scenarios developed were formulated by combining these three visions with three alternative second-period developments: hydrocarbon security-of-supply problems, undisputable CO2 problems & a smooth path to the future'.

[340] The overall aim of the Nordic Hydrogen Energy Foresight, carried out in 2003-2005 and covering the five Nordic countries (Sweden, Norway, Denmark, Finland, Iceland) and the home rule governments of Green-land, the Faroe Islands and Åland, was to find long-term promising ways for Nordic stakeholders of exploiting hydrogen in the drive to meet the 3 Es: Energy Security, Economic Growth and Environmental protection. More specifically, the aim was to build a Nordic Research and Innovation Area in hydrogen and fuel cells, contributing with a bottom-up approach to the European Research Area. The Nordic H2 Energy Foresight had the following objectives:
· To develop socio-technical visions for a future hydrogen economy and explore pathways to commercialization of hydrogen production, distribution, storage and utilization.
· To contribute as decision support for companies, research institutes and public authorities in order to prioritize R&D and to develop effective framework policies.
· To develop and strengthen scientific and industrial networks.
[Source: B. H. Joergensen, Nordic Hydrogen Energy Foresight 2030 (2005). EFMN Foresight Brief No. 11, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief11.pdf]

	Through a participative roadmap exercise the sequence of implementation and the inter-dependence of the hydrogen technology visions from today and until 2030 were roughly outlined. Furthermore, business opportunities for Nordic equipment industry and energy market opportunities for the energy companies in the Nordic countries were identified in three areas: • **Hydrogen Production and Transmission:** steam reforming and biomass gasification seem to be the most competitive technologies for hydrogen. With the scenario assumptions, the needed capacity (MW H2 out from production units) of steam reforming, biomass gasification and electrolysis units in 2030 were 1200-12000 MW, 1300-4000 MW, and 400-1300 MW, respectively. • **Stationary Use:** Niche applications of hydrogen/fuel cell based APU (Auxiliary Power Unit) and UPS (Uninterruptible Power Supply) form some of the first steps on the road. Both hydrogen and natural gas driven fuel cells for domestic and decentralized CHP (combined heat and power production) are seen as important steps towards the hydrogen economy in the Nordic countries. In the longer term, hydrogen driven CHP must be implemented in large-scale to arrive at the visions for 2030. In the scenario calculations, FC CHPs (Fuel cell combined heat and power) seem to be the most competitive for heat and power production in the long-term. The heat and power production with hydrogen fuelled fuel cells in 2030 is 2200-6700 MW, while with gas engines the maximum energy production capacity is 200-300 MW only. • **Transport:** Introduction of hydrogen in the Nordic transport sector will follow the same paths as in the rest of Europe. The first steps will be special vehicles, busses and fleets. A special Nordic issue might be the use of hydrogen in the marine sector. Another Nordic niche might be special vehicles where H2/FC systems can improve the functionality of these vehicles. In 2020, about 1-4 million hydrogen vehicles and in 2030 about 3-8 million hydrogen vehicles are needed to fulfil the 'big visions' for hydrogen energy in the Nordic transport sector. The number of fuelling stations needed in 2020 was estimated to 1000-4000 and in 2030 to 3000-8000, respectively. These scenarios for hydrogen supply per station were based on the assumption that 50% of the vehicles were powered by an internal combustion engine and 50% equipped with a fuel cell drive train. Nordic H2 Energy Foresight identified a number of Nordic business opportunities within industrial equipment and energy markets services, characterized in three main categories: Production and transmission of hydrogen, Use of hydrogen in the transport sector, Stationary use of hydrogen for power and heat.
Greek National Technology Foresight 2021[341]	**Environment and Energy Policies** now need to address the issue of s**ustainability,** concerns for the future of the planet and future energy sources. There is a need to explore renewable energy sources and develop applications for changing consumer behaviour and consumer attitudes towards the need for improved quality of life and more environmental friendly products. **Energy:** As Greece is a country with very low energy resources it is of extreme importance to examine ways of using energy rationally and exploiting renewable energy sources (RES) such as passive solar power and wind generation. The main objective is to achieve a more rational use of energy, to promote RES and the application of RES technology and to improve energy policy and energy demand by the year 2021. **Environment:** Sustainability and environmental protection is one of the major goals to be achieved. The use of new environmental technologies, clean manufacturing and the promotion of an eco-economy could play a major part in re-structuring the national economy. GDP could be improved by developing

[341] The National Foresight Programme in Greece carried out in 2001-2003 mainly focused on exploring the future of the Greek economy and society and the potential role of science, research and technology in shaping the future in terms of the development of a knowledge society. [Source: T. Damvakeraki, Greek National Technology Foresight 2021(2004). EFMN Foresight Brief No. 12, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief12.pdf]

	and exporting new ecotechnologies abroad.
Green Technological Foresight on Environmentally Friendly Agriculture 2024[342]	**Seven Recommendations on Future Environmentally Friendly Technologies in Agriculture:** future agricultural systems will be based on the following technologies that have the potential to contribute to future environmental friendly agriculture: • **Plant Gene Technology:** controversial, but can result in increased and environmental benign production as well as preserve landscape and nature values. • **Information and Communication Technology** (ICT) includes both decision support systems and a more efficient communication of the latest knowledge about environmentally friendly farming production. The technology does at the same time give completely new possibilities for supervising, modeling and controlling biological environments. • **Manure Technologies** include knowledge and techniques to handle manure as fertilizer from stable to plants aiming at reduced leaching to the environment. • **Biomass Technology** consists of technologies that can effectively and cheaply convert biomass into energy and material of high quality. • **Cultivation and soil preparation** implies intelligent utilisation of biological and agricultural knowledge and is an effective strategy to minimise environmental impact from agriculture. In short: '**good agricultural practice'** based on expert systems and ICT. • **Precision Farming** uses GPS, GIS, sensors and robots to precisely adjust and eventually avoid the use of fertilizer, pesticides, etc., based on knowledge about variations in conditions of cultivation or environmental fragile areas. • **New Stable Systems** focusing on low emission of odour and ammonium by means of stable design, new surface materials, feeding, ventilation, and chemical or biological absorption of odour and ammonium. The conclusion of the foresight is that the future of agriculture, whether it is intensive (industry-based) or extensive (organic-based), has to be holistic and it will be based on knowledge and co-operation between agriculture, research institutions and authorities. This is to secure a dynamic and long-term agricultural policy can be created, which will integrate consideration for the environment. Different agricultural concepts will utilise the technologies differently. Two tracks of agricultural concepts will mutually challenge one another in the future: ◎◎In ***industrial-based agriculture:*** intensive commercial enterprise, where technologies first and foremost are utilized with a view to production yield and effective environmental solutions. ◎◎In the ***organic-based agriculture*** the technologies are assessed in proportion to three central principles - precaution, re-circulation and subsidiarity.
AGORA 2020 – Transport,	**Housing and Construction** **One** issue for the future is **Energy Saving and Cost Reduction -** development of new insulation materials, renewable energies for housing and low

[342] The purpose of this exercise carried out in 2003-2004 and sponsored by the Danish Forest and Nature Agency and the Ministry of the Environment, has been to thoroughly examine those environmental challenges which agriculture will face in the future - and make policy recommendations on the efforts required to develop and promote technological and structural solutions that can minimize the environmental impact of agricultural production on the surroundings, improve animal welfare and provide new methods and products for agriculture. [Source: K. Borch, Green Technological Foresight on Environmentally Friendly Agriculture 2024 (2005). EFMN Foresight Brief No. 13, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief13.pdf]

Housing, Urbanism and Risk[343]	consumption equipments. **Earth Observation and Risk Management:** Issues for future research include • The development of tools and models for observation and • Networking and data standards. **Environmental Trend Breaks** • Acceleration of climate changes, multiplication of natural catastrophes; • Depletion of oil resources (for geological and geopolitical reasons); • New wave of health risks and diseases.
Sustainable Transformation of German Utilities 2025[344]	**Critical Fields of Innovation** **Combined Heat, Smart Buildings and Network Regulation** **'Micro-Cogeneration'** units are small power plants which produce energy for heating what are usually large buildings and electricity, which may then be fed into the grid. It is believed that combined heat and power production (CHP) provides a key to sustainable energy use. However there is a risk that indiscriminate promotion of micro CHP applications could displace competing innovations for sustainable energy generation which may in some cases be more appropriate. This may apply to cogeneration on larger scales (district heating), high building insulation standards (passive housing), or solar energy use. **'Smart Building'** technologies allow for the management of utility use and consumption on the basis of communication between building technology and household appliances, from within the house and from outside. **These technologies may influence energy and water consumption in buildings.** They provide opportunities for **efficient energy use and better resource management.** On the other hand smart building may result in additional energy consumption. Networking technologies applied inside buildings and with the outside world link the provision and consumption of energy. On this basis demand side management tasks such as load management and consumption analysis are possible. Furthermore they can help to optimise the operation of micro CHP either

[343] Agora 2020 is a foresight exercise on the demand of research on transport, mobility, housing, construction, urbanism and risks, launched in spring 2003 by the DRAST - Directorate of Research and Scientific and Technical Affairs of the Ministry of Infrastructure, a scientific agency linked to the department of transport, housing and building. The project's aim is to build up a clear vision of middle and long term issues in the field of transport, housing, town planning to establish priorities and incentives for the next research programs in France. [Source: I. Chatrie and J. Rachidy, AGORA 2020 – Transport, Housing, Urbanism and Risk (2005. EFMN Foresight Brief No. 27, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief27.pdf]

[344] This project sponsored by the German Federal Ministry of Education and Research and carried out in 2002-2006 was established to explore the consequences of structural change in German utility sectors and to raise awareness of the need for coordinated action by stakeholders as well as for the development of strategies for sustainable development. A three step procedure was applied comprising socio-technical scenarios, sustainability assessment and strategies for critical innovation processes. Interactions between four utility sectors - electricity, natural gas, water and sanitation, telecommunications - were considered. Stakeholders involved in production, consumption and governance have been involved at all stages. A multi-level approach was applied to link developments at the sector level with general societal developments and the dynamics of specific fields of innovation. The project also aimed at developing a general methodology for 'sustainability foresight'. [Source: K. Konrad, J.-P. Voß and B. Truffer, Sustainable Transformation of German Utilities 2025 (2005). EFMN Foresight Brief No. 34, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief34.pdf]

	on a local level or on the level of electricity networks.
Japanese S+T Foresight 2035[345]	Technologies and topics identified as very important for Japan: **Geoscience:** Paleo-climatic research, global-scale oceanic climate change research. networks and **viruses** were especially relevant. **Environment:** Topics about gases like **CO2** and **NOx** as well as topics about a "**recycling society**" got high ratings. **Disasters:** Half of the high relevance topics concerned **earthquakes** and countermeasures to decrease the numbers of victims by prediction and the use of simulation. **Energy:** The importance of topics concerning production processes with **non-fossil energy** sources, **fuel cells** for transport means and **solar cells** increased.
Third Korean Foresight exercise[346]	Among the 21 keys technology areas for the future selected based on their expected impact on quality of life, economic growth and public need, the **following key technologies were listed** in the domain of Environmental Sciences: • Biodiversity & Natural Resource Conservation • Clean and Renewable Energy • Climate and Weather Forecasting • Global Observation and National Resource Utilization • Hazard Disaster Forecast & Management Technology • Marine Territory Management Technology • Next Generation Nuclear Energy and Safety Technology • Satellite Technology • Thermonuclear Fusion Technology
New Zealand Futurewatch 2025[347]	**Industry and Environment - From Non-Renewable Commodity Products To Renewables:** The finite nature of fossil fuels, and oil shocks – coupled with advances in industrial biotechnology, both in the development of cost-effective technologies to convert biomass to its constituent parts and in the growth in scale of bio-processing capability – are driving a trend towards the increased production of commodity products (bio-fuels and bio-plastics) from renewable biomass, such as crops and trees. **Bio-processing Technologies:** Micro-organism- and enzymecatalyzed industrial processing is being transformed by emerging techniques such as metabolic engineering. These techniques manipulate microbial cells to bypass cell processes in larger organisms.

[345] Every five years Japan conducts a large national foresight exercise to gain new information and update insights gained from previous foresight activities. One of the most important elements of these foresight exercises is a comprehensive Delphi survey involving more than 2,200 independent experts from different disciplines. The results of this whole process serve as inputs for policy-making and provide valuable information for all interested parties including stakeholders from companies and students. In the eighth Japanese national foresight exercise carried out in 2003-2004 a wider approach was adopted. This exercise included a study on rapidly developing technologies, scenario development and a demand-oriented study. [Source: K. Cuhls, Japanese S+T Foresight 2035 (2005). EFMN Foresight Brief No. 35, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief35.pdf]

[346] The Third Korean Foresight Exercise entitled 'Future Perspectives and Technology Foresight for Korea – Identifying Challenges and Opportunities for Korea's Economy and Society' carried out 2003-2004 represents the most comprehensive effort to date by the Korean government in the field of S&T foresight. [Source: B. Park, Korea 2030 (2005). EFMN Foresight Brief No. 36, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief36.pdf]

	Renewable Bio-Plastics: It is estimated that by 2010 10% of the global plastics market will be renewable and that sometime in the period 2020 to 2025 this will have expanded to 20% of the market.
Turkish S+T Vision 2023[348]	**Energy and Environmental Technologies:** The development of new energy sources and the use of existing natural resources in the most efficient and cleanest way was also considered a key issue for the future. For this purpose R+D activities on the following technologies were identified as being crucial: Hydrogen technologies and fuel cells, renewable energy, nuclear energy, environmentally sensitive fuel and combustion technologies, as well as water treatment and reuse technologies.
Emerging S+T Priorities in the Triadic Regions[349]	Among the priorities identified in the fields of **sustainable development, global change and ecosystems** are: • Capture and storage of CO2 • Low-cost high-efficiency solar cells • More efficient energy consumption based on technologies such as hybrid cars, diode-based lighting technology, new technologies for monitoring and controlling heat and ventilation.

[347] The goal of this initiative sponsored by the Government of New Zealand is to alert the government to new scientific knowledge and technology and understand the opportunities and risks that they present for New Zealand. [Source: S. Mahroum, New Zealand Futurewatch 2025 (2005). Foresight Brief No. 37, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief37.pdf]

[348] 'Vision 2023: Strategies for Science and Technology' is a national project aimed at providing Turkish stakeholders with a vision for the development of science and technology vision in Turkey over a period of 20 years. [Source: O. Saritas, Turkish S+T Vision 2023 (2005). EFMN Foresight Brief No. 39, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief39.pdf]

[349] The objective of this Platform Foresight project is the analysis of emerging science and technology priorities in public research policies of the European countries, the US and Japan. The aim is to provide the European Commission and the member states with policy recommendations as to become leaders in these emerging technologies. [Source: F. Farhi, D. Lecoq, K-H. Steinmueller, A. Eerola and A. Einav, Emerging S+T Priorities in the Triadic Regions (2006). EFMN Foresight Brief No. 42, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief42.pdf]

	• New energy storage technologies using new approaches such as those based on flywheels, super-caps, supraconducting magneto-electrical storage.
Canada Looking Forward S+T 21C[350]	**Environmentally Sound Technologies:** The emerging global market for environmental technologies presents a significant economic opportunity for Canada. This refers to all technologies to manage pollution through control, remediation, avoidance and monitoring. According to OECD findings **bio-based technologies** will provide both economic and environmental benefits that include cost savings of 10-50%, a reduction of CO2 emissions by 10- 80%, water savings of 20-50% and a significant reduction in pollution and toxic substances. In Canada, a combination of abundant biomass resources, a strong science base for industrial bioproducts and bioenergy, and federal priorities in favour of biotechnology, are creating a favourable climate for the development of a **new bioproducts** and **bioprocessing industry**. Canada is recognized as a **world leader in bio-fuel.** Reducing the cost of technologies and systems for biomass harvesting and conversion into bioproducts and bioenergy is therefore a major R&D target. **Sustainable Energy and Economic Growth:** Access to adequate supplies of energy is both an opportunity and a prerequisite for growth. Although the potential benefits of **hydrogen and fuel cells** are significant, many challenges remain before they will offer a competitive energy alternative. Cost and storage are the biggest challenges. Research is needed to develop storage technologies using materials such as metal hydrides and carbon nanostructures. **Solar and wind** are renewable energy sources that offer more than just a solution to meet our growing energy needs and address oil depletion and climate change problems. They also create new opportunities for economic growth and provide security benefits. Solar and wind energy will also accelerate the transition to reliance upon domestically available clean energy technologies. There is a renewed interest in **nuclear power** as an emission-free energy source and as a natural hedge against the environmental costs of fossil fuels. Uranium is one of the world's most important energy minerals, but is notable for its very low energy efficiency. Less than 1% of the resource is extracted as energy and the rest is stored as 'waste'. At this rate, Canadian uranium resources, about 14% of world total, will be exhausted within 50 years. R&D is required to make that technology 10 to 50 times more efficient. The **oceans** contain a huge amount of power that can be exploited for generating useful energy. Developed conversion systems concern tidal energy, thermal energy, marine currents and ocean waves. Canada is particularly rich in tidal current and wave energy resources.
Spanish Nuclear Energy Futures 2030[351]	The panel identified 40 technology fields grouped under 6 headings of relevance for the nuclear energy sector. Topics were ranked according to their relevance and a variable 'degree of relevance' was established. The most relevant findings are summarized as follows: **1. General Topics** This category contains socioeconomic and political assumptions related to the development of new technologies for the nuclear sector. The topics identified are not strictly technological but are important for the perception of nuclear power in the Spanish society. They have to do with issues such as the assumed total

[350] The NRC or National Research Council of Canada undertook this foresight exercise with a time horizon of 2020 to initiate planning for its strategic and organizational renewal. The exercise provided a global perspective and critical insights on the future and impact of S+T in Canada, and on opportunities for the NRC to address national challenges as part of Canadian National System of Innovation. [Source: D. A. Isabelle, Canada Looking Forward S+T 21C (2006). EFMN Foresight Brief No. 46, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief46.pdf]

[351] The purpose of this exercise was to identify the main technologies that would influence the development of nuclear energy in Spain up until 2030. The picked up information is supposed to help to change the public opinion in Spain from a sceptic view towards a broader acceptance of the application of nuclear energy. [Source: B. Grunewald, Spanish Nuclear Energy Futures 2030 (2006). EFMN Foresight Brief No. 54, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief54.pdf]

	capacity for energy production, the option to reduce carbon emissions and public acceptance of technologies to reduce nuclear waste. Two of the identified relevant topics are related to: • Capacity • Infrastructure and auxiliary services in the sector. The third was related to the need to initiate activities that would inform and develop public opinion about nuclear energy as a future energy option. **2. Design, Construction and Management of Nuclear Power Stations** The experts expected that during the next decades the application of nuclear energy to produce electricity will develop along two lines. One line will follow research to extend the lifetime of existing nuclear plants already in use. The other line is the development of future nuclear plants based on new reactor designs and incorporating passive safety features. **3. Management of nuclear waste and decommissioning** Here the most relevant topics for the near future - a period spanning 2011 to 2020, were identified as the development of alternatives to the storage option for long term nuclear wastes and the development of methods for the evaluation and management of technologies for nuclear safety. **4. Safety and Protection** All topics grouped under this heading are expected to be developed before 2010. This was the shortest time horizon identified in the whole exercise. Globally these topics are of high priority and have high importance for the sector. The two most important topics are related to procedures necessary for the licensing of nuclear power plants and to legislation for the nuclear waste transport and management. **5. Other Applications** Accelerators for the production of radioisotopes can be expected as short term nuclear industry developments. The radioisotopes are typically intended for use in industrial production and in the medical sector. The most relevant long-term prospects however are for the use of nuclear energy in the production of hydrogen and other industrial chemicals. This research area is expected to give rise to whole new industry sectors. **6. Fusion** One of the most promising topics of interest for international experts is the development of solutions to the question of how fusion can be used as source of energy. Magnetic Confinement Fusion uses strong magnetic fields to confine the hydrogen heated by microwaves to very high temperatures. Inertial Confinement Fusion or ICF is a radically different approach that uses high energy laser beams to compress and heat hydrogen fuel to the point where fusion occurs. The inertia of the fuel itself is used to confine it long enough for fusion to take place. **Nuclear fission energy can play an important role in the development of the hydrogen industry. It provides a way of producing hydrogen in the quantities required by the energy industry. It is therefore capable of contributing to the development of an entirely new system of energy production. This possibility requires a strong response in terms of R+D. Nuclear fusion shows up as a source of energy able to address different future scenarios for energy demand. On a time scale longer than 50 years fusion remains an important field for research and development to demonstrate its technological and economical viability.**
Russian Critical Technologies 2015[352]	In **rational utilization of nature**, the main areas of technological development will result from more sophisticated technologies for environmental monitoring and forecasting together with the introduction of technologies for ecologically safe mining and oil and gas extraction, as well as for processing and utilizing technogenic substances and wastes and decreasing the risks and minimizing the consequences of natural and technogenic catastrophes. The following products

[352] The Ministry of Education and Science of the Russian Federation conducted a foresight exercise aimed at identifying national S&T priorities and developing the list of critical technologies. The results obtained were used as a background for the Federal Science and Technology Programme. [Source: A. Sokolov, Russian Critical Technologies 2015 (2006). EFMN Foresight Brief No. 79, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief79.pdf]

	with the greatest ecological effect can be named here: technologies and devices for minimizing negative consequences for human health and environment of natural and technogenic emergencies and systems for utilization and burial of highly toxic wastes, for restoring water quality in surface water objects, for industrial and public waste and drainage water treatment, treatment of medical wastes and biological wastes from food industry and agricultural facilities. In **power engineering and energy saving**, the most important areas are fast neutrons nuclear reactors, hydrogen power research, broad scale introduction of various renewable energy sources, and power generation from organic fuels. There are domestic technologies in these areas as well as production facilities for manufacturing plants and equipment for hydrogen power generation, ecologically safe and highly efficient hybrid power plants based on high-temperature fuel elements, highly efficient steam and gas turbine plants, and other competitive products meeting the best foreign equivalents. Some of the most important priorities for technological development are creating power-saving transportation systems, heat and electricity distribution and consumption systems based on superconductor and semiconductor devices, etc. In **transport, aviation and space**, priority will be given to technologies providing production of new competitive types of high-speed land transport, navigation systems, aircrafts, rockets and long-distance space ships, as well as integrating Russian technologies into global value-added chains. The area with the next greatest possible production volumes is **power engineering and energy saving**, where Russian companies are capable of achieving sales volumes of US$ 3-4 billion, with several dozen million dollars' worth of exports.

Law, Economy and Finance

Name of the Foresight initiative	Trends identified
Anticipating Change for Europe's Industries 2020 to 2025[353]	**Financial Services** The main drivers of change in the sector are sector restructuring such as the: • **Introduction of the single market,** • **Mergers,** • **Globalization,** • **Niche markets.** IT is driving change via the introduction of • **E-Banking &** • **Virtual money.** Social trends such Europe's 'pension time bomb' and the Role of the state play an important role and the environment is a driver due to Climate change. Three scenarios were envisaged for this sector: **1 - The 'Surprise-Free' Scenario**: A world where the single market and its common currency, continuing globalization, an extensive use of information technology and new employment opportunities shape the financial services sector. **2 - The 'Alternative' Scenario**: The Euro has not been universally adopted following its rejection in a number of national referenda. **3 - The 'What if?' Scenario**: This is characterized by a slow recovery in the stock market, increasing personal and government debt, and the domination of financial markets by derivatives, created an accident waiting to happen. A terrorist attack brings financial meltdown.
Greek National Technology	The most important findings concerning the Greek progress towards a knowledge society are as follows: The **changing structure of the economy** in other words the **transition from a 'traditional' economy to a more knowledge intensive one** is a hot topic. Greece needs to maintain its high rate of economic growth without Community funding all the while promoting structural change and building up its research

[353] Sector Futures - an initiative launched by the European Monitoring Centre of Change (European Foundation for the Improvement of Living and Working Conditions) in 2003 - provides insights at the sectoral level on the future of Europe. The broad objectives of the Sector Futures initiative are to: 1. Understand drivers of change as they apply to specific sectors of the European economy; 2. Highlight possible scenarios and probable futures on a sector by sector basis; 3. Provide information and links to access additional information and data at sectoral level; 4. Identify and highlight topics and issues for debate in relation to the changing futures of sectors, for the companies and individuals who work in them and depend on them. [Source: C. Blackman, Anticipating Change for Europe's Industries 2020 to 2025 (2004). Foresight Brief No. 4, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief04.pdf]

Foresight 2021[354]	and development potential. The **quality of human capital** is also an issue. **Employment and the promotion of training** to increase employability and better address emerging market needs is an issue. There is a need to set new objectives in educational and training policies and identify emerging market needs. Due to regional disparities and changing patterns of the population issues of **social cohesion and exclusion** in terms of economic immigration, regional disparities, geographical seclusion, etc are considered as very important and they affect significantly the course towards a knowledge based economy/ society, as knowledge should be shared between the people. **Quality of social capital** is an issue of great interest in the sense that the promotion of collaboration with non profit and non governmental organisations and the development of synergies with social partners is important for the application of R&D and innovation. The following policy measures were proposed in order to tackle the challenges identified in the foresight exercise: • **Structural changes in the labour and product markets:** In order for an economy to maintain a high level of competitiveness it is necessary that product, labour and capital markets work efficiently. Regulatory reforms are required in product markets that are dominated by the public sector enterprise and suffer from low competitiveness. The dominance of the public sector in these markets should also be decreased by selling parts of the enterprises to the private sector, in order to lead into stabilization and more intense involvement of the private sector through the liberalization of the markets to increase innovation and encourage development capabilities. Furthermore there is a need to transform social security legislation since the current system encourages self-employment. This reduces the labour pool for enterprise, limiting their growth and leading to low productivity and low competitiveness. • **Social Capital** should be enhanced through upgrading governance and Public Administration, eliminating bureaucracy and corruption from the economy and society and decreasing the intermediate phases for the provision of public goods through an efficient assessment of public servants and by providing incentives connected to performance.
Operation FutuRIS – France 2020[355]	**Main Conclusions - Focus on the Social Value of Research and Innovation** Results of research and innovation contribute to meet social needs especially by improving social well-being. This point is particularly relevant in European societies with low levels of population growth and high levels of fixed capital because the increase in revenue mainly comes from intangible investments in research, innovation, education and training. According to economic experts, it is possible to envisage that unemployment, compounded by the rising number of pensioners (2010-2020), might lead to an explosion in social spending that would result in the breakdown of the current system, assuming that economic and social systems remain unchanged and that the economy does not return to sustained growth. On the other hand**, changes in democracy will continue to transform the relationships between science, technology, and society.** It will no longer be just a

[354] The National Foresight Programme in Greece carried out in 2001-2003 mainly focused on exploring the future of the Greek economy and society and the potential role of science, research and technology in shaping the future in terms of the development of a knowledge society. [Source: T. Damvakeraki, Greek National Technology Foresight 2021(2004). EFMN Foresight Brief No. 12, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief12.pdf]

[355] Operation FutuRIS is the result of an initiative launched by the French Association for Technical Research (ANRT) to bring together leading players of the public and private sectors with the aim of laying the foundations for the future of the French Research and Innovation System. FutuRIS is a systemic foresight exercise that uses a number of exploratory scenarios to simulate potential changes from which key issues can then be identified. [Source: I. Chatrie, J. Rachidy, Operation FutuRIS – France 2020 (2005). EFMN Foresight Brief No. 24, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief24.pdf]

	matter of keeping citizens informed of developments in science and technology. Instead, it will be necessary to incorporate research and innovation into the interaction between scientific, political, economic, and social trends. Beyond questions on the existence of a basic consensus regarding values, behaviours may result in differences of opinion as to what is at stake, which would create major tensions. In this sense, group 3 (interaction of research and innovation with society) concluded that: "reviving ambitious innovation policies requires an open and informed debate, looking at the innovation process both in terms of its goals and the methods used". This foresight exercise underlines new approaches to organisation, finance, marketing, logistics, software development, research and training. In this context according to the expert group, **horizontal economic and social policies should ideally include:** • Actions offering compensation for the underprivileged, while avoiding the maintenance of obsolete structures, • Macroeconomic policies to facilitate sustained economic growth • Employment policies aimed at reducing unemployment by increasing labour market flexibility, • Life-long education and training policies that foster initiative-taking and that increase the adaptability of the workforce.
AGORA 2020 – Transport, Housing, Urbanism and Risk[356]	**Identification of the Main Socio-economic Issues** **Cities and Territorial Planning Issues** Questions arising here fall under the following main headings: • **Demographic Change and its Consequences:** The living conditions of elderly persons, their needs in terms of specific housing and access to medical infrastructure, as well as the risk of geographic segregation between 'young areas' and 'old areas'. • **Social Exclusion and Precariousness:** This includes issues related to care for the homeless, those living in ghettos and related risk to the community. • **Sustainable Land-Planning and Urban Development:** How to limit or manage the extension of peri-urban areas? • **Multileveled Governance:** How to develop a country in a homogeneous fashion coping with territorial competition and heliotropism? **Trans-European Issues** Considering the international environment, five main trends or trend breaks were identified: • The decline of Europe and the emergence of Asia as the centre of the world economy, • A return to protectionism and local consumption, • The impact of terrorism and its spill over effects, • The construction of a 'Wider Neighbourhood' for Europe taking in countries from the Mediterranean Sea to the Ukraine. **Territorial Trend Breaks** • Concentration and polarisation of economic activity. • Urban exodus and the repopulation of rural areas.

[356] Agora 2020 is a foresight exercise carried out in 2003-2005 on the demand of research on transport, mobility, housing, construction, urbanism and risks, launched in spring 2003 by the DRAST -Directorate of Research and Scientific and Technical Affairs of the Ministry of Infrastructure, a scientific agency linked to the department of transport, housing and building. The project's aim is to build up a clear vision of middle and long term issues in the field of transport, housing, town planning to establish priorities and incentives for the next research programs in France. [Source: I. Chatrie and J. Rachidy, AGORA 2020 – Transport, Housing, Urbanism and Risk (2005. EFMN Foresight Brief No. 27, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief27.pdf]

	• The decline of the suburbs and outskirts of major cities as well as major crisis in these areas. • Restrictions or limitations on the use of private cars. • The expansion of teleworking practices. • The importance of urban regeneration and social mix policies.
FORETECH – Bulgarian Technology and Innovation Foresight 2015[357]	**E-services Central to e-Government Policy** During workshop discussions the e-Government stakeholders expressed a common view that the foresight exercise should focus on the following priority topics: • The development of e-Government services, • The development of e-Government enabling technologies, • Financial aspects of e-Government implementation, • Education, vocational training and human resource development for e-Government, • Legal aspects of implementation and development of e-Democracy, • Development of the channels for provision of e-Services, • And the need of a differentiated approach for delivering eServices to the targeted users. **Foresight and Policy Reaction and Key Policy Recommendations** The recommendations evolved from scenarios elaborated on the basis of a normative approach. In this approach scenario writing focuses on the possible sequence of events that could lead to a desired future and the key actions that needed to be taken now in order to ensure the occurrence of that future course of development. **e-Government improving Quality of Life & Performance of the Economy** The interim progress report of the ForeTech project was based on the country review framework, and stressed the importance of the information society and the application of information society technologies to the economy. During the transition towards the information society, it is very important that public information and services should become widely available to citizens through electronic means. **e-Government services are of major importance for the life of citizens and for the performance of the economy.** Bearing in mind that e-Government is a combination of information and communication technologies accompanied by organisational changes and new skill development, e-Government experts from the foresight panel proposed the following set of recommendations to national government: • The national government should set **clear policy goals for e-Government**. They should provide roadmaps and create a continual political focus to ensure that identified strategic goals continue to be addressed and continue to feature high on the political agenda. • **e-Government policy should be adaptable and demonstrate long-term commitment**. It should allow risk taking and pursue of long-term objectives. Rather than adopting a centralised approach it should play a coordinating role.

[357] This first-ever foresight initiative in Bulgaria, carried out in 2003-2004, was developed for the purpose of introducing the use of foresight as a tool for policy development at national, regional and sectoral level. The aim was to adapt foresight techniques and methodological frameworks to the Bulgarian environment. This was achieved by implementing two foresight pilots in the fields of:
• e-Government, as well as
• Agriculture & Biotechnology. [Source: T. Damvakeraki, FORETECH – Bulgarian Technology and Innovation Foresight 2015 (2005). EFMN Foresight Brief No. 28, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief28.pdf]

	• It is necessary to establish a **responsive legal framework** which takes into account of the challenges posed by internet-based information and communication environments. • A clear vision is needed for ICT development in the public sector, backed up by a strategy for development and deployment.
Futur Radar 2030[358]	*Futur Radar 2030* therefore focused on the challenge of demographic change and its effect on: 1. Communal Affairs, 2. Industry and Labour, 3. Cooperation of the Generations, 4. Market Opportunities. **Demographic change implies several major challenges:** • In the long-run **shortage of young specialists** mainly in technical professions. • Rise in the average age of the work force. Companies have to deal with **senior personnel**. This causes a fear of a declining capacity for innovation in enterprise. • The number of elderly people in society increases. This has consequences for the welfare system. In particular it has consequences for the **pension system**. More and more senior citizens rely on the contributions of fewer employees and previous 'inter-generational contracts' loose their validity. • The changing proportion of old and young people in society harbours potential for **social conflict**. It is possible that younger generations will not feel adequately represented in the political realm, whereas a growing number of senior citizens may feel rejected by a youth-centred consumer strategy in advertisement and production. • Demographic change will differ from region to region. While the urban centres and their greater surroundings will keep on growing in the upcoming decades, **rural areas with a poor infrastructure** will face serious loss of population. This could lead to challenges in ensuring adequate supplies of goods and services in these regions. • **Fewer taxpayers** in regions with declining working populations will put pressure on communal budgets and the maintenance of cultural, recreational infrastructure and other services will challenge local authorities. **Chances and Opportunities** Demographic changes present not only challenges but opportunities too. Some of these opportunities are: • New markets for **specialised products and services** aimed at seniors are opened up by the increasing number of elderly people in society. • The quality of **educational systems** could benefit from the lower number of schoolchildren. • **Communal administrations** could benefit from technological progress and increase their efficiency. • Due to the shortage of a young work force, personnel managers will have to develop new strategies to conserve the operating experience of their **senior employees**. **Strategies proposed:**

[358] The population structure of the German federal state of Rhineland-Pfalz (The Rhineland-Palatinate) in South-West Germany will change considerably in the coming decades. This will have impact on every sphere of private and public life. Taking account of projections for population growth in the region Futur Radar 2030 (Zukunftsradar 2030) took a closer look at these developments and the impact they could have on citizens in the region. The Foresight exercise was carried out in 2002-2005. The goal was to sensitize the public and decision-makers to this and emerging related issue and to make proposals for various actors as to how they might handle the expected change. [Source: H. Kolz, C. M. Hadnagy, Futur Radar 2030 (2005). EFMN Foresight Brief No. 29, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief29.pdf]

	Communal Affairs - a modern service provider *Futur Radar 2030* advocates the continuous inclusion of model calculations on the population development into any kind of municipal planning. This is one of the most important tasks for communal administrations. Local authorities should also increase the efficiency of their structures. In order to save costs, several promising instruments were identified: • The administration as a whole should be transformed into a modern service provider and bureaucratic regulations should be reduced. • Incentives should be used to entice companies into playing a more active role in the community. This will increase the companies' attachment to the region and could be a key for corporate success. • The voluntary actions of citizens should become a central means for the inexpensive maintenance of communal services. In order to raise birth rates effectively and thereby lower the effects of demographic change, the legislator and likewise the communal authorities should take measures to improve family-friendly structures. **Maintaining a workforce of senior employees** An important task for the future is to keep up the productivity of the economy with fewer and older employees. The conservation and use of the accumulated know-how of the workforce, especially of elder workers is one of the major challenges for companies. Trainee and mentoring programs could be initiated so as to pass on hard-earned knowledge to the next generation of employees. **Family-friendliness** will be one of the key issues for the future. The number of female specialists and executives in higher positions must be increased. Work-life-balance must therefore be improved. Politics and the economy must find appropriate actions leading to better compatibility between family-life and work. They need to provide a framework in which women will find the same working conditions as men, in which flexible employment is encouraged, and in which the productivity of elder employees will be preserved by means of workplace design and improved personnel planning. **Next Steps proposed:** • The education system must be adapted to the new requirements. The promotion of specific skills and talents of the individual should drive the educational agenda. • Local business development and regional policy should put their focus on creating high tech jobs. At the same time professional training should be organised to provide appropriate qualifications. • The working people of the region must realise that they are to a great extent self-dependent in their career planning. Individual initiative is needed for success. On the other hand employers will need to offer employees further training programs on a regular basis. • Payment should be based at least to some extent on individual skills and personal performance. As criteria for remuneration, age and seniority should play a subordinate role. **Cooperation among the Generations** Mutual respect for the needs of each generation is the key for a harmonious and healthy community. Above all the family as an institution needs to be encouraged and supported. The position of the family in society needs to be strengthened through political and social measures. The place and reputation of children in our community must be improved through measures taken by decision-makers in politics, economy, society, and culture. This includes improvement in child are facilities and the promotion of better work-life-balance. The general framework must be constructed by the federal state and the economy, but local decision-makers have to design it according to the needs of the region. Senior citizens on the other hand have to be enabled to choose their individual life-style according to their abilities and interests.

	The preservation of mental and physical ability should be supported through access to dedicated services. The elderly will become more active and the availability of special age based spare-time activities should be extended and improved. Local authorities have to consider the needs of all generations into their planning. The citizens on their part contribute to communal life by volunteerism. Well directed projects might contribute to a better balance between the generations. New public and private buildings should facilitate and create opportunities for inter-generational contact. The main intention is to improve relations between the generations. Therefore, modular, flexible and obstacle free methods of construction are required.
East German Cross-Border Regions 2020[359]	These surveys and discussions lead to the conclusion that Regional Foresight is: • A medium for dialogue involving citizens and private industry, • A tool for regional planning, • Sensitive to the effects of mega-trends on regional development, • Supportive of active, society-oriented commitment of the region for the region, • An appropriate way to increase the effectiveness of planning for regional innovation activity.
Quebec S+T Development Based on Social Needs[360]	40 main socio-economic challenges that Quebec society will have to face in the near future were identified. They can be grouped into 6 thematic categories, among them: • **The Economy, Research and Innovation**: Priorities involving research, globalization, the solidarity economy, high value added jobs, agriculture, networks, the regions of Quebec and a highly qualified workforce. • **Demographics and Communities**: The increasing the birth rate, immigration, and issues related to specific groups such as the First Nation people and the Inuit. Among the seven major socioeconomic challenges identified where research could improve our understanding of the real problems that lie behind each challenge and provide insight into how they could be tackled: • Increase **the efficiency of the public health-care system** that must support an gradually aging society while at the same time controlling costs. • Target **strategic and priority market niches** in the areas of research, economic development and education, on the basis of current strengths and emerging sectors.

[359] Despite the progress they have made to restructure and modernize, Eastern German regions today still lag clearly behind most regions of Western Germany. For this reason there is a need for a specific East German Innovation Policy. This has led the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung of BMBF) to supplement federal innovation programs in support of East Germany with a Regional Foresight exercise. The initiative on 'Regional Foresight in German Border Regions'(2004-2005) funded by the Federal Ministry of Education and Research was concerned with the exploitation of the potential of regional foresight in the cross-border regions of Germany, Poland, and the Czech Republic. [Source: A. Braun, East German Cross-Border Regions 2020 (2005). EFMN Foresight Brief No. 30, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief30.pdf]

[360] The STS Perspectives project is a foresight study examining Science-Technology-Society issues, designed to mobilize Quebec's scientific and technological resources in order to address important socio-economic challenges that Quebec society will face over the course of the next 15 to 20 years. This project started in 2003 and is still ongoing. [Source: A. Bergeron,
G. Drolet, Quebec S+T Development Based on Social Needs (2006). EFMN Foresight Brief No. 47, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief47.pdf]

	• Adopt **innovative interventions for controlling poverty** and the factors that generate and maintain it, so as to stave off the consequences of poverty such as marginalisation and a sense of powerlessness as well as inequity and violence.
Greece's Path to the European Knowledge Society[361]	**Socio-Economic and Technological Trends for Greece** • **The Ageing Population and Retirement**: The ageing of the population is linked to the ability of the public health system to cope with increasing demand for health care and medical treatment. A constantly increasing retirement age in combination with possibilities for part-time occupation will result in the appearance of new forms of work after the age of 60 or 65 - part time occupation in the same field, as well as 'alternative' or 'social-voluntary' occupation. Some people may continue working. This life-long working will be supported by lifelong training. Others may be excluded from work after the age of 50 for a variety of social reasons. This may result into the appearance of new categories of employees, unable to be insured or retired. • **Peripheral Disparities:** Peripheral disparities in Greece hinder balanced development of the Knowledge Society. Large urban areas will develop faster because of their better infrastructure and access to human resources. The rural, mountainous, frontier and island areas will lag in their development. The unbalanced 'territorial' distribution of people of different ages and incomes will lead to unbalanced development of the Knowledge Society in Greece. Alternative forms of tourism in some rural and mountainous areas could lead to the development of poles of attraction not just for tourists but for tele-workers, boosting quality of life in these areas. • **Industrial Relations:** Industrial relations and working conditions in Greece do not promote the development of the knowledge society and the economy. • **Economic Factors:** The 'dualism' that characterises the Greek economy will be intensified as competitive enterprises constantly improve their performances at national and European level, while 'traditional' and less competitive ones struggle to survive. The development of new peripheral markets in the Balkans, Eastern Europe and the Mediterranean may alter the orientation of the Greek enterprises. Some will exploit availability of cheap labour to become more competitive. Others may cover 'noncompetitive' markets that can be served by products and services of low quality. These strategies run against the trend of the emergence of a Knowledge Society. • **Governance Policies:** The 'conservative' organizational culture characteristic of areas in Southern Europe and in Greece will widen the 'distance' between management and employees, hindering timely exchange of information and the production of knowledge. On the other hand egovernance enhances transparency in the procedures concerning the relationship between the citizens and the state and may contribute to the decrease of the population moving to the urban areas.

[361] In the context of its four-year work programme, *Analysing and Anticipating Change to Support Socio-Economic Progress 2001-2004*, the European Foundation for the Improvement of Living and Working Conditions launched EUFORIA - a project on 'European Knowledge Society Foresights (KS foresights) for living conditions, working conditions and industrial relations'. The purpose was to understand the 'drivers' of the Knowledge Society and to anticipate their potential impact on living and working conditions and industrial relations. The underlying aim was 'to identify and support paths to positive transformation while avoiding unsatisfactory development paths'. Especially in the case of Greece the development of a knowledge society is considered a major challenge due to the country's lagging behind in terms of technological development and the knowledge society indices. [Source: T. Damvakeraki, E. Amanatidou, Greece's Path to the European Knowledge Society (2006). EFMN Foresight Brief No. 57, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief57.pdf]

Life Sciences

Name of the Foresight initiative	Trends identified
France - Technologies-Clés 2010[362]	**Trends and important areas identified:** Transgenesis Cellular Therapy Proteomics Gene Therapy Large-Scale Functional Genomics High Throughput Screening / High Throughput Experimentation) Monoclonal Antibodies Technology Recombinant vaccines Medical Imaging Food Allergy Nutrition
Danish Foresight - Teknologisk Fremsyn[363]	**The Bio & Health panel identified the following critical areas:** • Health problems related to aging, nutrition, and life style • Health care structure, including shortage of health workers, costs, & management • Patient relations, focusing on better quality, treatment of inter-related illnesses, personalized care, and more responsibility to the patient • Ethical issues arising from new technologies and new procedures **To address these issues the following technologies will play a key role in the future:** • Human genomics and proteomics (including products such Personal Genetic ID Cards, prenatal analysis, gene therapy, etc.): In the field of human genomes and proteomes, the mapping of the human DNA has paved the way a paradigm shift towards individualized and preventive forms of care based on genetic disposition, targeted screening, diagnostics and innovative medical treatments. These include: screening for genetically determined

[362] http://www.industrie.gouv.fr/pdf/technocles2010-1.pdf

[363] The purpose of the Danish technology foresight exercise, carried out 2001-2005 by the Danish Ministry for Science, Technology and Innovation, was to gain insights into, and prepare for future technological developments, market and social needs. It meant to assist government ministries and agencies formulate and develop a framework for new research programmes. [Source: S. Mahroum, Danish Technology Foresight 2015 (2004). EFMN Foresight Brief No. 5, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief05.pdf]

	characteristics, more individualized and targeted treatment of diseases and improved prevention of human pathogens (viruses and bacteria transmitted by humans). **• Stem Cells (for the treatment of neurodegenerative illnesses, traumatic brain and spinal cord injury, etc.):** The research in stem cells from early-stage human embryos, as well as from various types of tissue from adults, aims at engendering many exciting perspectives for developing new forms of treatment in which stem cells are used to replace malfunctioning cells or tissue (stem cell-based cell therapy). **• Bio-electronics (such nano-robots, biological computing, biosensors, biochips, electronic implants, etc):** Bioelectronics presents many interesting opportunities for fields such as medical equipment technology (including the development of electronic implants for rehabilitation, etc.) and biosensors for monitoring purposes. Recent research in cell properties, and the way they interact with their surroundings, has paved the way for new forms of integration and interaction between biological material and electronic systems, and nanotechnology has permitted the examination and understanding of systems right down to the atomic level. **• Pervasive Healthcare (such as automatic and mobile monitoring, virtual hospitals, etc):** Pervasive healthcare could be used to give patients, relatives and staff better access to information as and when they need it. There are also many possibilities for home care – healthcare and treatment in the home. Pervasive healthcare can be seen as a way of improving care, communication and the use of resources, and thus has the capacity to optimize the health sector in many areas. **The Hygiene Panel** identified Hygiene is seen as of strategic importance in Denmark for the following reasons: • Infection related illnesses are responsible for about 25% of disease related death worldwide, • Infections cost Denmark about €250M each year, • Increased incidence and risk of global spread of infectious diseases, • Growing resistance of micro-organisms to antibiotics, • An aging population with reduced immunity, • Increased mobility between world parts and regions. **The following areas of study have been identified as being critical for the future:** • Bacteria transfer from food to people, between people, and resistant (of anti-biotic) viruses (including cold & flu) and bacteria, • Food poisoning and intestinal diseases, • Relationship between antibiotics and resistance, • Alternatives for existing hygiene practices. Addressing these issues will require advances in the following technologies for the future: • Technologies for hygiene in hospitals and other intensive care environments, • Technologies for hygiene in public and community institutions such as kindergartens, schools, prisons, etc • Technologies for hygiene in the workplace, • Technologies for hygiene in food products, • Technical Hygiene (technologies for water distribution and sewage handling etc).

Green Technological Foresight on Environmentally Friendly Agriculture 2024[364]	**Seven Recommendations on Future Environmentally Friendly Technologies in Agriculture:** future agricultural systems will be based on the following technologies that have the potential to contribute to future environmental friendly agriculture: **Plant Gene Technology:** controversial, but can result in increased and environmental benign production as well as preserve landscape and nature values. **Information and Communication Technology** (ICT) includes both decision support systems and a more efficient communication of the latest knowledge about environmentally friendly farming production. The technology does at the same time give completely new possibilities for supervising, modeling and controlling biological environments. **Manure Technologies** include knowledge and techniques to handle manure as fertilizer from stable to plants aiming at reduced leaching to the environment. **Biomass Technology** consists of technologies that can effectively and cheaply convert biomass into energy and material of high quality. **Cultivation and soil preparation** implies intelligent utilisation of biological and agricultural knowledge and is an effective strategy to minimise environmental impact from agriculture. In short: '**good agricultural practice'** based on expert systems and ICT. **Precision Farming** uses GPS, GIS, sensors and robots to precisely adjust and eventually avoid the use of fertilizer, pesticides, etc., based on knowledge about variations in conditions of cultivation or environmental fragile areas. **New Stable Systems** focusing on low emission of odour and ammonium by means of stable design, new surface materials, feeding, ventilation, and chemical or biological absorption of odour and ammonium. The conclusion of the foresight is that the future of agriculture, whether it is intensive (industry-based) or extensive (organic-based), has to be holistic and it will be based on knowledge and co-operation between agriculture, research institutions and authorities. This is to secure a dynamic and long-term agricultural policy can be created, which will integrate consideration for the environment. Different agricultural concepts will utilise the technologies differently. Two tracks of agricultural concepts will mutually challenge one another in the future: ◎◎In ***industrial-based agriculture:*** intensive commercial enterprise, where technologies first and foremost are utilized with a view to production yield and effective environmental solutions. ◎◎In the ***organic-based agriculture*** the technologies are assessed in proportion to three central principles - precaution, re-circulation and subsidiarity.

[364] The purpose of this exercise carried out in 2003-2004 and sponsored by the Danish Forest and Nature Agency and the Ministry of the Environment, has been to thoroughly examine those environmental challenges which agriculture will face in the future - and make policy recommendations on the efforts required to develop and promote technological and structural solutions that can minimize the environmental impact of agricultural production on the surroundings, improve animal welfare and provide new methods and products for agriculture. [Source: K. Borch, Green Technological Foresight on Environmentally Friendly Agriculture 2024 (2005). EFMN Foresight Brief No. 13, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief13.pdf]

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<tr><th></th><th>Industrially Oriented Production</th><th>Organically Oriented Production</th></tr>
<tr><td>Genetic Technologies</td><td>Total use of GMOs and crossing of arts boundaries</td><td>Limited to the utilisation of bio-markers in traditional processing</td></tr>
<tr><td>Bio-Energy Technologies</td><td>Straw and energy crops for centralised power stations, ethanol and RME factories</td><td>Domestic animal fertiliser and N-fixing energy crops for de-centralised bio-gas and thermal gasification</td></tr>
<tr><td>Automation</td><td>Milking robots in the stable</td><td>Milking robots in the field</td></tr>
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Table: An illustration of future uses of green technologies within the two generic production paradigms that can be envisaged for Danish farming.
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<tr><td>The Food Industry in Flanders – Towards 2010[365]</td><td>
Promising fields and Anticipated Developments
Seven promising scientific and technological fields have been identified with respect to the future developments in the sector.
Ingredients Production and Raw Materials:
• The replacement of natural ingredients by artificial ingredients.
• The development of ingredients to compensate for the loss of organoleptic characteristics in ‘healthier’ foods.
Food Processing:
• Up to 50% of the thermal processes used in food processing will be replaced by non-thermal processes such as use of high pressure processing techniques.
• New processes will be based on scientific insight and computer based models instead of laboratory research.
Packaging:
• Intelligent packaging.
• Bio-degradable packaging.
• Taste preserving packaging.
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[365] The food sector is one of the most important industrial sectors in Flanders. The aim of the foresight exercise, sponsored by the FSTPC - Flemish Science and Technology Policy Council, and FEVIA - The Federation of the Flemish and Belgian Food Industry, and carried out in 2002-2003 was to identify and map future scientific and technological developments in the food sector from a socio-economical perspective and to identify future needs for industry working in the sector. The outcome of the study directly feeds into the strategic policy making process of the Flemish Government. At company level the aim is to provide managers, R&D managers and researchers with a ‘window of opportunity’ through which to ‘benchmark’ their own company strategy. [Source: A. Verbeek, The Food Industry in Flanders – Towards 2010 (2005). EFMN Foresight Brief No. 26, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief26.pdf]

	• Functional packaging. **Biotechnology as an enabling technology for the food sector:** • Intensive use of biotechnology for the production of ingredients. • The use of herbicide resistant crops. • The use of GMO techniques to create new species. • Functional and nutraceutical food products. **Food Science and Engineering Technology:** • Unraveling the relationship between the structure of food ingredients and their properties. • A full understanding of the effect of existing food technologies on human health. **Measurement and analysis:** • Online process monitoring. • The introduction of biosensors. • Personified testing and analysis of food quality. **Water purification and supply:** • The introduction and application of new purification techniques such as membrane and plasma technologies aimed at generating zero waste. On the socio-economical level the **reputation** of the food industry with the perspective of the broader public is crucial for growth in the sector. Consumers should have available objective and trustworthy information about food, safety, and health. Adequate safety systems need to be put in place. The need to address this will become more urgent with the creation of a European Food Safety Agency. The **alienation** of the consumer is a second major challenge that all companies face. Consumers and the NGO's that represent them refer to a **growing knowledge gap between the industry and the consumer.** Experts judge this to be of great importance for progress in the sector. They caution that this will be difficult if not impossible to remediate. Knowledge from disciplines such as psychology, the communication sciences, sociology and anthropology, will need to be used by the food sector when approaching the consumer and when addressing consumer related issues such as alienation and consumer trust. Another challenge is that of **sustainable development**. Food related processes must now be redesigned with a view to achieving 'zero-waste'. The availability of suitable **human capital** is as important as any other challenge faced by the food sector. The decreasing numbers of students in the food sciences worries those involved in the sector. The government together with industry now needs to take steps to promote the sector as an attractive and challenging career option. It may be necessary to provide incentives such as support through scholarships to encourage young people to pursue degrees in areas of importance for the sector.
Japanese S+T Foresight 2035[366]	The bibliometric study carried out in the scope of this Foresight exercise identified 153 technologies, of which 51 are regarded as very important for Japan. The classification started from the traditional disciplines, although important topics often occur at the borders of the classical

[366] Every five years Japan conducts a large national foresight exercise to gain new information and update insights gained from previous foresight activities. One of the most important elements of these foresight exercises is a comprehensive Delphi survey involving more than 2,200 independent experts from different disciplines. The results of this

	disciplines and have an interdisciplinary nature. These topics can be analyzed into clusters, among which: ***Clinical Medicine:*** **S**tudies on telomerase, hormone therapy, immune disease research, viral hepatitis, glutamine receptors, stem cell regeneration, the impact of air pollution particles on the health of human beings and others. ***Plant and Animal Science:*** Cell membrane channels, study of the biological clock, molecular biotechnology, influenza etc. Technologies and topics identified as very important for Japan: ***Human life:*** Topics about **cancer** were very often rated as important. The same was true for illnesses resulting from the ageing society like **Alzheimer**. But also treatments for infectious diseases and allergies were becoming more important. ***Harmful chemicals:*** In particular their impact on human health was also regarded as a relevant problem.
Third Korean Foresight exercise[367]	Among the 21 keys technology areas for the future selected based on their expected impact on quality of life, economic growth and public need, the **following key technologies were listed** in the domain of Life Sciences: • Biotechnology-based New Materials and Medicine • Drug Discovery, Diagnostics and Personalized Medicine • Regenerative Medicine Technology
New Zealand Futurewatch 2025[368]	'Biotechnologies to 2025' has identified important areas for technology development that will shape the biotech sector in the period leading up to 2025. Additionally it has identified influential market developments. **Emerging Areas of Development** **Health and Wellbeing - From Repair to Regeneration:** The development of regenerative medicine that is accompanying a growing understanding of stem cells and the neurological system signals a shift from an emphasis on the replacement of tissues to a more biologically

whole process serve as inputs for policy-making and provide valuable information for all interested parties including stakeholders from companies and students. In the eighth Japanese national foresight exercise carried out in 2003-2004 a wider approach was adopted. This exercise included a study on rapidly developing technologies, scenario development and a demand-oriented study. [Source: K. Cuhls, Japanese S+T Foresight 2035 (2005). EFMN Foresight Brief No. 35, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief35.pdf]

367 The Third Korean Foresight Exercise entitled 'Future Perspectives and Technology Foresight for Korea – Identifying Challenges and Opportunities for Korea's Economy and Society' carried out 2003-2004 represents the most comprehensive effort to date by the Korean government in the field of S&T foresight. [Source: B. Park, Korea 2030 (2005). EFMN Foresight Brief No. 36, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief36.pdf]

368 The goal of this initiative sponsored by the Government of New Zealand is to alert the government to new scientific knowledge and technology and understand the opportunities and risks that they present for New Zealand. The ambition is to find things that are new or unusual that may act as signposts to important changes on the horizon. Another aim is to think about the impacts of new science and technology in a way that include a range of perspectives in particular perspectives from outside the world of science and technology. This is intended to improve the Goverment's ability to anticipate and respond to new science and technologies from a context of broad reflection on New Zealand's future. [Source: S. Mahroum, New Zealand Futurewatch 2025 (2005). EFMN Foresight Brief No. 37, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief37.pdf]

	based method for the repair and regeneration of tissues. **Primary Production - From High-Volume Low-Value' to 'Low-Volume, High-Value' primary production:** Primary industry products have traditionally been characterized by the production of high volumes for relatively low returns. Biotechnology is enabling a move towards more value added products being produced in the primary industries (for example, pharmaceutical proteins produced in livestock and plants). **Industry and Environment - From Non-Renewable Commodity Products To Renewables:** The finite nature of fossil fuels, and oil shocks – coupled with advances in industrial biotechnology, both in the development of cost-effective technologies to convert biomass to its constituent parts and in the growth in scale of bio-processing capability – are driving a trend towards the increased production of commodity products (bio-fuels and bio-plastics) from renewable biomass, such as crops and trees. The fourth important area of development is **'Security and Defense**'. **Potential application areas identified by 'Biotechnologies to 2025'.** **Health and Wellbeing** **DNA chips:** DNA chips and genetic testing will become integrated into standard clinical practice as the genetic nature of more complex diseases is unraveled and diagnostic tools become cheaper. This has been forecast to occur in around 2012. **RNA interference (RNAi):** The therapeutic application of gene silencing could theoretically be applied to any disease that is linked to an overactive gene or genes. The first filing of an investigational drug application based on RNAi technology occurred in August 2004. The earliest prediction for an RNAi drug to reach the market is around 2019. **Stem Cell Therapies:** Stem cells are the cells 'most likely' to enable anticipated tissue engineering applications due to their innate ability to differentiate into other forms of tissue. The emergence of stem cell based therapies for the treatment of chronic diseases such as diabetes, Parkinson's and Alzheimer's and heart disease are forecast to emerge sometime between 2015 and 2025. **Neuro-prosthetics:** Neuro-prosthetics use brain signals to operate devices such as artificial limbs or computer keyboards. It is also possible that wearers may regain the sense of touch with the use of such devices. Successes in the lab indicate that they may be available on the market soon after 2010. **Embryo Screening for Multiple Genetic Traits:** Recent improvements to DNA amplification techniques mean that doctors will be able to screen pre-implantation embryos for multiple genetic traits. **Primary Production** **GM Crops - Stacked Traits:** The ability to genetically modify plants with multiple genetic traits is known as 'trait stacking'. GM crops with multiple genetic improvements will enable in the first instance, greater control over production traits, such as pest resistance. More complex transformations will follow, targeting for example 'output traits' in plants such as increased yield of oils or sugars. Artificial chromosome technology and chloroplast transformation are the two most promising technologies for achieving controlled 'stacked trait' transformations. **Marker–Assisted Selection:** Breeding technologies for both plants and animals based on marker-assisted selection is likely to allow controlled, increasingly complex genetic traits in animal and plant reproduction, without the need for genetic modification. **Bio-pharming:** The production of high-value proteins using plants or animals as bioreactors or 'factories' is forecast to occur between 2007 and 2020. An important market could be the pharmaceutical industry. The application of bio-pharming based on farm animals is expected to happen

	before it becomes possible using plants. **Industry and Environment** **Bio-processing Technologies:** Micro-organism- and enzyme-catalyzed industrial processing is being transformed by emerging techniques such as metabolic engineering. These techniques manipulate microbial cells to bypass cell processes in larger organisms. **Renewable Bio-Plastics:** It is estimated that by 2010 10% of the global plastics market will be renewable and that sometime in the period 2020 to 2025 this will have expanded to 20% of the market. **Security and Defense** **Diagnostics:** National security needs are driving the development of live cell bio-sensing technologies and real-time lab-on-a-chip processing capabilities. This is particularly true in the United States. These technologies are anticipated to have spin-offs into civilian markets. **Antiviral Therapeutics:** The development of antiviral therapeutics is being driven by bio-defense requirements as well as the emergence of diseases such as SARS and the Avian Flu. Approaches include targeting 'commonalities' between different viruses and attempting to counter viral pathogens in a generic way.
The Polish Foresight Pilot - Health and Living 2013[369]	The eleven thematic areas were: • Primary and secondary prevention. • Diagnosis and treatment of disease. This concerned all diseases which occur on a large scale or which are capable of spreading quickly among members of the population. • Methods and technologies supporting intensive therapies. • Veterinary protection of public health. • Medical and psychological rehabilitation. • Bioinformatics and biomedical engineering. • New bio- and nanotechnologies in medicine and healthcare. • Conditions of the quality of life. • Food safety and health. • Food production and the environment as well as environmental protection. • New pharmacological methods and social pharmacy.

[369] This pilot Foresight project in the area of Health and Living, sponsored by the Ministry of Science and Information Society Technologies and carried out in 2004-2005, was aimed at speeding up the process of predicting development paths that would lead to improvement in the health and quality of life of Polish citizens. This activity provides a basis for determining the paths of science and technology policies that support economic priorities and for building broad consensus on complex social issues. The 'Health and Living' area was selected for analysis due to the widespread perception that the biological and medical sciences develop very fast nowadays and this pace of change poses new challenges for policy makers across a range of domains. [Source: M. Łepeta, The Polish Foresight Pilot - Health and Living 2013 (2005). EFMN Foresight Brief No. 38, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief38.pdf]

Main Findings of the Pilot

During the foresight process many issues were selected by experts as priorities. In order to choose the most important ones the Main Thematic Panel used the leads that emerged from the reports of the eleven panels and classified priorities into two different categories 'high priority areas' and 'priority areas'.

On the sub-theme of 'Fighting Diseases and Educating People' the selected **HIGH PRIORITY** areas were:

- Development of effective screening test systems
- Development of perinatal care, early detection of genetic and development defects
- Development of medical rescue methods and techniques

The **PRIORITY** areas were:

- Development of the methods and technologies for the needs of the **public pro-health education**.
- Construction of programmes for continuous development of **nutritional awareness** and rationalization of society's nutritional habits.
- Development of methods and techniques associated with prevention, diagnosis and treatment of **contagious diseases and infections** that are important from the public health's point of view.
- Development of methods and techniques of **ergonomic shaping** of the living and working conditions, with a special focus on the elderly and handicapped people.
- Development of methods and techniques associated with prevention, diagnosis and treatment of disorders related to **advanced age**.
- Research on **stress** and development of methods to reduce it.
- Development of research and technologies concerning **genetically modified organisms** and monitoring of their impact on the human beings and the ecosystem.
- Improving **food and eating habits** within the context of their significance to the protection of human and animal health, with a special focus on natural biologically active substances.
- Development of rehabilitation methods and techniques related to somatic and mental disorders which are of great public interest.

A Healthcare System in Pain

The aim of the introduction of the social consultations to the Pilot Foresight Project was to achieve three basic objectives, namely:

- To initiate a sense of cooperation and participation among the participants;
- To maximize the effectiveness and pertinence of the decision processes;
- To obtain the social acceptance of the decisions made during the project.

The results of the **social consultation** showed that the priorities recommended by experts were on some points different to those of representatives of the general public. The representatives of the public identified the most important challenges facing Polish society in the area of 'Health and Life-Science' as being:

- Poor organization of the healthcare system (a sentiment reflected by 29% of respondents).
- Insufficient funds spent on healthcare.
- Insufficient availability of diagnostic techniques
- High prices for medication.

	• Insufficient scope and extent of screening tests. **Framework Programme** The first step in using the findings of the foresight programme carried out in Poland is that some of the domains that were selected by experts as key areas have already been placed into the National Framework Programme. **Healthy Nutrition** This field covers issues related to the development of production and rules of evaluating healthy food which are based on nutrigenomics. The development of healthy food production methods should become one of the pillars of agricultural policy and one of the main efforts fostering health in Poland and in the European Union. **Veterinary Protection and Public Health** The priority direction should include: • The use of molecular and cellular biology to identify and analyze the risk of appearance of animal and animal derived diseases • To assess the quality of animal-derived fodder and food and • To develop alternative methods of evaluating medical products used in protecting animal health.

Social Sciences

Name of the Foresight initiative	Trends identified
Futur – The German Research Dialogue[370]	**Identification of Lead Visions**[371] **'Creating Open Access to Tomorrow's World of Learning'** is a lead vision hinting at a society where every individual is capable and willing to continue learning throughout life. It envisages a society where each member is guaranteed access to his/her individual worlds of learning, adaptable to personal needs, comprising institutional as well as human resources. Other aspects of this lead vision are questions of certification of education and qualification as well as the networking of locations offering education. **'Healthy and Vital throughout Life by Prevention'** is a lead vision that reflects the aging society in Germany – not only in order to save medical costs. The goal to stay healthy by preventive activities rather than mending health problems by conventional medicine is to be attained by means of health conscious behaviour by each individual. The focus is thus put on research and development to create the conditions for efficient prevention in the future. **'Quality of Life through Healthy Nutrition'** addresses the question how a balanced diet can increase human health. The topic has recently become a lead vision and touches issues such as sustainable supply chain of nutrition, transfer from nutrition science into every-day practice, and the role of the food sector in the innovation system.

[370] Futur - the German Research Dialogue, sponsored by the Federal Ministry of Education and Research and carried out in 2001-2005, was designed to assess the future needs and demands for science and technology and to consider their broader implications for the socio-economic and cultural development of the country. The intention was to include a large number and broad variety of participants in the exercise representing not only science and technology but also the various stakeholders of German society. So far about 1250 experts have been involved. [Source: S. Giesecke, Futur – The German Research Dialogue (2004). EFMN Foresight Brief No. 1, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief01.pdf]

[371] The Lead Visions have helped to identify a number of priorities for R&D policy makers in Germany. Some of these are being addressed on the basis of projects funded in existing or new funding programmes. The most prominent ones which are already being acted upon are as follows:

• Among the projects with regard to the lead vision *'Living in a Networked World'* the ministry initiated *'Verisoft'* to support the development of IT security standards. The project's goal is to achieve the uniform and formal verification of computer systems and to mathematically prove the correctness of the systems used. This research will be applied to the automotive industry, security technology as well as to the medical sector.

• Another project initiated was *'SmartWeb'* in order to develop software that helps the web to understand the content of entire sentences.

• In response to the lead vision *'Understanding Thought Processes'* the ministry set up a '*National Network on Computational Neuroscience'* consisting of local centres reinforced through the concentration and expansion of already existing capacities.

• An ongoing medical research programme took up the incentives given by *'Healthy and Vital throughout Life by Prevention'*. Accordingly prevention research projects will develop new concepts and instruments against the diseases of civilisation.

Swedish National Foresight - Teknisk Framsyn[372]	Sweden faces a number of driving forces that will be crucial to its long-term development and prosperity. In the field of Social Sciences and Humanities: **Individualization** is on the rise, while new groups are being formed and values are changing. New values based on strong individualization, combined with clear group affiliations are replacing old ones. Individualization, new groups and changing values open up new opportunities for new products and services and provide a strong potential for economic growth. Technology is **reshaping** society, and society is reshaping technology. In particular, developments in information technology (IT) and biotechnology will greatly change how people live. The digital revolution, with its new communications and information technology, has changed society and its way of living. The effects of the new biology will probably be equally great over time. There will be a greater need for human resources capable of adopting and adapting new technology in the economy and society in general. **Strategic Choices:** - Sweden must see the opportunities of an enlarged world, not just the threats. To take advantage of the opportunities of globalization, Sweden must establish clear specializations. Sweden must build alliances with emerging markets, **internationalize its educational system** and actively pursue those issues that it believes to be the most important in the global arena. - Sweden must become better at utilizing, evaluating and allowing room for the skills, creativity and commitment of every individual. Sweden must **create optimism and a broad sense of participation of individuals in society. There must be clear leadership and opportunities for work, developing sound and healthy work organizations, taking advantage of diversity,** ensuring the efficient exercise of government authority and creating a system of transfer payments and taxation that encourages studies and work. Sweden has to encourage innovative, knowledge-intensive operations, entrepreneurship, risk-taking and investments. Such activities must be allowed to be profitable for those who are prepared to engage in them.
FISTERA - Foresight on Information Society Technologies in the European Research Area 2020[373]	**Education and Learning as a Top-priority** Within the different scenarios, eight different application areas were elaborated upon in terms of their future development and resulting requirements with respect to IST: · Social and family relationships; · Leisure and recreation;

[372] Teknisk Framsyn's second foresight study, carried out 2003-2004, aimed to identify the preconditions for sustained technological progress and economic growth for Sweden over a 15-20 year period to 2025. With its intention of inspiring the coming generation of decision-makers who will shape Sweden's future, the project was directed at the private sector as well as government, public sector policies and organizations. [Source: S. Mahroum and C. Blackman, Swedish Technology Foresight 2004 (2004). EFMN Foresight Brief No. 2, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief02.pdf]

[373] FISTERA is a thematic network aiming to understand the key factors driving IST in a future Europe and to elaborate options on how to strengthen Europe's position in key IST areas. As such it serves as an input to the debates on strategies to reach the Lisbon objectives and on preparations for the IST Programme in FP 7. FISTERA has been launched in time to deliver thought provoking results that should feed the debates about the Lisbon strategy, the future of IST research in Europe in general and the preparations for FP 7 in particular. [Source: M. Weber, FISTERA - Foresight on Information Society Technologies in the European Research Area 2020 (2004). EFMN Foresight Brief No. 9, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief09.pdf]

	· Ageing population; · Health; · Cultural diversity; · Transport and mobility; · Learning and education; · Social welfare and public services; · Government. The scenario-building activity was complemented by a European online-Delphi process. Among other findings, it underlined the outstanding importance of **Education and Learning as top priority area driving the future of IST from the application side, well ahead of Government, Social Welfare and Public Services, and Cultural Diversity.**
Greek National Technology Foresight 2021[374]	• **Brain drain** – the loss of high qualified human capital due to the inability of the system to absorbing high level human resources such as scientists and researchers that could make a difference in their fields is a challenge that Greece has faced for years. Not much has been done in order to tackle this issue apart from small scale initiatives aimed at the repatriation of young scientists. • Many countries of the European Union face the issue of **population ageing.** The issue is even more pressing where small countries like Greece are concerned. As a consequence there is a **risk of disruption to work-life balance and worsening quality of life, whereas health and welfare issues related to changes in work-life balance, the need for better health care and the need for better quality of care sector are becoming more important.** • The **quality of human capital** is also an issue. **Employment and the promotion of training to increase employability and better address emerging market needs is an issue. There is a need to set new objectives in educational and training policies and identify emerging market needs.** • Due to regional disparities and changing patterns of the population issues of **social cohesion and exclusion** in terms of **economic immigration, regional disparities, geographical seclusion, etc** are considered as very important and they affect significantly the course towards a knowledge based economy/ society, as knowledge should be shared between the people. • **Quality of social capital** is an issue of great interest in the sense that the promotion of collaboration with non profit and non governmental organisations and the development of synergies with social partners is important for the application of R&D and innovation. **Policy measures proposed:** • **Education:** It is necessary to **increase investments in education**. The quality of the educational system needs to be improved. **Reforms of the educational system should focus on providing more freedom and autonomy to Universities while all educational institutes should be assessed regularly.** Furthermore **linkages should be created between education and training**, between educational qualifications and skills and

[374] The National Foresight Programme in Greece carried out in 2001-2003 mainly focused on exploring the future of the Greek economy and society and the potential role of science, research and technology in shaping the future in terms of the development of a knowledge society. [Source: T. Damvakeraki, Greek National Technology Foresight 2021(2004). EFMN Foresight Brief No. 12, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief12.pdf]

	market needs. Finally, it is **necessary support life-long-learning and vocational training in order to enhance and improve the skills of the work-force.** • **Social Capital** should be enhanced through upgrading governance and Public Administration, eliminating bureaucracy and corruption from the economy and society and decreasing the intermediate phases for the provision of public goods through an efficient assessment of public servants and by providing incentives connected to performance.
Operation FutuRIS – France 2020[375]	**Key Political Issues** This foresight exercise underlines new approaches to organisation, finance, marketing, logistics, software development, research and training. In this context according to the expert group, horizontal economic and social policies should ideally include: • **Actions offering compensation for the underprivileged**, while avoiding the maintenance of obsolete structures, • **Employment policies aimed at reducing unemployment by increasing labour market flexibility,** • **Life-long education and training policies that foster initiative-taking and that increase the adaptability of the workforce.**
AGORA 2020 – Transport, Housing, Urbanism and Risk[376]	**Cities and Territorial Planning Issues** Questions arising here fall under the following main headings: • **Demographic Change and its Consequences:** The living conditions of elderly persons, their needs in terms of specific housing and access to medical infrastructure, as well as the risk of geographic segregation between 'young areas' and 'old areas'. • **Social Exclusion and Precariousness:** This includes issues related to care for the homeless, those living in ghettos and related risk to the community. • **Sustainable Land-Planning and Urban Development:** How to limit or manage the extension of peri-urban areas? • **Multileveled Governance:** How to develop a country in a homogeneous fashion coping with territorial competition and heliotropism?
Futur Radar 2030[377]	**Demographic change implies several major challenges:**

[375] Operation FutuRIS is the result of an initiative launched by the French Association for Technical Research (ANRT) to bring together leading players of the public and private sectors with the aim of laying the foundations for the future of the French Research and Innovation System. FutuRIS is a systemic foresight exercise that uses a number of exploratory scenarios to simulate potential changes from which key issues can then be identified. [Source: I. Chatrie, J. Rachidy, Operation FutuRIS – France 2020 (2005). EFMN Foresight Brief No. 24, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief24.pdf]

[376] Agora 2020 is a foresight exercise on the demand of research on transport, mobility, housing, construction, urbanism and risks, launched in spring 2003 by the French DRAST - Directorate of Research and Scientific and Technical Affairs of the Ministry of Infrastructure, a scientific agency linked to the department of transport, housing and building. The project's aim is to build up a clear vision of middle and long term issues in the field of transport, housing, town planning to establish priorities and incentives for the next research programs in France. [Source: I. Chatrie and J. Rachidy, AGORA 2020 – Transport, Housing, Urbanism and Risk (2005. EFMN Foresight Brief No. 27, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief27.pdf]

[377] The population structure of the German federal state of Rhineland-Pfalz (The Rhineland-Palatinate) in South-West Germany will change considerably in the coming decades. This will have impact on every sphere of private and public life. Taking account of projections for population growth in the region Futur Radar 2030 (Zukunftsradar 2030) took a

	• Constant low birth rates lead to a decreasing number of young people in society. This leads not only to a declining population but in the long-run to a **shortage of young specialists** mainly in technical professions. Generally this has **implications for the educational system as well as on family policy.** • The lack of junior employees will lead to a **rise in the average age of the work force**. Companies have to deal with **senior personnel**. This causes a fear of a declining capacity for innovation in enterprise. • **As the estimated life expectancy rises the number of elderly people in society increases**. This has consequences for the welfare system. In particular it has consequences for the **pension system**. More and more senior citizens rely on the contributions of fewer employees and **previous 'inter-generational contracts' loose their validity.** • The changing proportion of old and young people in society harbours **potential for social conflict. It is possible that younger generations will not feel adequately represented in the political realm, whereas a growing number of senior citizens may feel rejected by a youth-centred consumer strategy in advertisement and production.** • Demographic change will differ from region to region. While the urban centres and their greater surroundings will keep on growing in the upcoming decades, **rural areas with a poor infrastructure** will face serious loss of population. This could lead to challenges in ensuring adequate supplies of goods and services in these regions. • **Fewer taxpayers** in regions with declining working populations will put **pressure on communal budgets and the maintenance of cultural, recreational infrastructure and other services will challenge local authorities.** • **Migration** is an important demographic factor. Although it cannot reverse changes in population structure, it may help to slow down such trends. **When migration is used as an instrument for managing population change, strategies for integration would need to be improved.** **Chances and Opportunities** Demographic changes present not only challenges but opportunities too. Some of these opportunities are: • New markets for **specialised products and services** aimed at seniors are opened up by the increasing number of elderly people in society. • The quality of **educational systems** could benefit from the lower number of schoolchildren. • **Communal administrations** could benefit from technological progress and increase their efficiency. • Due to the shortage of a young work force, personnel managers will have to develop new strategies to conserve the operating experience of their **senior employees**. **Maintaining a workforce of senior employees** An important task for the future is to keep up the productivity of the economy with fewer and older employees. **The conservation and use of the**

closer look at these developments and the impact they could have on citizens in the region. The Foresight exercise was carried out in 2002-2005. The goal was to sensitize the public and decision-makers to this and emerging related issue and to make proposals for various actors as to how they might handle the expected change. [Source: H. Kolz, C. M. Hadnagy, Futur Radar 2030 (2005). EFMN Foresight Brief No. 29, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief29.pdf]

accumulated know-how of the workforce, especially of elder workers is one of the major challenges for companies. Trainee and mentoring programs could be initiated so as to pass on hard-earned knowledge to the next generation of employees.

Family-friendliness will be one of the key issues for the future. **The number of female specialists and executives in higher positions must be increased. Work-life-balance must therefore be improved.** Politics and the economy must find appropriate actions leading to **better compatibility between family-life and work.** They need to provide a framework in which women will find the same working conditions as men, in which **flexible employment is encouraged**, and in which the productivity of elder employees will be preserved by means of workplace design and improved personnel planning.

The whole world of employment will face major challenges due to demographic change, globalisation and technological progress. It is thereby inevitable that the whole economy of Rheinland-Pfalz should embark on a strategy of technical advance and productivity improvement in order to turn the country into a high-tech centre. This will require reasonable steps in many fields of action:

- **The education system must be adapted to the new requirements. The promotion of specific skills and talents of the individual should drive the educational agenda.**
- Local business development and regional policy should put their focus on creating high tech jobs. At the same time **professional training should be organised to provide appropriate qualifications.**
- The working people of the region must realise that they are to a great extent **self-dependent in their career planning**. Individual initiative is needed for success. On the other hand employers will need to offer employees further **training programs on a regular basis.**
- **Payment should be based at least to some extent on individual skills and personal performance. As criteria for remuneration, age and seniority should play a subordinate role.**

Cooperation among the Generations

Mutual respect for the needs of each generation is the key for a harmonious and healthy community. **Above all the family as an institution needs to be encouraged and supported.** The position of the family in society needs to be strengthened through children in our community must be improved through measures taken by decision-makers in politics, economy, society, and culture. This includes **improvement in child care facilities and the promotion of better work-life-balance.** The general framework must be constructed by the federal state and the economy, but local decision-makers have to design it according to the needs of the region.

Senior citizens on the other hand have to be enabled to choose their individual life-style according to their abilities and interests.

The preservation of mental and physical ability should be supported through access to dedicated services. **The elderly will become more active and the availability of special age-based spare-time activities should be extended and improved.**

Local authorities have to consider the needs of all generations into their planning. **The citizens on their part contribute to communal life by volunteerism. Well directed projects might contribute to a better balance between the generations. New public and private buildings should facilitate and create opportunities for inter-generational contact. The main intention is to improve relations between the generations. Therefore, modular, flexible and obstacle free methods of construction are required.**

Third Korean Foresight exercise[378]	**Societal Issues** **The Aging Population** The current Foresight exercise has assessed various aspects of global challenges that the country will face inevitably and will have to deal with in the future. For example, the rapid process of **demographic transition** in Korea has brought about an increase of both the absolute number and the proportion of the elderly in recent years. The proportion of people aged 65 stood at only 3.3 percent in 1966. However it increased to 9.1 percent in 2005 and is projected to increase to 24.3 percent in 2030. The aging speed of the Korean population is apparently faster than that of developed countries. Korea, which has already experienced large declines in fertility and mortality, has a tremendous momentum for further population aging. In 2005, the fertility rate is about 1.2. If this situation persists, it would eventually cause a decline in the population size (overall and of working age) presenting various socioeconomic challenges to pension and healthcare services, in particular.
The Polish Foresight Pilot - Health and Living 2013[379]	The **PRIORITY** areas were: • Development of methods and techniques of **ergonomic shaping** of the living and working conditions, with a special focus on the elderly and handicapped people. • Development of methods and techniques associated with prevention, diagnosis and treatment of disorders related to **advanced age**. • Research on **stress** and development of methods to reduce it.
Youth Foresight Germany 2020[380]	The Mega-Trends covered in the framework of Youth Foresight Germany are: • **Lifelong learning** • **Demographic change and the aging society** • Resource conflict and excessive use of ecological systems • Life in the networked world: o The use of Information and Communication Technologies, o The Knowledge Company, o The Information Society and o Globalization • New technologies, miniaturization and nanotechnologies

[378] The Third Korean Foresight Exercise entitled 'Future Perspectives and Technology Foresight for Korea – Identifying Challenges and Opportunities for Korea's Economy and Society' carried out 2003-2004 represents the most comprehensive effort to date by the Korean government in the field of S&T foresight. [Source: B. Park, Korea 2030 (2005). EFMN Foresight Brief No. 36, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief36.pdf]

[379] This pilot Foresight project in the area of Health and Living, sponsored by the Ministry of Science and Information Society Technologies and carried out in 2004-2005, was aimed at speeding up the process of predicting development paths that would lead to improvement in the health and quality of life of Polish citizens. This activity provides a basis for determining the paths of science and technology policies that support economic priorities and for building broad consensus on complex social issues. The 'Health and Living' area was selected for analysis due to the widespread perception that the biological and medical sciences develop very fast nowadays and this pace of change poses new challenges for policy makers across a range of domains. [Source: M. Łepeta, The Polish Foresight Pilot - Health and Living 2013 (2005). EFMN Foresight Brief No. 38, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief38.pdf]

	• **Migration,** Mobility, Urbanisation, **diversity in value systems** • Climatic change • Humans and economics • New epidemics • **Individualisation and self-responsibility.**
Canada Looking Forward S+T 21C[381]	• **Changes in Cultural Identity:** By 2025 it is expected that roughly 22% of the Canadian population will be aged 65 and over. By then Canada's population is expected to be around 35 million with visible minorities accounting for 19% to 23% of the total. Between 6.3 and 8.5 million citizens will reflect cultures, values and religions that are quite different from those upon which the country was founded. Demographic change will have economic and social impact in terms of a smaller workforce, lower productivity, pension payment liability, changing consumer expectations and increased demands on natural resources. • **Worldwide Decline of the Nation State:** Although democracy is on the rise there is also a growing number of failed nation-states. The nation-state is seen to be losing ground to trade and religious groupings as the primary source of identity and Canada's place in the world will decline. • **Loss of Leadership by Western Society:** In the 20th century it was widely assumed that the future would be owned and defined by western industrial cultures, technologies, economies and world views. Shifts in the way we think about the world contribute to a loss of confidence in institutions and leadership in western society. • **Demand for Greater Security:** Rapidly increasing global interdependence brings new threats and vulnerabilities. The ability of the state to deal with the privatization of conflict weakens. To some extent 'security' drives how we perceive the world and how we react within it.
Quebec S+T Development Based on Social Needs[382]	People are most concerned with **individual well-being**. The strongest predictions that we recorded concerning future deterioration involve the quality of family life, individual physical and psychological health, as well as the quality of the environment.

[380] 'Jugend denkt Zukunft' was setup to make this vision come true and translated directly into English it means 'young people are thinking about their future'. This single issue foresight exercise is designed to involve young adults in the process of economic development. Together with companies, students between the age of 15 and 18 develop new products and services for the world of tomorrow. The main pillar of this program is the nature of co-operation between companies and schools. Further support comes from politics and science. Together they are strong partners for re-creating a culture of innovation. [Source: A. Pechmann, Youth Foresight Germany 2020 (2006). EFMN Foresight Brief No. 43, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief43.pdf]

[381] The NRC or National Research Council of Canada undertook this foresight exercise with a time horizon of 2020 to initiate planning for its strategic and organizational renewal. The exercise provided a global perspective and critical insights on the future and impact of S+T in Canada, and on opportunities for the NRC to address national challenges as part of Canadian National System of Innovation. [Source: D. A. Isabelle, Canada Looking Forward S+T 21C (2006). EFMN Foresight Brief No. 46, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief46.pdf]

[382] The STS Perspectives project is a foresight study examining Science-Technology-Society issues, designed to mobilize Quebec's scientific and technological resources in order to address important socio-economic challenges that Quebec society will face over the course of the next 15 to 20 years. This project started in 2003 and is still ongoing. [Source: A. Bergeron,

	Above and beyond these important realities the Quebecois believe that Quebec society will become **increasingly multicultural** in nature, that the French language will decline and that at the same time the province will find itself ncreasingly in the grip of American culture. **Challenges identified**: • **Health and Life-Style:** The public health-care system, quality of life of senior citizens, nutrition, well-being, sports and leisure. • **Education**: Learning languages, teaching science, school drop-out and teaching in underprivileged environments. --> Provide **high-quality education** that combines rigour, creativity, flexibility and responsible citizenship, and that is accessible to all. • **Demographics and Communities**: The increasing the birth rate, immigration, and issues related to specific groups such as the First Nation people and the Inuit. • **Culture and Society**: Public participation in the democratic process, making science accessible to society, ethical considerations, reconciliation of work with family life, poverty and culture. --> Adopt **innovative interventions for controlling poverty** and the factors that generate and maintain it, so as to stave off the consequences of poverty such as marginalisation and a sense of powerlessness as well as inequity and violence.
Greece's Path to the European Knowledge Society[383]	**The Main Challenges to be Faced** **Education not Meeting Market Needs:** Education systems gradually change with the introduction of new technologies, especially information technologies. The biggest problem faced by the educational system in the development of a knowledge society is the lack of long-term planning and the lack of coordination with market needs. This was highlighted in the latest policy documents in Greece along with a need to promote life-long learning and vocational training. That part of the Greek workforce that has received tertiary education (25-64) in Greece is close to the EU average as is the pupil/teacher ratio especially in primary and secondary education. **Skills and Employment Suffer from Digital Divide:** A high level of unemployment coupled with the limited flexibility and adaptability of the labour market, as well as limited provision of and participation in vocational and self-training activities are areas that need attention. The same

G. Drolet, Quebec S+T Development Based on Social Needs (2006). EFMN Foresight Brief No. 47, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief47.pdf]

[383] In the context of its four-year work programme, *Analysing and Anticipating Change to Support Socio-Economic Progress 2001-2004*, the European Foundation for the Improvement of Living and Working Conditions launched EUFORIA - a project on 'European Knowledge Society Foresights (KS foresights) for living conditions, working conditions and industrial relations'. The purpose was to understand the 'drivers' of the Knowledge Society and to anticipate their potential impact on living and working conditions and industrial relations. The underlying aim was 'to identify and support paths to positive transformation while avoiding unsatisfactory development paths'. Especially in the case of Greece the development of a knowledge society is considered a major challenge due to the country's lagging behind in terms of technological development and the knowledge society indices. [Source: T. Damvakeraki, E. Amanatidou, Greece's Path to the European Knowledge Society (2006). EFMN Foresight Brief No. 57, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief57.pdf]

	applies for the 'digital divide' issue as well as for income inequality, low birth rates, ageing of the population and the increasing number of immigrants that are not fully integrated in the Greek society. **Socio-Economic Trends for Greece** Some of the most important **socio-economic and technological trends** identified for Greece are as follows: • **Education**: The Greek system is not built around the 'idea' of lifelong learning or knowledge management and creativity. This results in the production of 'less competitive' graduates than other countries. The development of private non-profit bodies for the provision of higher education could increase competition, improve the quality of the education in public universities and orient them towards the fulfilment of market needs in terms of specializations and skills. • **The Ageing Population and Retirement**: The ageing of the population is linked to the ability of the public health system to cope with increasing demand for health care and medical treatment. A constantly increasing retirement age in combination with possibilities for part-time occupation will result in the appearance of **new forms of work after the age of 60 or 65 - part time occupation in the same field, as well as 'alternative' or 'social-voluntary' occupation**. Some people may continue working. **This life-long working will be supported by lifelong training.** Others may be excluded from work after the age of 50 for a variety of social reasons. This may result into the appearance of new categories of employees, unable to be insured or retired. • **Peripheral Disparities:** Peripheral disparities in Greece hinder balanced development of the Knowledge Society. Large urban areas will develop faster because of their better infrastructure and access to human resources. The rural, mountainous, frontier and island areas will lag in their development. The unbalanced 'territorial' distribution of people of different ages and incomes will lead to unbalanced development of the Knowledge Society in Greece. **Alternative forms of tourism in some rural and mountainous areas could lead to the development of poles of attraction not just for tourists but for tele-workers, boosting quality of life in these areas.** • **Quality of Life:** Changes in the type of work and working conditions related to the Knowledge Society will cause changes in the personal life-styles and family structures. Our society has become a 'show-off' society in the sense that what is not promoted has no value. Mass media contributes to this by creating consumer models based on 'fictional' needs. This may hinder the development of the knowledge society.
The Household Horizon 2012[384]	**Social Networking** Like information work social networking will also be altered through the emergence of focal points, social objects, and persistent worlds. I&C

[384] Based on in-depth research on selected domains the Institute for the Future predicts major changes in household behaviour. These changes will, for example, materialize in new ways how we will adequately manage: information work, social networking, mobile life, and identity creation. The change of these and other daily routines and practices of a household will trigger innovations in products and services thus creating new markets and opportunities for companies. The report The Household Horizon: A Guide to Technology and Daily Life in 2012 presents major findings of the study and introduces a framework for analyzing technological shifts and their impact on household behaviour. [Source: W. Reuter, The Household Horizon 2012 (2006). EFMN Foresight Brief No. 58 European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief58.pdf]

	technologies already have affected the structure of social networking. Due to cell phones, e-mails etc. our social networks have become geographically expanded as well as socially and culturally more diverse. Sensors, wireless communication and mobile computing will add new dimensions to social networking. The report predicts that we will, first, move toward swarming, i.e. a practice by which a social network is created and maintained for a specific purpose (e.g. congregating a consumer group to profit from a discount). Second, the existence of social objects will lead to partnerships with machines. As we will be able to interact with machines we can offload work to them and let them make decisions for clearly defined tasks. Third, so far social networking is based on episodic contacts and intercourse. However, persistent worlds are based on continuity and permanence. Messages that go on for an indeterminate period of time can create a sense of presence, of "being" at a place, that one has left already. This sense of presence may be created and sustained by sounds, images or even scents that will be part of communication. Behaviourally the members of a household have to learn how to manage this new type of social networking. They also have to determine the degrees as to which they want to have machines make decisions - e.g. under which circumstances the vacuum cleaner turn itself on or off. At the same time they have to make sure that the possibility of continuous presence will not lead to social overexposure. Privacy and intimacy have to remain possible and guaranteed. **Creation of Identity** **Technologies can affect the creation of identity in two ways:** On the one hand, technologies very often are to symbolize **a specific status or attitude**. A certain technology might be used to set you apart from others. On the other hand, technologies are **means for expression**; they are media that enable us to represent our selves. As far as identity creation is concerned we rely **on context switching**, i.e. we switch our identity as soon as we enter a new social context. We switch from one role to another (e.g. from business man to friend to family member etc.). **The report forecasts that social networks will become far more complex and differentiated. Under those circumstances, switching social networks and our identities might create stress.** Yet, focal points conveying messages adapted to the environment can reduce the stress provoked by switching contexts because the context reacts to your needs and desires. Furthermore, you might use **social objects as conveyer of your identity**. This kind of "digital tattooing", as it is called in the report, allows you to **put aspects of your identity into the physical world** or to create a "chameleon body" - like cosmetics that adjust to temperature or light. Finally, the idea of being part of a persistent world will allow **you to remain present in a surrounding even if you are physically gone**. For example, you might implant your voice into your children's most favourite bedtime book, and each time your child opens the book it hears your voice.
South African Benchmark 2020[385]	**Cultural Sector** The study regards the cultural sector, especially the crafts and tourism industries as a springboard for development with the potential to create jobs and develop less favoured regions. The most important challenges consist in enabling communication technologies, technologies, which improve the product and technologies that provide marketing to the end-consumer. The following technologies with potential high impact on the Cultural Sector were identified:

[385] The overall goal of the South African Benchmark 2020 was the identification of global technological trends, which will influence the competitiveness and future development of South African industries over the next 15 years, focussing on innovation areas that hold the potential to reduce industrial dependency on foreign technology. [Source: S. Rijkers-Defrasne, South African Benchmark 2020 (2006). EFMN Foresight Brief No. 63, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief63.pdf]

	• Product Technologies, • Internet, • Online Marketing, • Mobile Technologies, • Wireless Technologies, • Advanced Materials, • Human Language Technologies (HLT), • E-Commerce, • Environmental Technologies, • E-Commerce, • Portals.
Technology Foresight Slovenia 2020[386]	Education and **livelong learning** has been perceived as an important element of the national development strategy. The research fields selected focus on better learning organization, establishment of networks for adult education, and the partnership between public and private educational systems. In an ageing society **care for the elderly** people is of most importance. The research fields point out different prevention methods, early diagnostics and organization of specialized expert systems.
Aufbruch Musik - German Music 2020[387]	General trends which apply to the German society and its economy like an aging society or an internationalization of top performer in the labour market have effects on the German music sector as well. Therefore, it is no surprise that the trends in the music sector are not radically new, in a general sense,

[386] The technology foresight study sponsored by the Ministry for Science and Technology, was conducted as part of the process of preparation for the mid term national R&D Programme 2006-2010 in Slovenia. This was the first national foresight exercise. It had several objectives: to promote the continuous forward thinking practice in society, to foster dialogue among main stakeholders in the innovation process, and to set preliminary R&D priorities for the future research and technology policy. [Source: P. Stanovnik and M. Kos, Technology Foresight Slovenia 2020 (2006). EFMN Foresight Brief No. 71, European Foresight Monitoring Network, http://www.efmn.info/kb/efmn-brief71.pdf]

[387] The music sector in Germany is going through major changes. Global technological and societal trends combined with major cuts in public spending for the cultural sector need to be faced. Right now these upcoming changes seem to be met by agitated melancholia instead of orchestrating these changes to a desired state of the future where music is established as an energy source for societal and personal development. The time to refer to the glorious German music transition rectifying public spending for 'high quality' music seems to be coming to an end. The border between different music lines has become more and more blurred. The German Music foresight project carried out in 2005-2006 was initiated by nine individual actors from different areas of the music sector. Though these individuals are of different disciplines and work in different areas and on different levels, they share, next to their love of music, at least one other thing: The opinion that the German music sector needs to start acting soon if it wants to be able to orchestrate the upcoming changes. [Source: A. Pechmann, Aufbruch Musik - German Music 2020 (2006). EFMN Foresight Brief No. 81, European Foresight Monitoring Network, http://www.efmn.eu/kb/efmn-brief81.pdf]

	but they will have revolutionary impact on some fields of the music sector. Some clear trends out of the following 13 categories have been detected: • Globalisation – Migration, • Education – Training • Financing • Quality and reception of music • Music business and business strategies • Working environment and job outline • Lay music • Associations • Media • Technology • Health • Orchestra – events – opera • Cultural policy. The demographic development will have a major effect on the municipal youth music schools who right now lean toward the age group of 3 to 21 year olds. The focus in the music schools lays on a solid education playing a musical instrument (including voice) and preparing to play classical, serious music. The decline in the absolute number of children and teenager will force the music schools to open up to other age groups, other groups of society and to new areas. This development is supported by the cut in financial support from the municipal government. Due to different reasons, it is seen as very unlikely that a major group of young people can be attracted to serious music. The financial support of traditional music institutions like opera, concert houses and music organisations through public spending will decline. Institutions not being able to cope with this situation will need to close. The number of music institutions will drop. The job market for the musician will change even more towards a market where permanent employment is the exception and either contracts for single events or for a season will be the rule. The music-programming of the German radio and television broadcasting under public law will not exclusively be designed under quality aspects. It is expected that on a German, European and world-wide scale intellectual property in the music area will not be rewarded in an appropriate way.

A5 Participants List

Interviews (January-February 2006)

Name	First Name	Institution
Kanz	Robert	CRP Santé
Wagner	Fernand	CRP Santé
Friederich	Evelyne	CRP Santé
Malvetti	Massimo	Université du Luxembourg
Schaeffers	Jos	CRP Henri Tudor
Feyder	Gusty	DuPont Teijin Films Luxembourg S.A.
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Soisson	Nicolas	Fedil
Hennicot-Schoepges	Erna	Membre du Parlement Européen
Bausch	Raymond	Fonds National de la Recherche
Hoffmann	Gérard	Telindus
Phillipe	Arthur	Commission de Surveillance du Secteur Financier
Kieffer	Monique	Bibliothèque nationale de Luxembourg
Backes	Marianne	Centre virtuel de la connaissance sur l'Europe
Wolter	Thierry	Ceratizit
Schneider	François	Laboratoire National de Santé
Weidenhaupt	André	Administration de la Gestion de l'Eau
Lickes	Jean-Paul	Administration de la Gestion de l'Eau
Ries	Jean-Marie	Administration de la Gestion de l'Eau
Wehenkel	Claude	CRP Henri Tudor
De la Hamette	Jean	CRP Henri Tudor
Reinig	Fernand	CRP Gabriel Lippmann
Van Merlen	Hubert Jacobs	CRP Gabriel Lippmann
Harms	Jochen	Luxspace
Schmidt	Jean-Claude	CRP Santé
Charbonnier	Jean-Claude	Arcelor ProfilArbed
Hoffmann	Jacques	Arcelor ProfilArbed
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Modert	Octavie	Secrétaire d'état à la Culture, de l'Enseignement supérieur et de la Recherche
Dubois	Eric	CRP Henri Tudor
Michel	Jean-Pol	CRP Henri Tudor
Erasmy	Jean-Jacques	Administration des Eaux et Forêts
Schley	Laurent	Administration des Eaux et Forêts
Wolff	Frank	Administration des Eaux et Forêts
Schlesser	Gilles	Luxinnovation
Cresswell	Ian	Luxinnovation
Walentiny	Marco	Luxinnovation
Hartmann	Roger	UBS
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Elsen	Yves	Hitec Luxembourg S.A.
Schoos	Aloyse	IEE
Gramegna	Pierre	Chambre de Commerce
Burkel	Jean-Christophe	Chambre de Commerce
Emering	Paul	Chambre de Commerce
Rommes	Jean-Jacques	ABBL
Kuhn	Marc	Circuit Foil Luxembourg Trading Sarl
Migeon	Henri-Noël	CRP Gabriel Lippmann

Lonardi	Emile	Paul Wurth SA
Wagner	Jean-Frank	President of the Scientific Council of the FNR / Universität Trier
Henrion	Romain	President of the Board of Administration of the FNR / Arcelor
Turmes	Claude	Membre du Parlement Européen
Hoffmann	Lucien	CRP Gabriel Lippmann
Plumer	Pierre	CRP Henri Tudor
Papin	John	Delphi
Bethscheider	Gerhard	SES ASTRA
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Otjacques	Benoît	CRP Gabriel Lippmann
Fayot	Ben	Député (LSAP)
Decker	Pierre	Ministère de la Culture, de l'Enseignement supérieur et de la Recherche
Kerger	Lucien	Université du Luxembourg
Max	Charles	Université du Luxembourg
Martin	Romain	Université du Luxembourg
Thiel	Lucien	Député (CSV)
Schaber	Gaston	CEPS/INSTEAD
Hausman	Pierre	CEPS/INSTEAD
Probst	Laurent	PricewaterhouseCoopers
Bergh	Jean	Goodyear S.A.
Bechet	Georges	Musée national d'histoire naturelle
Huss	Jean	Député (DEI GRENG)
Welfring	Joëlle	CRP Henri Tudor
Schosseler	Paul	CRP Henri Tudor
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Tarrach	Rolf	Université du Luxembourg
Ehmke	Adelheid	Université du Luxembourg
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Colling	François	Cour des comptes européenne
Muller	Claude	Laboratoire National de Santé
Ackermann	Charles-Louis	Accumalux
Nilles	Délia	University of Lausanne
Even	Jos	Laboratoire National de Santé
Gengler	Marc	Ecole supérieurs d'ingénieurs de Luminy/Marseille
Wiltzius	Pierre	Beckmann Institute, University of Illinois
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Young Researchers Workshop (7 and 8 March 2006)

Information and Communication Technologies		
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LAMBERT	Cécile	CRP Gabriel Lippmann

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Biomedical Sciences		
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DELHALLE	Sylvie	CRP Santé
DEROO	Sabrina	CRP Santé
ERNENS	Isabelle	CRP Santé
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GROVA HELD	Nathalie	Laboratoire National de la Santé
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Environmental Sciences		
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SOHN	Christophe	CEPS/INSTEAD
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VAN KERM	Philippe	CEPS/INSTEAD
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Exploratory Workshop (19 May 2006)

Information and Communication Technologies		
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Gengler	Marc	Ecole Supérieur d'Ingénieurs de Lumigny
Gillé	Serge	CRP Henri Tudor
Guelfi	Nicolas	Université du Luxembourg
Hagen	David	Clussil
Harpes	Carlo	Telindus
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Leprévost	Franck	Université du Luxembourg
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Schilling	Pierre	Service eLuxembourg
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Terzis	Jorge	CHL
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Behrmann	Iris	Université du Luxembourg
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Environmental Sciences		
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Delfosse	Philippe	CRP Gabriel Lippmann
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Ferring	Marc	Luxinnovation
Francis	Olivier	ECGS
Hoffmann	Lucien	CRP Gabriel Lippmann
Jung	Patrick	Agence de l'énergie de l'Etat
Kies	Antoine	Université du Luxembourg
Lamesch	Jean	Arcelor
Lickes	Jean-Paul	Administration de la Gestion de l'Eau
Pfister	Laurent	CRP Gabriel Lippmann
Pihan	Jean-Claude	Université de Metz
Plattes	Mario	CRP Henri Tudor
Schley	Laurent	Administration des Eaux et Forêts
Schmit	Frank	Service d'Economie Rurale
Schosseler	Paul	CRP Henri Tudor
Steinmetz	André	CRP Santé
Van Dam	Tonie	ECGS
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Welfring	Joëlle	CRP Henri Tudor
Wolff	Frank	Ministère de l'Environnement

Physical Sciences and Engineering		
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Baller	Jörg	Université du Luxembourg
Becker	Claude	CRP Henri Tudor
Belouettar	Salim	CRP Henri Tudor
Bergh	Jean	GoodYear S.A.
Cresswell	Ian	Luxinnovation
de la Hamette	Jean	CRP Henri Tudor
Duday	David	CRP Gabriel Lippmann
Feyder	Gusty	DuPont Teijin Films Luxembourg S.A.
Girot	Thierry	CRP Gabriel Lippmann
Henrion	Romain	Arcelor
Kerger	Robert	Ministère de la Culture, de l'Enseignement supérieur et de la Recherche
Krüger	Jan K.	Universität des Saarlandes
Kuhn	Marc	Circuit Foil
Papin	John	Delphi
Rauchs	Gaston	CRP Henri Tudor

Rech	Christian	Ciments Luxembourgeois
Sanctuary	Roland	Université du Luxembourg
Schaeffers	Jos	CRP Henri Tudor
Schoos	Aloyse	IEE S.A.

Social Sciences and Humanities		
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Berger	Frédéric	CEPS/INSTEAD
Bernacconi	Jean-Charles	CRP Henri Tudor
Blazi	Régis	Université du Luxembourg
Bourgain	Arnaud	Université du Luxembourg
Burkel	Jean-Christophe	Chambre de Commerce
Dautfl	Vincent	CEPS/INSTEAD
DiMaria	Charles-Henri	CRP Henri Tudor
Ferring	Dieter	Université du Luxembourg
Gerber	Philippe	CEPS/INSTEAD
Guigou	Jean-Daniel	Université du Luxembourg
Haensel	Jean-Marie	Inspection générale des finances
Hausman	Pierre	CEPS/INSTEAD
Hofmann	Herwig	Université du Luxembourg
Kerger	Lucien	Université du Luxembourg
Kieffer	Monique	Bibliothèque nationale de Luxembourg
Leboutte	René	Université du Luxembourg
Lehners	Jean-Paul	Université du Luxembourg
Margue	Michel	Université du Luxembourg
Marson	Pierre	Centre National de Littérature
Martin	Romain	Université du Luxembourg
Max	Charles	Université du Luxembourg
Molz	Markus	Université du Luxembourg
Moulin	Claudine	Université du Luxembourg
Munoz	Susana	Centre virtuel de la connaissance sur l'Europe
Portante	Dominique	Université du Luxembourg
Probst	Laurent	PriceWaterhouseCoopers
Rousseau	Anne	CRP Henri Tudor
Schlesser	Gilles	Luxinnovation
Van Kerm	Philippe	CEPS/INSTEAD
Willems	Helmut	Université du Luxembourg

Stakeholder Workshop (18 October 2006)

Name	**First Name**	**Institution**
Allegrezza	Serge	STATEC
Bergh	Jean	Goodyear S.A.
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Burkel	Jean-Christophe	Chambre de Commerce
Colling	François	Cour des Comptes Européenne
Decker	Pierre	Ministère de la Culture, de l'Enseignement supérieur et de la Recherche
Deepen	Marco	Caritas
Fayot	Ben	Député (LSAP d'Sozialisten)
Franck	Raoul	Ministère de la Santé

Guarda	Paolo	Banque centrale du Luxembourg
Hoffmann	Gérard	Telindus S.A.
Huss	Jean	Député (Déi Gréng)
Luchetta	Patrizia	Luxinnovation
Moulin	Claudine	Universität Trier
Schlesser	Gilles	Luxinnovation
Schoos	Aloyse	IEE S.A.
Schronen	Danielle	Caritas
Thiel	Lucien	Député (CSV)
Wagner	Jean-Frank	Universität Trier
Walentiny	Marco	Ministère de l'Economie et du Commerce Extérieur
Cresswell	Ian	Luxinnovation

Expert Workshop (November-December 2006, February 2007)

Information and Communication Technologies WS1 (20.11.2006) / WS2(05.02.2007)		
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Cresswell	Ian	Luxinnovation
Duhr	Joel	DELPHI
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Férard	Jean-François	Université Paul Verlaine Metz
Greger	Manfred	Université du Luxembourg
Fischer	Marc	Laboratoire National de Santé
Hastert	Carlo	Ministère de l'Economie et du Commerce extérieur
Heck	Peter	Fachhochschule Trier, Umwelt-Campus Birkenfeld
Hoffmann	Lucien	CRP Gabriel Lippmann
Kraus	Georges	SEBES
Lickes	Jean-Paul	Service de la Gestion de l'Eau
Maas	Stefan	Université du Luxembourg
Morel	Jean-Louis	Institut National Polytechnique de Lorraine
Offermann	Jean	Agence de l'Énergie S.A.
Pfister	Laurent	CRP Gabriel Lippmann
Rothstein	Benno	European Institute for Energy Research
Schley	Laurent	Administration des Eaux et Forêts
Schulz	Christian	Université du Luxembourg
Stoll	Jean	Convis
Welfring	Joëlle	CRP Henri Tudor
Werner	Charles	Arcelor S.A.
Winkin	René	FEDIL
Decker	Pierre	Ministère de la Culture, de l'Enseignement supérieur et de la Recherche
Lemmer	Andreas	Universität Hohenheim
Lemmer	Marc	Luxcontrol S.A.
Leviandier	Thierry	ENGEES
Thein	Jean	Universität Bonn / Geologisches Institut
Wagner	Jean-Frank	Universität Trier
Wietor	Léon	Administration des Services Techniques de l'Agriculture

Physical Sciences and Engineering WS1 (21.11.2006) / WS2 (06.02.2007)		
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Cresswell	Ian	Luxinnovation
Duhr	Joel	Delphi
Gillé	Serge	CRP Henri Tudor
Hirtt	Pierre	HITEC Luxembourg S.A.
Jacque	Etienne	Delphi
Louge	Alain	Eurobéton/Chaux de Contern/FEDIL
Malvetti	Massimo	Université du Luxembourg
Marso	Michel	Forschungszentrum Jülich GmbH
Migeon	Henri-Noël	CRP Gabriel Lippmann
Odenbreit	Christoph	Université du Luxembourg
Roth	Jean-Luc	Paul Wurth S.A.
Schlapbach	Louis	CEO EMPA
Schoos	Aloyse	IEE S.A.
Chtaib	Mohammed	Luxcontrol S.A.
Girot	Thierry	CRP Gabriel Lippmann
Kieffer	John	University of Michigan
Ramsden	Nigel	FEDIL (& FANUC Robotics Europe S.A.)

Environmental Sciences WS1 (27.11.2006) / WS2 (07.02.2007)		
Name	**First Name**	**Institution**
Bechet	Georges	Musée national d'histoire naturelle
Cresswell	Ian	Luxinnovation
Duhr	Joel	DELPHI
Eser	Thiemo	Ministère de l'Intérieur et de l'Aménagement du Territoire
Férard	Jean-François	Université Paul Verlaine Metz
Greger	Manfred	Université du Luxembourg
Fischer	Marc	Laboratoire National de Santé
Hastert	Carlo	Ministère de l'Economie et du Commerce extérieur
Heck	Peter	Fachhochschule Trier, Umwelt-Campus Birkenfeld
Hoffmann	Lucien	CRP Gabriel Lippmann
Kraus	Georges	SEBES
Lickes	Jean-Paul	Service de la Gestion de l'Eau
Maas	Stefan	Université du Luxembourg
Morel	Jean-Louis	Institut National Polytechnique de Lorraine
Offermann	Jean	Agence de l'Énergie S.A.
Pfister	Laurent	CRP Gabriel Lippmann
Rothstein	Benno	European Institute for Energy Research
Schley	Laurent	Administration des Eaux et Forêts
Schulz	Christian	Université du Luxembourg
Stoll	Jean	Convis
Welfring	Joëlle	CRP Henri Tudor
Werner	Charles	Arcelor S.A.
Winkin	René	FEDIL
Decker	Pierre	Ministère de la Culture, de l'Enseignement supérieur et de la Recherche
Lemmer	Andreas	Universität Hohenheim
Lemmer	Marc	Luxcontrol S.A.
Leviandier	Thierry	ENGEES
Thein	Jean	Universität Bonn / Geologisches Institut
Wagner	Jean-Frank	Universität Trier
Wietor	Léon	Administration des Services Techniques de l'Agriculture

Law, Economy and Finance WS1 (28.11.2006) / WS2 (12.02.2007)		
Name	**First Name**	**Institution**
Ahlborn	Pierre	Banque du Luxembourg
Allegrezza	Serge	STATEC
Beaulieu	Paul	University of Quebec / Luxembourg School of Finance
Brosius	Jacques	CEPS/INSTEAD
Conac	Pierre Henri	University of Luxembourg
Corbisier	Isabelle	University of Luxembourg
Goergen	Marc	University of Sheffield
Guarda	Paolo	Banque centrale du Luxembourg
Jung	Rüdiger	ABBL
Kyriakou	Dimitris	IPTS, European Commission
Probst	Laurent	PricewaterhouseCoopers
Ray	Jean-Claude	Université Nancy
Van Kerm	Philippe	CEPS/INSTEAD
Wampach	Claude	Commission de Surveillance du Secteur Financier
Burkel	Jean-Christophe	Chambre de Commerce
Cosma	Antonio	Université du Luxembourg
Keenan	Michael	University of Manchester / PREST
Michel	Jean-Pol	CRP Henri Tudor
Plasman	Robert	Université Libre de Bruxelles
Reding	Kurt	Universität Kassel
Reuter	André	EUPRONET
Thiel	Lucien	Luxembourg School of Finance
Wagner	Pol	Institut Universitaire International Luxembourg
Grulms	Fernand	ABBL

Life Sciences WS1 (04.12.2006) / WS2 (13.02.2007)		
Name	**First Name**	**Institution**
Alesch	François	Universitätsklinik für Neurochirurgie
Beismann	Heike	VDI Technologiezentrum
Bjerkvig	Rolf	NorLux Neuro-Oncology / University of Bergen
Bormann	Jeanne	ASTA
Creitz	Mesbah	Cellon S.A.
Delfosse	Philippe	CRP Gabriel Lippmann
Differding	Edmond	UCB S.A.
Even	Jos	Laboratoire National de la Santé
Fischer	Marc	Laboratoire National de la Santé
Friederich	Evelyne	CRP Santé
Fromes	Yves	Institut de Myologie - INSERM
Kozlik	Thierry	Chambre de l'Agriculture
Lair	Marie-Lise	CRP Santé
Menzel	Alain	Laboratoires Réunis Junglinster
Meyer	François	Fonds National de la Recherche
Plumer	Pierre	CRP Henri Tudor
Schmit	Jean-Claude	CHL / CRP Santé
Sedrani	Richard	Novartis Pharma
Stoll	Jean	Convis
Tschirhart	Eric	Univerité du Luxembourg
Van Crienkinge	Wim	Universiteit Gent
Weber	Bernard	Laboratoires Réunis Junglinster
Metz	Henri	Fonds National de la Recherche
Zachariah	Rony	Médecins Sans Frontières

Beaulieu	Paul	University of Quebec / Luxembourg School of Finance
Grotz	Mario	Ministère de l'Economie et du Commerce extérieur
Hoffmann	Lucien	CRP Gabriel Lippmann
Keenan	Michael	University of Manchester / PREST
Muller	Claude	Laboratoire National de la Santé
Wolf	Romain	Novartis Institutes for Biomedical Research
Smits	Elke	Economie, Wetenschap en Innovatie (EWI)
Wagener	Yolande	Ministère de la Santé

Social Sciences and Humanities WS1 (05.12.2006) / WS2 (14.02.2007)		
Name	**First Name**	**Institution**
Borsenberger	Monique	CEPS/INSTEAD
Bousch	Patrick	CEPS/INSTEAD
Eser	Thiemo	Ministère de l'Intérieur et de l'Aménagement du Territoire
Ferring	Dieter	Université du Luxembourg
Gillen	Erny	Fondation Caritas Luxembourg
Hausman	Pierre	CEPS/INSTEAD
Kafai	Amina	Ministère de l'Education Nationale
Kieffer	Monique	Bibliothèque nationale de Luxembourg
Kollwelter	Serge	ASTI
Langers	Jean	STATEC
Margue	Michel	Université du Luxembourg
Martin	Romain	Université du Luxembourg
Meyer	Morgan	University of Sheffield
Moulin	Claudine	Universität Trier / Université du Luxembourg
Muxel	Anne	Centre d'etudes de la vie politique française / CNRS
Peters	Manfred	Facultés Universitaires Notre-Dame de la Paix
Sadowski	Dieter	Universität Trier
Tonnar-Meyer	Christiane	Ministère de l'Education Nationale
Wagener	Raymond	Inspection générale de la sécurité sociale
Gauthier	Clermont	Université Laval
Peiffer	Patrick	Bibliothèque nationale de Luxembourg
Lanners	Michel	Ministère de l'Education nationale et de la Formation professionnelle
Margue	Charles	TNS ILRES Luxembourg
Schanen	François	Université Paul Valery Montpellier
Schmit	Paul	Caritas Luxembourg
Weber	Germain	University of Vienna
Willems	Helmut	Université du Luxembourg