

NATIONAL RESEARCH AND INNOVATION STRATEGY

FOR LUXEMBOURG

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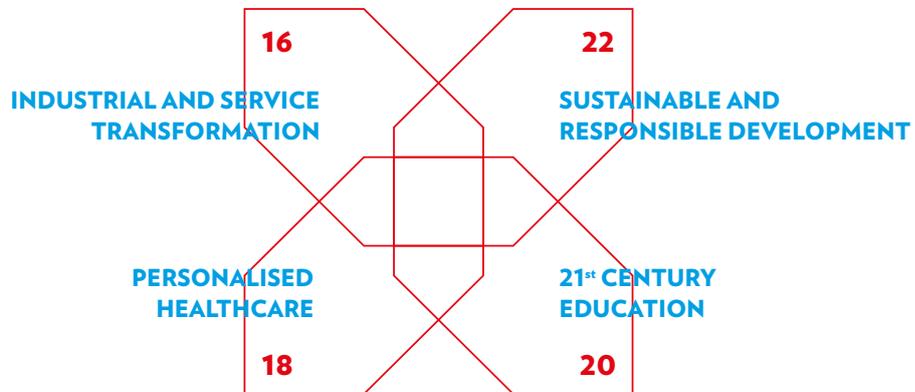
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FOREWORD

Luxembourg has reinvented itself a number of times in the course of its history.

After being a mainly agrarian society, the country started to industrialize around the middle of the 19th century to then turn into one of the world's leading steel producers. The decline of the steel industry in the 1970s opened the way for a second major economic development phase, namely the emergence of an important financial sector, which continues to be a key engine of today's economy. Around the turn of the millennium, Luxembourg started to pave the way for its future, a future characterized by a knowledge-based society, with a broader and more diversified economic base. Luxembourg has ever since consistently invested in higher education, research and development.

Today, Luxembourg is again reinventing itself in a context marked by developments that have an impact on a global scale. Climate change and its effects require new production and resource management models. Digitalisation implies fundamental changes in all areas of the economic and societal functioning. The data that we generate in unimaginable quantities through our connected lifestyle is a new resource with a yet unexplored potential, raising also questions related to privacy. Ongoing migration flows lead to a rethinking of the concept of identity within a society that perceives itself as open to diversity and to exchanges beyond cultural borders.

All these developments imply opportunities as well as risks. Luxembourg has the ambition to seize the opportunities lying ahead and mitigate the risks associated to them. This ambition of seizing the opportunities is associated to one major goal: initiate changes that will ultimately be beneficial for the citizen through an improvement of the general quality of life, be it with regard to health, job satisfaction, training opportunities, mobility, housing or environment.

To meet its ambitions, Luxembourg must resolutely invest in research and innovation, because the research ecosystem will be the main catalyst allowing us to seize the aforementioned opportunities. Research will generate the innovations that can improve the quality of life of tomorrow and it is by initiating collaborations between the research ecosystem and the different societal stakeholders that we will be able to introduce those innovations into our daily life.

To meet this challenge, a small country like Luxembourg must adopt a strategic approach that clearly defines the expected contribution from its research ecosystem to societal development and maximizes the synergies and complementarities between the different actors of research and innovation.

The present National Research and Innovation Strategy aims to provide the general framework that will allow for a targeted development of Luxembourg's research ecosystem in the years to come. It aspires to maximise its impact on the progress of the country and beyond while positioning Luxembourg as a major international player visible through its excellent research activities.

I am convinced that research will be one of the best ambassadors for a small country with a big impact.



Claude Meisch

Minister of Higher
Education and Research

INTRODUCTION

Public research in Luxembourg is a young and dynamic field and has progressed remarkably over the last two decades. Once a leading steel producer, later a global financial centre, Luxembourg started around the turn of the millennium to pave its way to the future, a future into a knowledge-based society with a broader and more diversified economic base. Since then, an attractive and fertile research and innovation ecosystem has emerged and gained international recognition in a number of fields, such as ICT and data science, health and biomedicine, materials or education. Time has now come to consolidate those achievements and to accompany research and innovation activities in such a way that they serve the implementation of the Luxembourg 2030 vision of a sustainable knowledge society and hence contribute to the future prosperity of the country.

In 2016, the Organisation for Economic Co-operation and Development (OECD) carried out a review of the innovation policy of Luxembourg, in which it identified three main challenges, namely:

- to consolidate the progress Luxembourg made over the past decade, and advance further to become a widely recognised location for research and innovation in Europe;
- to better link and orient more strategically the promising initiatives in the area of research and innovation that have been initiated during the recent period of rapid growth and change; and
- to improve governance and steer the innovation system in a way that enhances coordination across ministries and agencies, strengthens linkages between public research centres and the University of Luxembourg and helps better target long-term funding to the most promising research areas and groups.

In the governmental programme 2018-2023 and in line with the targets of the Europe 2020 strategy defined at European Union level, the government aims at raising public investment in research and development to 1% of the gross domestic product (GDP) by 2023 for the public and private sector, while “maximising the efficiency of the investment and the action deployed”.

To this end, the governmental programme foresees the development of a national higher education, research and innovation strategy. According to the governmental programme, “the University and the public research centres will dedicate the additional funding to a limited number of priority areas with a strong socio-economic potential and which contribute to international visibility.” The programme also defines the priority fields identified for the current legislative period, i.e. finance and in particular green finance, education, biomedicine, information and communication technologies, innovative materials, environmental sciences and ecological transition, and contemporary history. It mandates the Luxembourg National Research Fund (FNR) to prepare “an updated list of national priority areas for public research, which will allow reinforcing critical mass”. Furthermore, a trans- and interdisciplinary approach in public research as well as the transfer and use of research findings in priority areas should be encouraged in order to foster economic diversification in priority sectors such as the automobile industry, biotechnologies, environmental technologies, space technologies, information and communication technologies and logistics.

The present National Research and Innovation Strategy aims to contribute to the achievement of the goals defined in the governmental programme and to address the challenges identified by the OECD.

The present strategy has been developed on the basis of a *Revision of the National Priorities for Public Research* that the Luxembourg National Research Fund (FNR) had been mandated to carry out and the conclusions of which were presented to the Ministry of Higher Education and Research in April 2019. This review was complemented by consultations that were organised with the public research institutions, within the framework of a newly created coordination committee, and with all the ministries concerned between April and November 2019. The findings were consolidated in collaboration with the Luxembourg National Research Fund (FNR). The current document focuses on the National Research and Innovation Strategy. A similar document will follow on the national strategy for the organisation of higher education in Luxembourg.

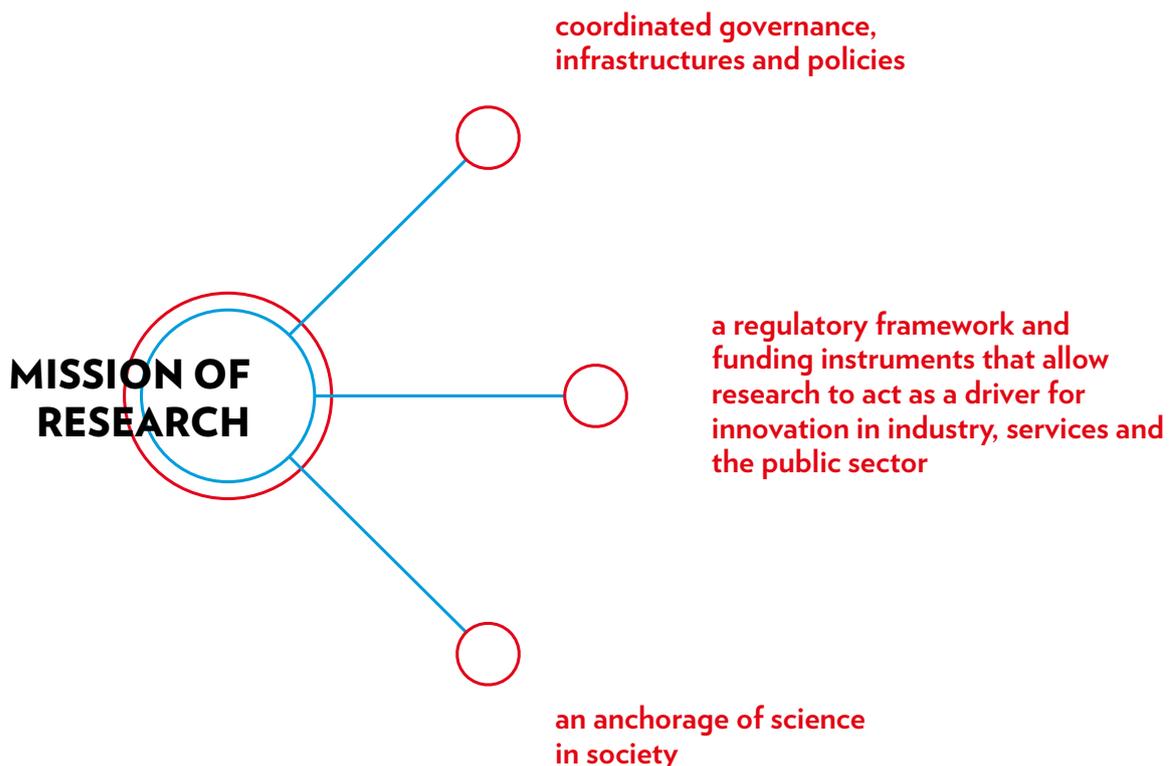
RESEARCH FOR LUXEMBOURG 2030

**HOW TO FULFILL
THE MISSION**

By 2030, Luxembourg aims to become a sustainable, knowledge-driven, diverse and trusted digital society. Today, we face many global challenges, including those related to poverty, inequality, climate change, environmental degradation, peacemaking and peacekeeping and access to justice for all. The 17 Sustainable Development Goals of the United Nations aim at addressing those challenges and Luxembourg should actively contribute to those efforts. Likewise, the six Political Guidelines of the new European Commission (A European Green Deal; An economy that works for people; A Europe fit for the digital age; Protecting our European way of life; A stronger Europe in the world; A new push for European democracy) will guide the Luxembourg research agenda. Luxembourg also strives to seize the opportunities linked to the unprecedented growth of digital technologies and their applications, and to become one of the most advanced digital societies in the world, with highest standards on data security, privacy and ethical data processing.

The science, research and innovation sector must be part of this vision. It must educate and attract the talents that a knowledge society needs, while valuing diversity. It must also contribute to assuring a high standard of living, a secure and eco-responsible environment, an innovative education system, better health care for the population, a startup and innovation friendly economy as well as a better understanding of Luxembourg's diverse society. In this way, science, research and innovation can play a decisive role in achieving Luxembourg's vision for 2030.

In order to be able to fulfill this mission, the following elements are crucial for the research and innovation sector:



COORDINATED GOVERNANCE, INFRASTRUCTURES AND POLICIES

In its 2016 review of the Luxembourg innovation policy, the OECD identified improved governance of and enhanced coordination between the different actors of the research and innovation sector as main challenges. As one of the results, the aforementioned coordination committee, chaired by the Ministry of Higher Education and Research and composed of executive representatives of the University of Luxembourg, the three public research centres and the Luxembourg National Research Fund (FNR), was created in view of becoming a central element for a coordinated governance of all major public research actors. This committee has provided input for the present strategy and will continue monitoring its progress. The committee will also aim at taking joint actions, e.g. in view of the national and international promotion and branding of the Luxembourg research ecosystem under the label “Research Luxembourg”, and in view of fostering Luxembourg’s efforts in Science Diplomacy.

In order to continue encouraging excellence in research, the government will further develop the current funding model of the public research institutions via coordinated multiannual contracts including key performance indicators. These will be adapted in order to monitor the different facets of the mission described in the present strategy. In line with the targets of the Europe 2020 strategy and as set out in the governmental programme 2018-2023, the government will aim at raising public investment in research and development to 1% of GDP. This 1% target will include public spending in both the public and the private sectors, while public sector spending is expected to reach 0.8% of GDP.

Besides excellence in research activities, another important means of advancing research and innovation and making Luxembourg attractive and competitive on an international level are excellent research infrastructures. In this sense, a national High Performance Computing (HPC) facility, comprising the facilities of the public research institutions complemented by the joint structure for the European high performance computing joint undertaking (EuroHPC) to be hosted in Luxembourg, will continue to play an important role as will the Integrated Biobank of Luxembourg (IBBL) of the LIH. Luxembourg will also continue participation in research

infrastructures at European level, such as ELIXIR, DA-RIAH, SHARE, EATRIS or PRACE and actively participate in the intergovernmental research organisation EMBL (European Molecular Biology Laboratories). At national level, Luxembourg will explore the idea of a national service provision model for services around the data value chain that would serve the entire research ecosystem.

In terms of research culture, the government will strongly encourage and support the adherence to fundamental values, including ethics and integrity, and will support the Open Science initiative in order to make research more open, global and collaborative and to bring it closer to society. Efforts will also continue to be made in view of increasing the attractiveness of researcher careers in Luxembourg, through a value reward and incentive system that recognizes the full range of outcomes from scientific activities, including knowledge transfer, training and developing people, fostering teamwork and communication. Concerted efforts will be made to significantly improve gender equality in public research and to make diversity and inclusion one of the priorities. The government’s aim is to position Luxembourg as a particularly attractive research location for the next generation of bright talents, women and men.

In terms of policy, joint guidelines for the public research sector will be developed on sensible topics, such as intellectual property, dual use of research results as well as privacy and security, which play an increasingly important role in research activities.

RESEARCH AS A DRIVER FOR INNOVATION IN INDUSTRY, SERVICES AND THE PUBLIC SECTOR

The Luxembourg government has made research and innovation the cornerstones of its vision for the country's future. In order to make research a driver for economic diversification and for innovation in industry, services and the public sector, an appropriate regulatory framework is essential. The government will therefore encourage the creation of public-public partnership units between research institutions and interested ministries, including a better integration of cultural institutes into public research activities, as well as the development of public-private partnership programmes in coordination with existing efforts by the Ministry of Economy or by Luxinnovation. Appropriate funding instruments will be implemented through the Luxembourg National Research Fund (FNR). In addition to the already existing programmes to fund collaborative research between the Luxembourg public research institutions and private companies in Luxembourg or abroad, new schemes will encourage joint funding with ministries.

ANCHOR SCIENCE IN SOCIETY

On its way towards establishing Luxembourg as a leading knowledge-based society, the government has also set itself the goal of solidly anchoring science in society and fostering societal impact. Besides the continuation and further development of a variety of science promotion activities, citizen science will be strongly encouraged as an integral part of all research activities. Promoting science to economic and societal stakeholders and raising awareness about the importance of knowledge and innovation is key and will be fostered, as will be the interaction between researchers and policy makers to encourage evidence-based policymaking.

MISSION LUXEMBOURG 2030

WHERE TO INVEST

As has already been outlined, the government has set itself ambitious goals regarding the increase of public spending for research and development. This increase of public investment in research will be realised in a targeted way. On the one hand, it will allow the consolidation and the further development of a research ecosystem delivering scientific excellence and making Luxembourg internationally visible and attractive for talented researchers. On the other hand, it will serve the mid- and long-term objectives of the country, whether they be ecological, societal or economic. The present research and innovation strategy describes the areas for which further development and investment are considered important in order to reach these objectives.

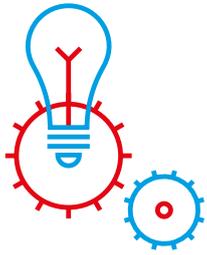
The National Research and Innovation Strategy will mainly be implemented through the funding programmes of the Luxembourg National Research Fund (FNR), especially through the multi-annual thematic research programme CORE, whose priority areas will be aligned with the present strategy, but also through talent-attraction programmes and through mission-oriented research programmes. The latter are research programmes aimed at addressing a concrete societal or technological challenge, generally in an interdisciplinary way, through collaboration of different – public and private – research institutions and possibly other stakeholders.

The present strategy does not make the distinction between fundamental and applied research, as both types of research will be supported in the priority areas. It should also be mentioned that the priority areas will not be the only areas in which research will be carried out and supported in Luxembourg. Luxembourg's public research ecosystem is composed of autonomous institutions, which are supported through substantial block grants provided by the government. All of these institutions will develop or have developed, in the context of their autonomy, institutional strategies that are of course expected to take into account the framework provided by the national research and innovation strategy. However, they can and should also set institutional

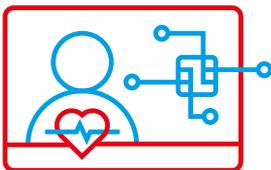
priorities that extend this framework in a meaningful way. Furthermore, the Luxembourg National Research Fund (FNR) will continue its funding schemes that support projects outside the priority areas (e.g. the OPEN and INTER programmes) necessary for a trusted data-driven economy.

FOUR INTERDISCIPLINARY RESEARCH PRIORITY AREAS TO PREPARE LUXEMBOURG FOR THE FUTURE

At the top level, the national research and innovation strategy defines four research priority areas, which have emerged to be of particular importance for the societal, ecological and economic development of the country. These areas are not considered as being distinct and independent from each other but as areas that mutually influence each other, so that the sub-themes that define each area can also have ramifications into other areas. The implementation of the research strategy will therefore put a particular emphasis on interdisciplinary projects, which take into account that each of the four broad research priority areas will benefit from results and projects situated in one or more of the other areas. The four chosen research priority areas should guarantee that beyond a development of its GDP, Luxembourg can warrant for a continuous and sustainable development of the well-being of its population, including notably health, environmental and educational factors.

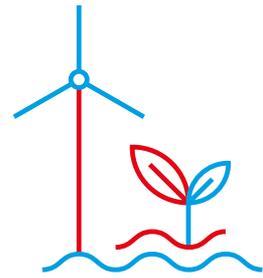


INDUSTRIAL AND SERVICE TRANSFORMATION

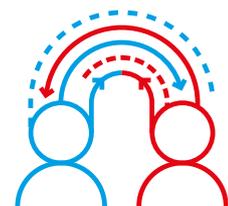


PERSONALISED HEALTHCARE

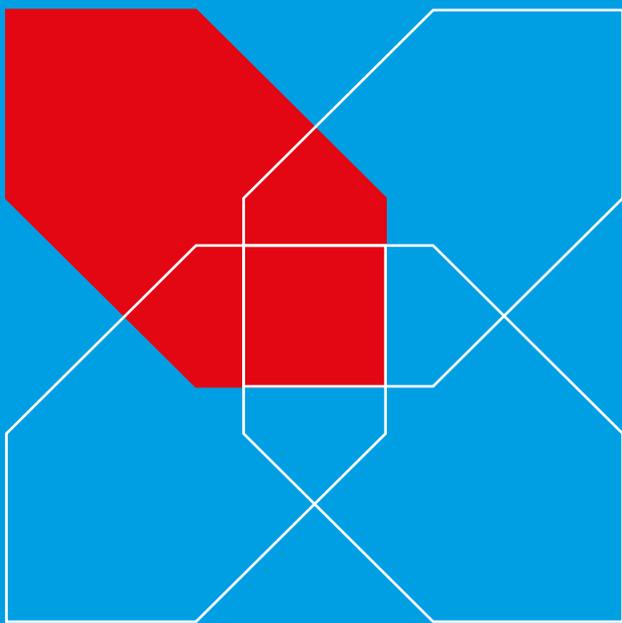
SUSTAINABLE AND RESPONSIBLE DEVELOPMENT

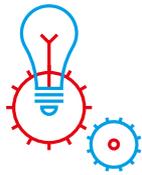


21st CENTURY EDUCATION



INDUSTRIAL AND SERVICE TRANSFORMATION





The upcoming digitalisation will imply fundamental changes for industry and service providers that are active in Luxembourg. The country has the ambition to become a knowledge-driven data economy actively seeking to diversify its economic activities taking up the latest technological developments and providing high value added. The research carried out in this area should provide the scientific basis for such a development. It encompasses research in the industrial fields in which Luxembourg wants to consolidate and further develop its assets, for example in material science, space industry, or in the field of automation and robotics.

Data modelling and simulation are seen as a key enabling technology in this area. It also includes new communication and computer systems and the associated challenges regarding cybersecurity needed for a trusted data-driven economy in an ever more connected world. Furthermore, this research seeks to bring new perspectives to Luxembourg's most important economic sectors, like the financial industry, through the development of key technologies in the fintech/regtech area or in the field of distributed ledger technologies. The latter can also be applied in the field of "govtech" in the public sector.



Autonomous and intelligent systems and robotics for earth and space



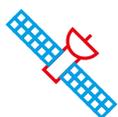
Fintech/RegTech and transformative applications of distributed ledger technologies



Future computer & communication systems



Fundamental tools and data-driven modelling and simulation



Space telecommunications, earth observation and space resources

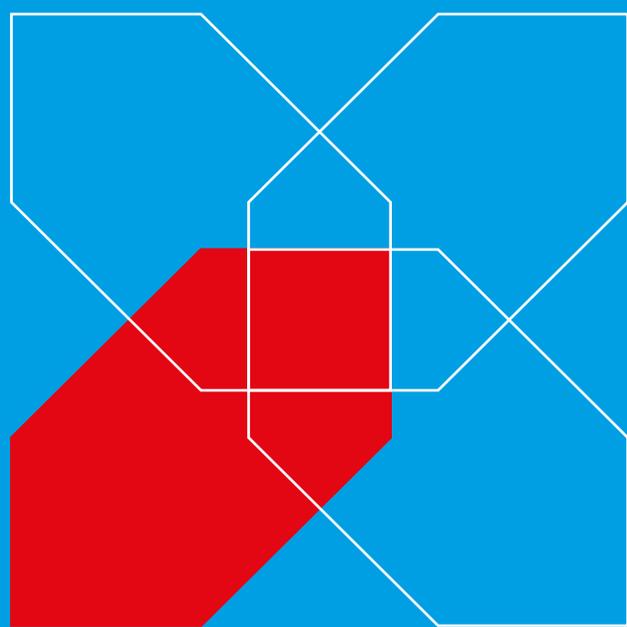


Trusted data-driven economy and critical systems



Integrative Materials science and technology

PERSONALISED HEALTHCARE





Health is considered to be a key indicator of well-being and Luxembourg has the ambition to provide excellent healthcare to its population and to be a frontrunner in the implementation of the latest health technologies. Especially in the field of personalised data-driven digital medicine, Luxembourg wants to be among the leading countries in the world. Luxembourg therefore needs biomedical research that will ultimately be beneficial to the patient and contribute to the consolidation of an innovative, sustainable and efficient health system. Following this logic, translational medicine will play an important role in the medical research carried out in Luxembourg.

Luxembourg will continue to promote the important contributions to personalised medicine from research, carried out notably under the European programmes Horizon 2020 and Horizon Europe, in order to speed up the development of more effective preventive and diagnostic tools as well as better and safer medicines for patients.

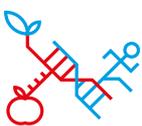
The perspective on health will nevertheless not be limited to a purely biological or medical perspective, but will include socio-economic and behavioural aspects considered in a longitudinal perspective throughout the lifespan, which should permit an emphasis on disease prevention and behavioural changes.



Complex biomedical systems – data and models



Understanding, preventing, and treating the health-disease transition

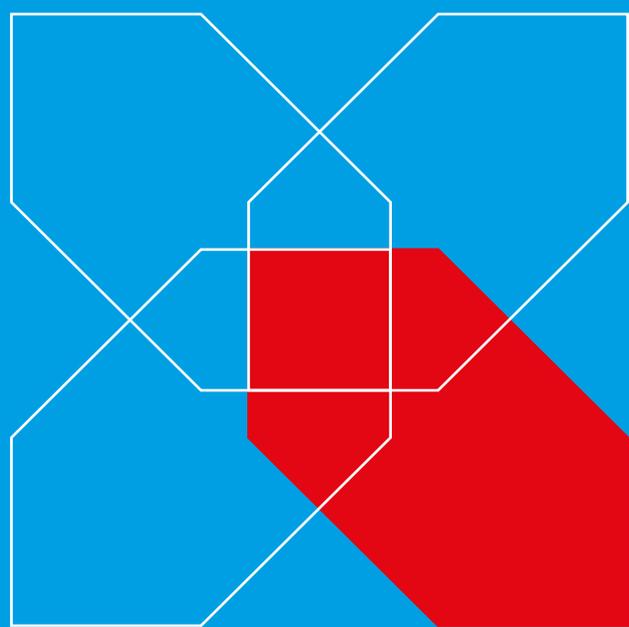


Precision medicine, including environmental, lifestyle and socio-economic factors



Data-driven healthcare

21ST CENTURY EDUCATION





Education is another major cornerstone for the well-being of a society, as it forms the basis for employment, societal participation and ultimately for our democratic functioning. It is foreseeable that education will undergo major changes throughout the 21st century, for different reasons.

Educational systems are currently educating for unknown professional environments, as the upcoming digitalisation will dramatically increase the speed of creation of new job profiles, while existing job profiles might disappear. The fast pace of technological developments therefore implies the need to better monitor the skills gap existing between need and supply and to train the population in new, highly dynamic digital skills.

Digital tools and technologies thus become the content of new training programmes while also being used as a means of delivery for these new contents. In terms of key competencies, transversal skills, such as problem solving and communication skills, are more and more valued, as they form a skillset that is needed in order to cope with these fast-paced developments and changes.

Lifelong Learning changes from a model that historically implied the update of existing skills to a model in which completely new skillsets have to be acquired in short periods of time in order to cope with the more fundamental changes in career paths that we will see in the future. These new educational challenges are added to the already existing ones of providing high-quality, inequality-avoiding initial training to a very heterogeneous and multilingual school population.

Luxembourg will therefore invest in educational research in order to develop innovative, digitally enhanced learning environments that will be beneficial to a diverse and multilingual school population and thus contribute to equal educational opportunities. Luxembourg also has the ambition to be among the frontrunners in the field of adult education and develop the needed research programmes in order to be well prepared for the upcoming major trends of upskilling and reskilling the workforce.



Innovative digitally enhanced learning and assessment environments



Equality of educational opportunity

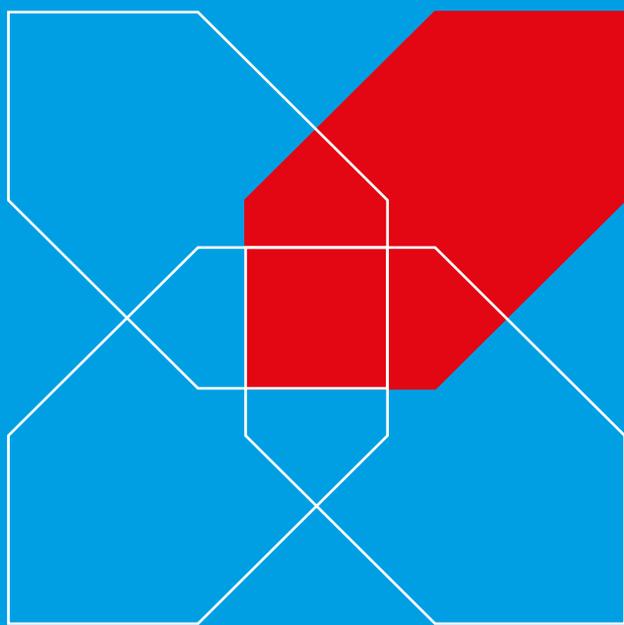


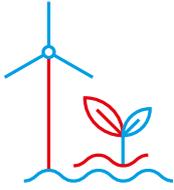
Learning in a multilingual and diverse society



Adult education, up/re-skilling and lifelong learning

SUSTAINABLE AND RESPONSIBLE DEVELOPMENT





Luxembourg fully subscribes to the sustainable development goals of the United Nations and will contribute through its research activities to a sustainable development from an ecological, economic and societal perspective, in line with the ten priority fields of action of the National Plan for Sustainable Development. In the ecological field, a focus will be on research in the context of a transition to sustainability and climate change. Luxembourg has the ambition to become a model country for the green transition. To this end, research in the field of sustainable construction will play an important role in order to integrate energy efficiency, renewable energy, aspects related to environmental health and circularity into new and existing buildings. A focus will also be on the integration of renewable energies and of electro-mobility into the energy management system thanks to smart grids. Sociological aspects related to the adoption of a more climate-friendly lifestyle as well as spatial planning and mobility concepts will be other important research topics.

Luxembourg will develop technologies to continuously monitor the effects of climate change on ecological systems and biodiversity and use this monitoring in

order to model future scenarios allowing for the country's best adaptation to a changing environment (e.g. in view of agricultural and forestry activities, but also in prevention of extreme events or with regard to water availability).

Economically, Luxembourg will innovate through research on new sustainable economic instruments and models, consuming fewer resources and producing less negative impact on the environment, especially in the areas of green and sustainable finance and circular and sharing economy.

A socially sustainable development is particularly important for a very diverse and multilingual country like Luxembourg and therefore research on different aspects of social cohesion, such as the social consequences of migration, of the energy transition and of labour market developments, but also questions of cultural identities, cultural heritage and nationhood will be included in this research area. Increased collaboration will be sought with cultural institutes on research topics related to cultural heritage, including digital aspects thereof.

Finally, increasing digitalisation raises the question how all these new developments and disruptive technologies can be responsibly implemented within an innovative legal environment in Luxembourg and Europe. In this context, questions about regulations for a responsible and privacy-respecting use of data, as well as ethical questions around data use and disruptive technologies such as artificial intelligence will be in the focus of Luxembourg's research efforts. Indeed, the transformations towards the 2030 objectives require a retooling of the legal framework.

The objective of becoming one of the most advanced digital societies in the world in terms of sustainable development, governed by inclusive democratic decision-making processes, requires innovative solutions in Luxembourg and European regulation. Examples include the adaptation of national and European legal systems to a data-driven and artificial intelligence-led

decision-making process, a legal framework that can foster the development of a data-driven and personalised healthcare environment, or the protection of the environment in a digitalised world that requires an in-depth rethinking of applicable standards both from a national perspective and in the light of the EU Digital Single Market. This strategy will therefore promote advanced legal research in the areas mentioned, including the development and implementation of tools to establish a legal framework that provides legal certainty for both citizens and businesses in the context of future developments. This is an important element in unlocking the full modernisation potential of technological progress for the benefit of society by providing the regulatory framework for a knowledge-driven economy and society.



Climate change: energy efficiency and smart energy-management/resilient eco- and agrosystems



Social: migration and social cohesion/cultural identities, cultural heritage and nationhood



Economic: green and sustainable finance/circular and shared economy



Responsible development: regulations and ethics for a data-driven society

THE ROLE OF ARTIFICIAL INTELLIGENCE – LUXEMBOURG AS A LIVING LABORATORY FOR THE USE OF AI

The present strategy fully subscribes to the artificial intelligence strategy of the Government. Artificial intelligence is considered as a key enabling technology that will be used in each of the main four research priority areas. In line with the national strategy on artificial intelligence, Luxembourg has the ambition to scale AI for selected use cases at country level (for example in the fields of personalised healthcare or personalised education) and to become a living laboratory, showcasing how this technology can be used at country-level for the benefit of societal development. As a small country, Luxembourg can benefit in this context from its size and its ability to scale up more rapidly than larger countries, in order to become internationally visible as a frontrunner for the implementation of this disruptive technology. Moreover, Luxembourg can contribute to the elaboration of the standards of tomorrow by developing a legal framework for the use of AI based on ethical principles and by testing its implementation.

LEVERAGING THE IMPACT OF RESEARCH LUXEMBOURG THROUGH COORDINATION WITH LUXEMBOURG'S DEVELOPMENT COOPERATION POLICY

The country has the ambition to leverage the global impact of the efforts made at national level through a systematic scrutiny of the research results for their potential use and transfer to Luxembourg's development cooperation efforts. Luxembourg is indeed among the countries making the highest per capita contribution to development cooperation and many challenges that the development cooperation policy tries to address can benefit from technologies and results stemming from the research ecosystem. The process of transfer and adaptation of the output of the research ecosystem will therefore be implemented in a more systematic way and potentially combined with specific funding schemes in order to be beneficial in the context of cooperation development.

ROADMAP FOR THE FURTHER DEVELOPMENT AND ADAPTATION OF THE NATIONAL RESEARCH AND INNOVATION STRATEGY

This national research and innovation strategy should not be considered as fixed and unalterable, but as an ongoing process. During the first half of 2020, the third edition of the "Assises de la Recherche" will bring together important actors of research and innovation as well as societal stakeholders in Luxembourg in order to further discuss and consolidate the strategy. While the overarching ideas and principles underlying the strategy, and the four interdisciplinary research priority areas forming the backbone of it, should remain unchanged, the sub-themes within the four areas may be further discussed and may evolve in light of those discussions and of future developments.

They should be reviewed on a regular basis over the years to come through input provided by the coordinating committee chaired by the Ministry of Higher Education and Research, by the scientific board of the Luxembourg National Research Fund (FNR) and by governmental, economic and societal stakeholders.



LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Enseignement supérieur
et de la Recherche

LU  **EMBOURG**
LET'S MAKE IT HAPPEN