# CORE

## MULTI-ANNUAL THEMATIC RESEARCH PROGRAMME

Programme Description

Fonds National de la Recherche Luxembourg

INVESTIGATING FUTURE CHALLENGES

www.fnr.lu

# PROGRAMME DESCRIPTION

## CORE 2016 CALL

This programme description provides general information about the objectives and thematic research priorities of the FNR's 'CORE Multi-Annual Thematic Research Programme'.

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### Note

Please carefully read the call documents. They give indications about the submission and selection process. Further call documents, forms and guidelines are available on the FNR webpage http://www.fnr.lu/funding-instruments/core. Please do not hesitate to contact FNR staff for any further explanation.

# 1. General Principles of the CORE Programme

## 1.1. Objectives

CORE is a **multi-annual thematic research programme** and is the central programme of the FNR. The prime objective of CORE is to strengthen the scientific quality of Luxembourg's **public research** in the country's **priority research domains** (section 1.2).

In the eyes of the FNR, high quality research capacities form the essential pool of knowledge and expertise from which **social, environmental** and **economic impact** emanate. CORE projects should directly contribute to the **strengthening of the research competences** in the priority fields and be of **international competitiveness**. CORE aspires to create strategic national resources and an increased visibility in the international research community.

**The CORE programme should contribute to the**

- Funding of **high quality scientific research**, leading to the generation of new knowledge and **scientific publications** in the leading international peer-reviewed outlets of the respective fields;
- Development of a strong research basis in Luxembourg which can be exploited for sustainable long-term socio-economic and environmental benefits;
- Advancement of the research group or institution in view of **international visibility** and critical mass;
- **Training** of doctoral students and advancement of the involved researchers in general.

Research activities under the CORE programme should fulfil the general FNR principals (see CORE application guidelines http://www.fnr.lu/funding-instruments/core/core-supporting-documents.

## 1.2. CORE Domains

With CORE the FNR provides funding for high quality research projects in the following 5 priority domains identified in the Foresight exercise of 2005[1] and retained by the government:

| CORE Domains | Thematic Research Priorities |
|---|---|
| Innovation in Services | Information Security and Trust Management |
| | Business Service Design |
| | Development and Performance of the Financial Systems |
| | Telecommunication and Multimedia |
| Sustainable Resource Management in Luxembourg | Water Resources under Change |
| | Sustainable Management and Valorisation of Bioresources |
| | Sustainable Building and Bioenergy |
| | Spatial and Urban Development |
| New Functional and Intelligent Materials and Surfaces and New Sensing Applications | New Functional and Intelligent Materials and Surfaces |
| Biomedical and Health Sciences | Regenerative Medicine in Age-related Diseases |
| | Translational Biomedical Research |
| | Public Health |
| Societal Challenges for Luxembourg | Social and Economic Cohesion |
| | Education and Learning |
| | Identities, Diversity and Interaction |

A detailed description of the CORE domains is available in section 5.

[1] The FNR launched a 'Foresight' exercise in December 2005 with the objective to define and assess the most relevant research priorities for Luxembourg.

## 1.3. Duration and Funding

CORE projects have a lifespan of **two to three years** and funding is allocated on a **competitive** basis. All projects are peer reviewed by international reviewers. CORE calls are launched on an **annual basis**.

The FNR allocates a maximum financial contribution of 17 Mio € for the CORE 2016 Call.

CORE funding may cover research projects of **PhD students** who are involved in the project **full-time** and from the beginning.

## 1.4. CORE Junior Track

The Luxembourg research environment is characterised by the youth of the research institutions and by a large number of researchers at an early career stage. The FNR considers that supporting young promising principal investigators (PIs) at the start of their independent career is of benefit for the national innovation system. The 'CORE Junior Track' **provides an opportunity for non-established PIs to obtain their own funding and start their independent career**.

**FNR expectations of CORE Junior Track projects**

- CORE Junior Track projects should help PIs to establish own independent research lines; the CORE Junior project should be seen as the PI's first project at FNR;
- The research has to be conducted by the Junior PI him/herself with limited additional human resources and collaborations;
- The project is initiated by the Junior PI and is hosted within an existing research group. The project is accompanied by an experienced internal group leader who provides sufficient freedom to the Junior PI to pursue his/her own research ideas;
- Additional independent advice on the scientific orientation of the project, career development and networking is the role of the mandatory mentor abroad.

CORE Junior Track applications are subject to the same rigorous peer review as the standard CORE proposals but it is acknowledged that the Junior Track applicants generally have short track records in terms of project management experience, and little preliminary work directly related to the proposed project. By providing a submission scheme more suited to the track record of the applicant and requiring support by supervisor and mentor, the FNR expects that applications by Junior PIs to the CORE Junior Track will have increased chances of success. Ambitious projects, especially the ones involving the management of a consortium require experienced project management, and should therefore be avoided by Junior PIs.

## 1.5. International Co-funding within CORE

The FNR has signed **cooperation agreements** with the following funding agencies:

- Deutsche Forschungsgemeinschaft (DFG, Germany),
- Schweizerischer Nationalfonds (SNF, Switzerland),
- Fonds zur Förderung der wissenschaftlichen Forschung (FWF, Austria),
- European Molecular Biology Laboratory (EMBL, Germany).

- National Centre for Research and Development, Poland (NCBR, Poland).

By signing these cooperation agreements, the FNR intends to support **funding of bi-lateral projects** between Luxembourg researchers and their colleagues abroad.

**DFG, SNF and FWF**

Cooperation agreements with DFG, SNF and FWF foresee that applicants can submit bi-lateral proposals for evaluation either to the FNR or to the foreign research funding agency. All five CORE domains are eligible for projects in collaboration with these three agencies. The **Lead Agency** is the funding organisation of the country where the main research effort is accomplished. Both agencies base their funding decision on the results of one single evaluation procedure, the so called 'Lead Agency' principle.

**EMBL**

The cooperation with EMBL is restricted to the domain of Biomedical sciences and the FNR will always be the evaluating agency i.e. the Lead Agency.

**NCBR**

The cooperation with NCBR is restricted to the domain of Innovation in Services and the FNR will always be the evaluating agency i.e. the Lead Agency.

Further international co-funding with other funding agencies can be applied for through the FNR INTER programme http://www.fnr.lu/funding-instruments/inter.

# 2. Requirements for Proposals

## 2.1. General Requirements

- Projects selected under the CORE Programme have a lifespan of **two to three years**.
- The projects should have the nature of a typical research project – funding of infrastructure or of data collection is not intended if this is not associated with the answering of a clear research question.
- The applicant has to ensure that the formal and personal requirements for submitting an application are met. Details are available in the CORE Application Guidelines http://www.fnr.lu/funding-instruments/core/core-supporting-documents.
- It is recommended to contact the FNR for guidance before submitting the proposal.

## 2.1. Domain Coverage

The CORE programme intends to support innovative research projects of high scientific quality within the 5 thematic priority research domains (see section 1.2 and 5).

Applicants should be aware that in case their proposal does not fall within the remit of the CORE programme, the proposal will be rejected.

## 2.2. Eligible Host Institutions and Principal Investigator

The following organisations[2] established within Luxembourg are eligible for financial support from the FNR under the CORE programme:

1. Public institutions performing research in Luxembourg;
2. Non-profit associations and foundations[3] performing research in Luxembourg and that have obtained a special authorization from the Ministry for Higher Education and Research.

Each entity has to be registered at the FNR in order to be able to submit proposals through the online submission system.

For more information on eligibility on institutions, please consult the CORE application guidelines and the information on the FNR website http://www.fnr.lu/en/about-us/beneficiaries

For each proposal, project partners designate one 'Principal Investigator'[4] (PI) per project, who is the project leader responsible for submitting the proposal on their behalf. The formal submission of the proposal to the FNR is done by an official representative of the coordinating institution. The PI must be employed at an eligible organisation at the time of the start of the project and for the full duration of the research project. The FNR requirements for principal investigators and supervisors within FNR funded projects apply and are available on the FNR website www.fnr.lu/guidelines.

[2] FNR's law dating May 31, 1999, art 3 (2).

[3] To be eligible for FNR support, non-profit associations and foundations must be accredited by the Ministry in charge of public sector research. To obtain an accreditation, associations or foundations have to introduce a formal request at the Ministry of Higher Education and Research.

[4] The PI is the researcher proposing the project idea and leading the project on a 'daily basis'.

# 3. Submission and Selection Process

## 3.1. The Submission Process

The submission procedure is organised in a single full proposal stage. The proposals must be submitted in electronic format using the online submission system (FNR Grant Management System) https://grants.fnr.lu until the deadline. All proposals have to be written in English.

## 3.2. The Selection Process

The selection process is based on a Peer Review process that guarantees an independent state-of-the-art evaluation with the objective to select those research projects that reflect the highest **scientific quality**. All proposals undergo the following selection process:

- The proposals undergo an **eligibility check** based on the formal requirements. Submitted full proposals are **peer-reviewed** by independent, international experts;
- An **expert panel** ranks the proposals and recommends funding;
- **FNR decision bodies** select and approve the proposals to be funded;
- The detailed description of the review process and the selection criteria can be found in the publication '**CORE Peer Review Guidelines**' available on the FNR webpage http://www.fnr.lu/en/funding-instruments/core/core-supporting-documents.

## 3.3. The Selection Criteria

The **scientific merit** of the proposal is assessed based on:

1. Innovativeness of idea and scientific relevance;
2. Appropriateness of the approach;
3. Feasibility (competence of the PI and applicant team; research plan; institutional infrastructure, research environment);
4. Expected outcome and impact of results.

# 4. Time Schedule for the CORE 2016 Call

| | |
|---|---|
| 18 December 2015 | Launch of the CORE Programme 2016 Call |
| 27 January 2016 | FNR Research Information Day |
| 21 April 2016 14:00 (CET) | Deadline for the submission of proposals (all domains) |
| Second half of October 2016 | Funding decision communicated to the applicants |
| 1 September 2017 | Latest start of the project. Please note that for projects which are not able to start before 1 September 2017, the FNR may revise its funding approval. |

# 5. Thematic Research Priorities and Budget

## 5.1. Innovation in Services

### 5.1.1. Business Service Design

#### 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 have its share in the Luxembourg economy reduced. 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. ICT is also recognised as the key enabler for the innovation in new e-services central to new value-based propositions with business services offered by companies belonging to the private sector as well as by public administrations. Additionally as customers of e-services are mainly located outside of Luxembourg, the market potential and thus the economic impact is enormous in comparison to the size of the country.

In order for the Luxembourg service sector to stay competitive at an international level, it is of utmost importance to increase the productivity and innovation of service-related industries by means of research. Research in business service design is a multidisciplinary field that seeks to bring together knowledge from different areas to improve the service industry's operations, performance and innovation. The challenge now is to exploit the results of appropriate research activities to support higher-quality and more productive service provision taking particular account of the deployment of technology.

#### Research Issues

- Efficiency and flexibility of Business Services
- Seamless service architecture including adaptability and interoperability
- Optimisation and structuring of the legal and fiscal environment of the service sector
- Business service regulation compliance
- Technologies for web services and business processes

Research should contribute to the design and engineering of flexible and efficient Business services strategies and innovative business models through business Services (including deployment, operation and monitoring).

Public research may cover many different applications and e-services of different levels of granularity: business related e-services and public e-services (e-government, e-administration, e-health and e-learning). Future public research should also concentrate on the growth sector of services e.g. goods production, multimedia services, financial sector or transport and logistics sector.

#### Long-term 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;
- becoming a reference point for services science in order to increase Luxembourg's scientific reputation in this domain and attract talents.

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. Additionally, research related to and needed for the alignment with the regulatory and legal framework within the Luxembourgish context should be undertaken.

### 5.1.2.Development and Performance of the Financial Systems

#### Challenges in the National Context

The financial sector underpinned Luxembourg's high economic growth during the last two decades and can be rightly considered as the heart of the Luxembourg economy. Today, the Luxembourg economy is growing at around 5-7% p.a. and the financial sector, currently accounts for approximately 30% of economic activity thus making Luxembourg economy very dependent on the performance of the financial sector. With the emergence of many competing markets, a major effort in terms of training and research is required to safeguard its future. Public research related to performance and development of the financial sector 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

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:

- Client advice, financial education and culture, private agent behaviour;
- Distribution of financial products, development of new innovative products and solutions;
- Optimisation and structuration of the fiscal and regulatory environment, financial stability;
- European harmonisation/EU directives and competition between different financial centres;
- Monitoring of production and productivity of financial services.

Research aiming at optimising the fiscal and regulatory environment will play an important part in ensuring the development of new products and business lines as well as in assuring the overall competitiveness of the financial sector as a whole.

### Long-term Objectives

Public research in “Performance and Development of the Financial Systems” 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 Luxembourg’s financial sector in particular – especially in the context of European harmonisation.

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. Research on the regulatory framework will play an important part for innovation in the sector.

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.

## 5.1.3.Information Security and Trust Management

### Challenges in the National Context

“Information Security and Trust Management” is one of the cornerstones of the Information Society, 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. Integrity of financial transactions, accountability for electronic signatures, confidentiality within a virtual enterprise, privacy of personal information, dependability of critical infrastructure, all depend on the availability of strong, trustworthy security mechanisms. By virtue of its responsibilities to customers, its role in maintaining safety and soundness in the financial system, and the requirements of increasingly demanding compliance standards, the financial service industry makes “security and trust” its first priority. This sector is viewed as a leader in security innovation and applications.

Information security research in Luxembourg should concentrate on the needs of Luxembourg as a market place and contribute to consolidate its reputation as a safe harbour for information and services.

### Research Issues

- Trust, Information Security and Risk Management
- Identity and Privacy Management, including Digital Rights Management
- Critical Infrastructure Protection including Reliability and Resilience
- Legal Framework for Trust

Research in this domain should be steered towards the development of IT-based secure applications considering the interdisciplinary character of growth sectors. Additionally secure services should not only be developed for businesses but also for citizens, e.g. e-government and e-health applications. Topics of interest are for example application design and specification, application development and testing as well as concerns for secure operation and monitoring.

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 within the EU directives as this could be of high relevance for companies and a competitive advantage over other countries.

Furthermore there is also a need for research on social and behavioural aspects of security and trust, for instance addressing how to communicate security aspects. Beyond its social impact, research on these aspects may increase the public awareness of the threats in e-services and e-applications.

Public research in this domain should be carried out in an interdisciplinary way involving ICT experts, users of security solutions, business law researchers and public decision makers.

### Long-term Objectives

Luxembourg public research should endorse the know-how in aspects of trust and security in order to reinforce business services in Luxembourg and further help to develop the economy based on services and finance. Public research in “Information Security and Trust Management” should:

- provide excellent fundamental research in order to reach internationally recognized excellence and visibility in information security issues
- contribute to improve the performance of the financial and banking sector and of the Luxembourg economy as a whole and therefore, indirectly maintain Luxembourg’s standard of living
- 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
- have a high 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) and therefore, help at some extent to reduce the digital divide in the society
- balance security and privacy needs within new security and identity management solutions, taking in account the limitations imposed by the legal framework

## 5.1.4.a. High-performance Telecommunication Networks

### Challenges in the National Context

Public research focusing on Telecommunications / ICT Architecture on the one hand has a high potential societal impact as it contributes to increase people’s connectivity and to offer more convenient personalised services; on the other hand, telecommunication is an essential factor of innovation in the service sector and the economic impact of research may 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 testbed for requirements of the ICT infrastructure and for wireless infrastructure all over the country. The research should enable the development of new services and applications, relying on already existing technologies. Therefore it is very important to develop research collaboration networks on a national and international level.

### Research Issues

- Development of new innovative satellite-based services and applications;
- Development of IP based applications within the services sector;

- Analysis and improvement of infrastructure quality. In particular:
  - Communication speed, time delays (latency), capacities,
  - Network security,
  - Virtual networks,
  - Rational use of energy.

Research in telecommunications should include the distribution and personalisation of satellite signals and build on the existing competencies in the private sector.

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.

IP communications research should involve the development of IP-based protocols, platforms and technologies for next generation user interfaces, services and applications for enterprise communications.

Crisis and disaster management could significantly profit from advanced ICT networks supporting an End-to-End communication between users, especially regarding monitoring, early warning and alerting.

### Long-term Objectives

Public research in this domain should:

- Create a centre of excellence for research to attract the best researchers to provide an innovative and internationally competitive environment to become more competitive, and – in combination with the other domains of Innovation in Services – make Luxembourg more attractive for companies from abroad.
- Help 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 infrastructure, broadband access, network applications, etc. as well as of the broad public acceptance of these new services.
- Lead to improve 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. standardization procedures).

## 5.1.4.b. Multimedia

### Challenges in the National Context

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:

- Users (in particular the young generation) not only want to consume content, but also to create and interact with it – Web 2.0 has drastically changed the media sphere;
- Users want to have “their” content available whenever, wherever and on whatever mobile device they chose, making mobility a challenge for future ICT architectures.

Additionally the presence in Luxembourg of a satellite-based communication operator 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

- Management of multimedia content
  - Aggregation, convergence and distribution of media content
  - Multilingual content management and search engines (tools that enable “barrier-free” communication by being accessible in multiple languages, including Luxembourgish)
  - Knowledge management and data mining
- Development of new services
  - New services regarding interactive TV and/or interactive Internet content
  - Geo-localization and location-based services
  - Multilingual e-governmental services
- Standardization
  - Legal framework for purchasing and distribution of multimedia content
- Lifelong learning
  - Data-retrieval and developing new tools for cross-format (audio, visual, video, language)

## Long-term Objectives

Research in this field will help to create Public-private Partnerships which could offer promising opportunities for Luxembourg, especially regarding Web 2.0 applications.

Research collaborations with some of the major companies in the field of multimedia could be very beneficial to increase their investment in Luxembourg, attract other players and create innovative spin-offs.

Specifically in the Luxembourg context, the development of new multilingual, multimedia applications can contribute to 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.

## 5.2. Sustainable Resource Management in Luxembourg

The domain Sustainable Resource Management, formerly covering 5 subdomains (Sustainable Management of Water Resources, Understanding Ecosystems and Biodiversity, Sustainable Agro-Systems Management, Sustainable Uses and Sources of Energy, Spatial and Urban Development) has been reshaped in order to contribute to the development of critical mass and scientific quality. The description has been updated to current and future research agendas.

As a consequence and in line with the Government's efforts to concentrate research investments in key research areas of importance to Luxembourg, and also based on a stakeholder and expert workshop, the FNR has re-organised end of 2012 the domain covering now 4 subdomains: Water Resources under Change, Sustainable Management and Valorization of Bioresources, Sustainable Building and Bioenergy, Spatial and Urban Development (unchanged).

Internationally competitive research in this field is of relevance to national policies. It bears the potential of orienting national policies in the fields of climate change mitigation and adaptation, water resources protection and management, sustainable agriculture and biodiversity conservation.

Beyond the direct contribution to the advancement of the international state-of-the-art in science, research in conjunction with policy may increase:

- the understanding of ecosystem functions and services, their enhancement, mobilization and restoration,
- the development of decision making tools in the field of life cycle assessment and related instruments,
- the development of integrated resources management tools,
- the development of green infrastructure and
- innovation in the field of green and bio economy.

### 5.2.1. Water Resources under Change

While today water still is an abundant resource in Luxembourg, its future availability is threatened by increasing demands of a growing population and economic expansion, chemical and microbiological risks, as well as the potential impacts of climate change. The situation now calls for a wise use and a more adequate management and protection of this resource.

#### Research issues

Changes to water quantities

- Determine spatio-temporal variabilities in water cycle components at high resolutions / reduce uncertainties in measurements,
- Holistic understanding of hydrological systems functionalities from plot to catchment, water flow pathways, water residence times, eco-hydrological interactions and feed-back mechanisms, fluxes in the soil-plant-atmosphere continuum, etc.,
- Simulate hydrological regimes and groundwater recharge rates of hydrological systems under change,
- Simulate water availability and consumption under future climate change & societal changes,

- Develop new perceptual and mathematical (hydrologic, hydraulic, environmental) models / identify and reduce uncertainties in the monitoring-conceptualisation-modelling chain and
- Overcome the limitations of field measurements and inherent uncertainties by developing new monitoring approaches (based on e.g. remote sensing, innovative sensors, high-frequency monitoring, etc.)

Changes to water quality

- Monitor / simulate water quality changes as a response to fluctuations / changes in hydrological regimes,
- Risk assessment and management of chemical and microbiological pollution scenarios, including understanding of processes and interactions, impacts on aquatic biota, source control, etc.,
- Studying / simulate the origin and fate of emerging pollutants and contaminants in surface and ground water bodies / impacts on biodiversity and ecosystem functioning
- Develop new risk assessment and management strategies of chemical and microbiological pollution scenarios, incl. measurement methods, impact assessment methods and monitoring strategies, etc.

Sustainable urban water management

- Developing innovative solutions for water treatment
  - Treatment of emerging pollutants in drinking water, industrial process water, municipal and industrial wastewater by innovative processes, e.g. membrane filtration, disinfection,…,
  - Sludge treatment and
  - Optimisation, simulation and control of water and sludge treatment processes
- Studying the supply of water, alternative water resources, reuse (including research on improving the environmental footprint),
- Developing new technologies, planning and management tools for urban water management,
- Studying the origin and fate of pollutants (including emerging pollutants) in urban water systems and
- Environmental assessment of (waste)water treatment: dynamic modelling, water resource depletion characterization, assessment indicators, assessment of the effects of climate change (present and future).

### 5.2.2.Sustainable Management and Valorization of Bioresources

Food security at a regional, national and global level as well as the potential for using plants as a source for novel biobased products are placing increasing demands on agriculture. Continuous innovations are thus needed to maintain or increase the levels of yield and food quality. It is therefore necessary to advance our understanding of plant functioning for the production of biobased compounds and develop novel approaches to agriculture.
The preservation of biodiversity is a fundamental component of any sustainable development and research on biodiversity and ecosystem functions is of great importance for Luxembourg due to the social-environmental benefits associated with it. It is therefore necessary to develop our understanding of the ecosystem functions. One objective of public research in

this domain should be to reach a systematic assessment of ecosystem services in order to properly ascertain the socio-economic benefit of biodiversity.

### Research issues

Plant cell factories

- Understand factors that impact the formation of micronutrients and phytochemicals within the plant, and to obtain an in-depth understanding of their metabolism, by employing –omics technologies, in order to select varieties and conditions favouring their formation,
- Evaluate how these health promoting ingredients can be optimally integrated into palatable and typically consumed foods, supplements, or nutraceuticals, to maximise their bioactivity following ingestion,
- Study dietary and host factors that alter their bioavailability, including investigating the interaction between the microbiota and humans, and to determine the impact of these compounds on biomarkers related to chronic health complications such as inflammation and oxidative stress, and
- Understand the metabolism of plants by implementing different –omics approaches focused on the plant cell wall dynamics for the biosynthesis of valuable biopolymers and on the carbon-lipid metabolisms for the production of next generation biofuels,

Plant health and pest management

- develop innovative pathogen detection and monitoring methods,
- enhance our understanding of the reasons for changes in the efficacy of pest and pathogen control methods at the genomic, proteomic and metabolomics levels, and
- improve the management of pest species and epidemiology of plant pathogens under climate and/or land-use change.

Ecosystem functioning and services

- Understand and evaluate ecosystem dynamics, functions and services (including modelling approaches),
- Develop new methodologies and strategies to assess, monitor and restore biodiversity over various spatial (e.g. habitat to landscape) and temporal scales, and
- Understand and predict impacts of climate change and/or anthropogenic influences on ecosystems

## 5.2.3.Sustainable Building and Bioenergy

**Sustainable building** is also known as “green” and “high-performance building” and is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort[5]. Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity

[5] http://www.epa.gov/greenbuilding/pubs/about.htm

- Reducing waste, pollution and environmental degradation

**Generally, sustainable building research** includes any environmental, technical, social or business research on the negative environmental or public health impacts of buildings, on approaches to reducing or eliminating those impacts, and on promotion of the design, construction, and operation of man-made (built) environments in harmony with natural and ecological environment ("Zero-Net-Energy Buildings"). The definition of green building research includes:

- basic and applied research, and
- technology transfer work, including the development – but not implementation – of relevant case studies and standards.

**Within the Luxembourg context, the research agenda** is organized around the following systems-based categories:

- Integrated Building Systems
    - Eco-balance and life-cycle-energy use
    - Efficient generation, usage, storage and recovery of energy
    - Development and integration of renewable energy technologies
    - Climate Adaptive Building Form and Envelope
    - Passive, Active and Hybrid HVAC and Controls
    - Materials Life Cycle Assessment
    - Water Use and Management
- Buildings' Interaction with Local Environments
    - Ecosystems and Site Design
    - Land use, Building Location and Transportation
- Indoor environmental quality.
    - Pollutants and Stressors
    - Occupant Health and Performance

In order to encompass the complexity of sustainable buildings as described above, research activities may address:

- Various types of buildings: private housing, offices, public buildings, industrial buildings, etc., and
- The planning, development and management of entire sites

Many of the research activities will require multidisciplinary collaboration and integrated development that recognizes complex system interactions and linkages with other national research priorities in Luxembourg: e.g. traffic and transport optimization is covered within the sub-domain "Spatial and Urban Planning".

Generation of **bioenergy** from photosynthetically produced biomass and organic wastes in an integrated concept involving e.g. the bioprocesses of anaerobic digestion, alcoholic fermentation, algaculture, thermal processes and the recycling of essential nutrients.

The research focus in Luxembourg will be on:

- a better understanding of the biomass-biowaste-bioenergy cycle, addressing e.g:
    - Process understanding and the optimization of the conversion of biomass into biogas and H2 through anaerobic digestion,

  - Integration of the biogas production with other processes, such as bioethanol production from carbohydrates (second generation bioethanol) and algaculture promoted by the recycling of biogas digestate as algal nutrients, and the CO2 from the biogas known as boosting the algal photosynthetic activity,
  - Recycling of the essential nutrients retrieved from the bioprocesses as by-product (mainly biogas digestates), into agricultural and algal production systems while monitoring the effects of such nutrient amendment on crop/algae productivity, soil quality and greenhouse gas (CH4, CO2, N2O) emission from soils, and
  - Assessment of concepts and methodologies for biomass-based energy systems.

- a better understanding of the various biological processes in view of their optimization for conversion of biomass into energy, and

- Thermal treatment of solid biomass aiming at improved energy and nutrient recovery.

### 5.2.4.Spatial and Urban Development

#### Challenges in the National Context

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

Urban and rural development has to take into account the impacts and risks of environmental issues which are affecting the territory of Luxembourg in multiple ways. It is essential to find new ways of living (manufacturing, housing, mobility) that allow for a sustainable development and sustainable land use.

In a context of globalisation and competition, spatial planning could reinforce the attractiveness of a country through living quality, efficiency of the transport system 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.

Social exclusion is rather regularly associated with processes of spatial segregation. A model of spatial development could counterbalance urban inequalities.

Luxembourg has become a hub of transportation benefiting from increasing commerce 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.

With its increasing population and the transformation from an industrial to a knowledge and service society, Luxembourg is experiencing processes of urbanisation and redefinition of land use. The geographic challenge consists in promoting a controlled urban development, particularly concerning urban sprawl, density and mixing of land use.

#### Research Issues

- Integrated spatial and urban development at different scales:
  - Processes of urbanisation: urban sprawl, urban density
  - Processes of metropolisation: polarisation of streams and activities, centralisation and concentration of activities, specialisation of space

  - Processes of (spatial) exclusion: social inequalities and segregation, functional specialisation
  - Urban development and periurban land use changes: natural habitat fragmentation, natural habitat and species management and conservation, compensation measures
  - Urban living quality, urban comfort
  - Infrastructures (transport, water supply and sanitation, energy supply...)
- Environmental health and ecological aspects of urban development (air, water and soil pollution, noise, etc.):
  - Urban biodiversity and management of 'green' space
  - Air quality: assessment, human health impact, management tools, relation with transport and energy use
  - Noise
  - Emerging pathogens
- 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 behaviour
  - 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
- Modelling and simulation of urban growth and spatial development as well as environmental impacts of these developments (scenario and prospective approach), development of management tools.

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, nature conservation, 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, medical, psychological, political, economical, environmental, as well as technological aspects.

Research in spatial development in and for Luxembourg will have to adapt, improve on or even invent methodologies and tools to investigate, model (or meta-model), and forecast territorial development and its environmental impacts within the country and the Greater Region. Within this research domain, monitoring, simulation and management tools have to be employed or to be developed. This includes quantitative tools (e.g. studies on statistics, optimisation, the use of earth observation data and geographical information systems (GIS)) and their use in model and meta-modelling approaches. Other topics include empirical surveys and databases on e.g. the environmental quality, the mobility and habitat behaviour of people within and around Luxembourg, qualitative studies on their intrinsic motivations and basic research on how processes of metropolisation and polarisation 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.

### Long-term Objectives

In the midst of the transition from an industrial society to a knowledge society, research in the field of spatial development will contribute to find answers to the question of how Luxembourg can foster economic development, provide a liveable habitat for its population and protect its natural environment which is crucial to the future quality of life within the country. This process can only be successfully organised within Luxembourg itself in combining research with stakeholder participation.

# 5.3. New Functional and Intelligent Materials and Surfaces, and New Sensing Applications

## 5.3.1. New Functional and Intelligent Materials and Surfaces

### Challenges in the National Context

On a national basis, there are many R&D activities on materials and surfaces in the industrial sector focusing on polymers, on composites and multicomposites, on ceramics, on metals and alloys.

Furthermore, the FNR funded research through the NANO and TRASU programmes has helped achieve critical mass and international visibility of national research institutions in the highly competitive field of material science.

Publicly funded research on materials with new properties should contribute to the enhancement of the competitiveness of Luxembourg based industries thus playing the role of an enabler for new economic activities (new applications, new production processes, spin-offs, start-ups, licensing). If Luxembourg based industry is to further strengthen its competitiveness it needs innovation in high-added value products, related processes and technologies.

### Research Issues

- New functional and intelligent materials, surfaces, interfaces and coatings
- Sustainable synthesis and production processes
- Nanobiosciences

The main objective of this research domain is to focus on developing new intelligent multifunctional materials and surfaces with tailored properties and predictable performance for new products and processes with a wide range of applications. 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 the major focus of this domain. This relies on the control of intrinsic properties and performance, processing and production, and taking into account potential impacts on health and the environment.

A multi-disciplinary approach will be fostered, involving physics, engineering sciences, chemistry including computational modelling and biological sciences. Materials characterization, design and simulation will contribute to better understand and predict materials phenomena. Studying and optimising the synthesis at laboratory scale as well as the scale-up and the production of new materials at industrial scale should be investigated.

### Long-term Objectives

Major progress and applicable results will be achieved by reaching critical mass and high scientific quality in the public research institutions and through strengthening the collaborations with the private research sector. By this, public research will contribute to the enhancement of the competitiveness of Luxembourg based industries.

Public research in this domain should be accompanied by pro-active 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.

# 5.4. Biomedical and Health Sciences

## 5.4.1. Regenerative Medicine in Age-related Diseases

### Challenges in the National Context

Regenerative medicine and tissue engineering in particular are a promising area for public research in Luxembourg. It holds high promises for generating potential novel therapies for untreated severe chronic diseases affecting predominantly the elderly population.

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 attractive opportunity for Luxembourg and significant progress in this research area is expected in the next 5-10 years. Regenerative medicine has the potential to develop therapies for previously untreatable diseases and conditions and help repairing some of the damage caused by ageing, for instance by replacing tissues and organs to treat degenerative diseases like Alzheimer’s and Parkinson’s disease, cardiovascular diseases, injuries resulting from strokes, ocular degeneration, orthopedic and spinal injuries etc.

Research in tissue engineering is from a scientific point of view very attractive and there are many entry points, such as the development of tissue and cell engineering in combination with the development of novel materials for bio-devices (osteobiologic, cardio-vascular and other prostheses, encapsulation devices for cells or biologics etc.).

### Research Issues

- Tissue and cell therapy
  - Tissue engineering
  - Biomaterials
  - Development of appropriate modelling, characterisation and diagnostic tools /technologies
- Age-related medical indications:
  - Cardio-vascular Diseases
  - Cancer
  - Neurodegenerative Diseases

Tissue engineering is the regeneration of biological tissue through the processing of cells or tissue, incorporated into supporting structures and/or biologics and thus comprises both the development of tissue and cell engineering and the development of novel materials for bio-devices (osteobiologic, cardio-vascular and other protheses, encapsulation devices for cells and tissues or biologics).

Given the high international competitive nature of research in regenerative medicine, Luxembourg should do research addressing primarily the age-related diseases which are already the major focus of the national public research programme: cancer, cardiovascular diseases and neurodegenerative diseases. The focus should primarily be on potential cell and tissue therapies, including biomaterials, tissue engineering, research on pluripotent stem cells, development of appropriate modelling and imaging tools.

### Long-term Objectives

Tissue engineering has the potential of generating novel therapeutic modalities in surgical reconstructive medicine changing the traditional paradigm of pharmacological treatment all together. Therefore research in this domain is expected to have an important economic impact on the long run through tissue implants and encapsulation devices for tissues or biologics.

By supporting high quality projects, public research will form a solid basis from which new economic activities may develop. Collaboration between the scientific and medical community is stimulated and an attractive environment is created that fuels the establishment of a biomedical industry in Luxembourg over the next 5-10 years.

## 5.4.2.Translational Biomedical Research

### Challenges in the National Context

Translational biomedical research refers to research at the interface between fundamental research and clinical application. Bridging this gap holds the promise for improved treatment efficacies and better diagnostic tools, which will benefit the patient and the health care system. Translational approach could thus provide new impulses for improving public health measures, clinical procedures and cures and can lead to the development of new technology and technology transfer to personalised medicine.

By capitalising on the existing competences of Luxembourg research in medical sciences, translational research is expected to lay the ground for the development of new industries (e.g. medical devices, diagnostic tools, etc.) in Luxembourg.

One promising line is the concept of 'Personalised Medicine', an emerging new approach in molecular medicine.

### Research Issues

- Molecular medicine for improved diagnostics and leading to personalised medical care for the individualised prevention of age-related diseases;
- New technologies should be translated from their basic discoveries into the clinical world:
  - Development of new biomarkers for diagnostic purpose;
  - Development of improved biomedical devices;
  - Development of improved therapeutics and treatments;
- Specific groups of diseases:
  - Cardiovascular diseases, including contributors such as metabolic diseases (diabetes), *etc*.
  - Cancer
  - Neurodegenerative diseases

Translational biomedical research encompasses multidisciplinary research groups which are focussed on translating basic research findings into a potentially useful therapeutic or diagnostic drug candidate. This is being achieved by studying safety, pharmacokinetic and pharmacodynamic parameters and efficacy in clinically relevant animal models and if proven warranted in a select clinical patient population.

The research projects should focus on the translation of basic research findings into possible clinical practice for the diagnosis, prevention or treatment of diseases related to ageing

including cardiovascular, cancer and neurodegenerative diseases. Subjects of the research projects should include the investigation of molecular targets and their pathways for their potential suitability as novel therapeutics or diagnostics, the investigation of specific bio-markers suitable for the clinical diagnosis in the disease group mentioned above.

Research activities should focus on the development of personalised medicine, in the disease groups listed above, by harnessing genomics and proteomics technologies for tailoring the most suitable pharmacotherapy for the each patient.

The FNR acknowledges that within the timeframe of a single three-year project it is often difficult to succeed the full transition 'from bench to bedside'. The FNR equally realises the necessity to gain an essential fundamental knowledge prior to embarking on the proof of concept trials. Therefore the FNR seeks to support non-human or non-clinical studies, which intend to advance therapies/diagnosis to the clinic or to develop principles for application of therapeutics/diagnostics to human disease. However, the possible future steps to take this knowledge to initial proof of concept trials or eventually to the clinical practice would need to be indicated in the project proposal.

Translational biomedical research also includes investigations in cells or tissues from animals or humans, which define the biology of disease and provide the scientific foundation for the elucidation and the development of new or improved therapies or the new therapeutic targets for human disease. Moreover, investigations that lead back from the bedside to the bench where basic science studies investigate the biological effects of therapeutics in humans fall under this call[6].

Furthermore, it is recognised that in order to study human health and disease states and the underlying cellular processes, which are governed by dynamic interaction of individual components (e.g. genes, proteins, metabolites) in complex biological networks, it is needed to make use of analytical approaches such as genomics, proteomics and metabolomics as well as advanced computational, bioinformatics and modelling approaches.

The FNR supports research using these approaches towards improving our understanding of complex biological systems. Examples for this type of research are:

- develop new technology and methodology at the analytical and computational level
- analyse the mechanisms of disease pathogenesis
- identify and validate new targets for disease prevention and intervention
- explore opportunities for the translation of knowledge from basic research into medical and industrial application

In general, PIs should to provide explanations (ideally in the form of a power calculation) for the number of recruits/patients/controls/animals intended to be studied in projects involving human and non-human subjects.

### Long-term Objectives

Building of new competences in translational biomedical research should strengthen Luxembourg's research community and attract innovative development programmes towards Luxembourg.

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[6] Mankoff SP, Brander C, Ferrone S, Marincola FM., Lost in Translation: Obstacles to Translational Medicine; J Transl Med; 2004 May 18;2(1):14.

These programmes should also increase public awareness of the tremendous efforts going on worldwide in the field of biomedical research, as well as Luxembourg's involvement. They should attract high-profile innovative clinical studies to hospitals in Luxembourg. They should be the foundations to attract the highly valuable biomedical industry to Luxembourg, which has so far been hesitating to settle in Luxembourg because of the lack of the required scientific competence.

In the view of developing new ways of prevention, diagnostics and treatments in the medium to long term, implementing a personalised medicine forms the basis of an efficient treatment of patients leading to better care, the decrease in the rates of adverse drug reactions and the lowering of health care cost.

### 5.4.3.Public Health

#### Challenges in the National Context

By international standards, Luxembourg has a high-quality health care 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. 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[7] and OECD activities[8]. In particular, regarding the ageing population, research should address the evaluation of economic and social effects of home-based health care.

The vision is that FNR-supported research will contribute to make citizens of Luxembourg benefit from the best possible evidence-based health care. This vision depends both on political choices as well as on research activities. Research is an essential component to develop an evidence-based treatment policy in Luxembourg. These research activities will need to be carried out by both the actors of the health care system as well as by scientists in research institutions by establishing a strong partnership between both groups.

Furthermore FNR-funded research should contribute to develop an understanding of health as a complex system, its components, the dynamics and the interaction of the various factors and determinants that cause disease and influence health in view of improving health/well-being of the individual and the development of personalised medicine.

#### Research Issues

**1. Assessment of health care system (Health care outcomes and cost-benefits)**

Research in the field of Assessment of health care system is interdisciplinary by nature and should focus on the following issues:

- System's approach to optimise the quality of health care
  - The quality of health care is often compromised by medical errors, disparities by social background, the lack of personal attention and continuity in care, but also by the absence of evidence-based standards. Research activities should provide data and contribute to expand the understanding of how to optimise the quality of health

[7] Cf. Area "Quality, efficiency and solidarity of health systems" of FP7 health-related activities.
[8] http://www.oecd.org/dataoecd/10/57/35101765.pdf

care (including health services) from a system's point of view (e.g. regulations, procedures, incentives, managerial practice, etc.) leading thus to real benefits for patients and efficiency improvements for the health care providers.

- Primary care quality linkage to costs
  - Primary care in this context is defined[9] by health services that play a central role in the local community: general practitioners, pharmacists, dentists and midwives. Primary care providers are usually the first point of contact for a patient and they follow a patient throughout their care pathway and thus represent a key figure in the coordination of care in the public health system. Research activities should contribute to the optimisation of efficiency and cost-effectiveness of the primary care system. Projects should improve our understanding of how to optimise care and resource utilisation in order to give the patient an optimal evidence-based treatment in an adequate place at the right time.
- Evaluation of the public health system in terms of efficiency and cost-effectiveness
  - Research activities should cover all interventions in the public health system in terms of efficiency and cost-effectiveness, ranging from preventive medicine, health education, control of transmissible diseases, application of sanitary measures, and monitoring of environmental hazards.

**2. Population-based public health research**

Population-based public health research includes both in-depth studies to investigate how well-defined health determinants can cause and influence disease conditions, as well as studies to assess the contribution of a large multitude of factors to disease development.

The research focus of this topic is population-based epidemiologic investigations of public health issues which should draw on integrative approaches to look at the various attributes and exposures that influence health (such as genetic factors, behavioral factors, environmental factors, socio-economic factors) and the study of distribution, variation, and determinants of health outcomes.

The research should clearly focus on relevant public health issues, build on and help expand existing research infrastructure in view of developing diagnosis (e.g. biomarkers), treatment, and prevention strategies.

Disease focus:

- Cancer;
- Cardiovascular diseases including contributors such as metabolic diseases (diabetes), obesity, sedentary lifestyle;
- Dementia;
- Mental health and stress-related conditions/diseases;
- Infection and immunity (particular topic of interest: influence on other diseases such as cancer, schizophrenia, etc.).

The choice of disease focus is based on the users' demands, the existing research basis and the statistical data on disease incidence, burden and cause of death.

In any case, projects should clearly address a specific research hypothesis and should be designed in such a manner that follow-up or complementary studies can build on the data and generate a broader view of the disease or the public health issue as it is recognised that

[9] Definition by UK Department of Health : http://www.dh.gov.uk/en/Healthcare/primarycare/index.htm

in many cases a specific public-health issue is not caused or influenced by a single factor but many different factors (genetic, behavioural etc.) that interact to determine the course of disease in the individual.

Therefore, particular care should be devoted to the design and maintenance of the data generated in the project and the means of integration with other data sources should be clearly indicated in the research projects. Furthermore, each project proposal needs to provide a power calculation of the study to ensure statistical significance of the findings of the project. Multidisciplinary research projects are encouraged in view of developing this broader view.

### Long-term Objectives

Research in public health is crucially important in establishing the knowledge base and providing concrete measures by which health research results will be fed into policy-making, for analysing and filling the gaps in environment and health activities. The main objective of research is to provide information to policy makers to maintain a high quality of health services and improve the population's health.

Research in public health is furthermore of high importance to reduce the additional health care costs due to population ageing. Health improvements could reduce by 50% the predicted increase in spending due to ageing by 2050[10], as "the demand for healthcare depends ultimately on the health status and functional ability of (elderly) citizens, and not on age per se"[11].

[10] Estimations of the Economic and Financial Affairs Directorate General of the European Commission. [Source: Braun, A. et al., EFMN ISSUE ANALYSIS REPORT 2006].
[11] "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.

## 5.5. Societal Challenges for Luxembourg

Luxembourg is facing a number of complex and interrelated socio-economic challenges, such as the necessity to foster employment and competitiveness, reduce inequalities, and increase well-being and social cohesion. Social, cultural and educational challenges have to be tackled, while issues like sustainability, demographic change, migration and integration or quality of life are just as important.

Within the CORE programme three main research topics were selected.

- Social and Economic Cohesion
- Education and Learning
- Identities, Diversity and Interaction

Within these topics there is a need for comparative research with other countries in order to increase the visibility of Luxembourg's research. For a small country like Luxembourg it is vital that local research addresses the Luxembourg specific problems and research issues which will not be addressed by the international research community. However, internationally visible research cannot only focus on Luxembourg problems, but needs to be embedded in research networks also addressing the international research trends covering these phenomena. Linking to international research, developing comparative research designs and data structures that will be used to compare the Luxembourg situation with the larger world will also add to enrich knowledge about the dynamics underlying social development and cohesion in Luxembourg.

Many issues from the above three thematic axes are transversal and inter-/transdisciplinary, for example integrating in particular questions concerning:

- immigration and migration
- mobility/cross-border studies and (inter)regional interactions
- gender dimension
- legal issues

Research projects combining these thematic axes or transversal/transdisciplinary issues are also highly welcomed.

### 5.5.1.Social and Economic Cohesion

#### Challenges in the National Context

Demographic changes will challenge European societies on several dimensions, most notably with respect to living standards and social cohesion, prosperity as well as sustainability of public finances. Economic globalisation as a further dynamic rapidly affects national economies. In the wake of this, social policy models are challenged, the "social welfare" state seems at risk, thus, alternative social policy models are projected. Moreover, the Luxembourg labour market will have to rely on a growing population of cross-border workers excluded from the political and democratic processes in Luxembourg. Furthermore, democratic institutions and political participation of citizens are challenged in times of crisis.

All these developments will have a strong impact on social cohesion and social peace as well as economic development. Luxembourg will thus have to face changes that are unprecedented in its history. Knowledge on influencing factors and on options for regulating societal development in a direction that will guarantee social cohesion and welfare on the basis of sustainable economic growth is needed.

Population dynamics (including demographic and social changes), dynamics underlying economic growth in a globalised world, well-functioning of political and social institutions and social sustainability are main domains or factors that have an impact on social and economic cohesion. They give rise to several key axes for public research in Luxembourg.

### Research Issues

- Population dynamics, in particular (over-)ageing of society and its diverse effects on society
- Effectiveness and sustainability of the social protection system, especially with respect to social inclusion and poverty risk reduction
- Impact of economic performance and economic competitiveness on social cohesion, as well as concepts of well-being of society as a whole (including new models of societal stratification and cohort dynamics)
- Impacts of economic decision making (in particular international/multinational companies) on social cohesion
- Individual conceptions of quality of life, social realities and inequalities
- Corporate/institutional behaviour and social dialogue (e.g. corporate social responsibility)
- Factors contributing to supply and demand of labour and employment (e.g., labour flexibility, new work models)
- Impacts of political decision making, political structures and practices on social cohesion and possible impact on cross-border regions
- Functioning of political and social institutions and political participation (e.g., participation of immigrants and cross-border workers on political decision making in Luxembourg; trend towards a “post-democratic” society)

## 5.5.2.Education and Learning

### Challenges in the National Context

In a global world with an increasing share of migrants, the heterogeneity of the population puts very specific challenges to the educational system. The ultimate challenge is to develop strategies that enable the educational system to perform one of its core tasks, namely to integrate a young generation and to train people so that they acquire and update over the lifespan the knowledge and skills needed to live and work in a modern society and economy.

### Research Issues

- Innovative strategies to cope with the heterogeneity of the population at school (in Luxembourg) and to solve inequalities related to the education system
- Performance of the educational system, including assessment methods for educational outcomes and the analysis of the interplay between individual learning and formal and informal learning environments across the lifespan
- Fundamental knowledge about learning and cognition, in particular in a multilingual context
- Developing new appropriate didactics for multi-language and multicultural school environments, taking into account the potential offered by new technologies
- Analysis of policy reform agendas, actual developments and reform success, in particular in a context of language and cultural diversity

These issues should be addressed through empirical and historical analyses using quantitative and qualitative methods.

Research should on the one hand help to develop a systematic knowhow on the educational system and how its national particularity performs and develops, through longitudinal data collected over the lifespan that track educational paths and system developments, as well as through educational monitoring.

On the other hand, research should also foster interventional studies at (pre-)school, for example explore language learning methods, gain knowledge about teachers' competences and assessment tools specific to a multicultural population, address gender and ethnicity issues, to name but very few.

Developing fundamental research in education, including the historical development of the educational system and social mechanisms behind educational inequalities regarding social origin, migration and gender, should be part of the research priorities.

Educational research may also include dissemination and implementation strategies for innovation in schools.

### 5.5.3.Identities, Diversity and Interaction

#### Challenges in the National Context

Research on "Identities, Diversity and Interaction" responds to a societal need to reflect upon itself in order to understand the current and historical transitions, the dynamics and the impact of change in an intercultural, pluri-generational and/or political context. The language diversity and cultural heterogeneity of the society puts specific challenges on governance and political participation and includes questions concerning integration and social cohesion.

#### Research Issues

- Construction of identities in intercultural contexts
- Inter- and pluri-generational relations
- Language diversity
- Multilevel governance and political participation

These issues are to be addressed in order to gain a better understanding of the dynamics of societal change and of inclusion and exclusion mechanisms.

Research on the construction of identities should take into account intercultural communication contexts in their historical, linguistic, spatial and/or political dimensions.

Empirical analyses on the present state of society, in particular with respect to cultural identities, barriers for political, social and work participation will also be encouraged.

The investigation of inter- and intra-generational relations should provide a better understanding of family interactions and other models of living together in past and present societies.

The analysis of language diversity in oral and written contexts should serve to establish new models of understanding social interactions and representations.

Multilevel governance is required with the involvement of civil society and economic actors in decision-making processes on local, regional, national and supra-national levels.

Interdisciplinary research approaches contribute to a better understanding of the dynamics of societal change under internal and external influences.

### Long-term Objectives for the Three Research Topics

The domain “Societal Challenges for Luxembourg” aims to establish a strong research base for the research topics listed above and to put into place an internationally visible (multi-disciplinary) research capacity that can respond to the identified societal challenges.

It is necessary to have a profound understanding of the dynamics of change and their impact on the society in order to govern social change. High-level socio-cultural and socio-economic research will help to improve governance and contribute to solving social problems as it will support policy-making with data, scientific expertise, conceptual clarifications, and well-grounded recommendations.

Luxembourg could function as a test bed, given that its multicultural society can have a “model character” for research on issues such as the construction of identities, cultural diversity as well as various aspects of social and political participation. These can be put to profit to develop new methodological tools and encourage international comparisons to test their validity for other contexts while remaining directly relevant at a local level. While involving actors for innovative societal solutions, research will contribute to modernising society as a whole.

The overall long-term goal is the contribution by a strong research base to a sustainable social and economic system. This is a long-term endeavour and requires that individual research projects do not always have to focus on Luxembourg, if their main goal justifies a different approach. Their focus can be on modelling, methodology, or themes of relevance in a context of international comparability.