

2026

NATIONAL RESEARCH AND INNOVATION STRATEGY

FOR LUXEMBOURG

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RESEARCH FOR LUXEMBOURG 2030 »

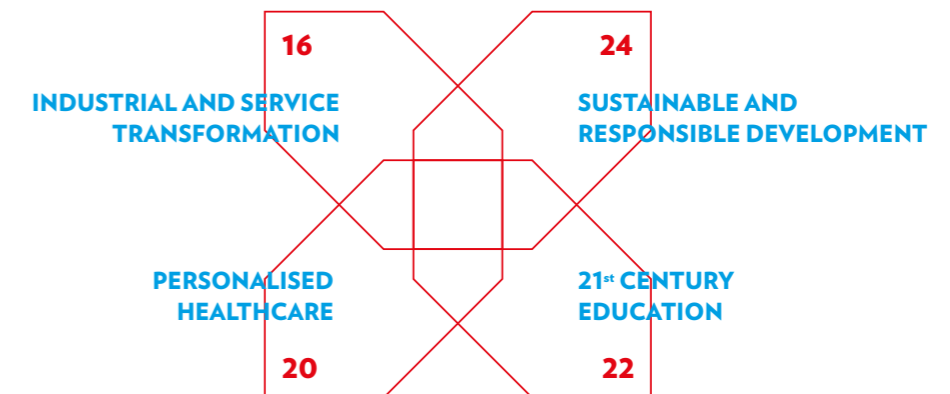
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FOREWORD

The world we live in today is no longer the same as it was in 2020, when the first National Research and Innovation Strategy was published. It is undergoing a period of profound transformation, driven by the emergence of disruptive technologies, foremost among which is artificial intelligence.

We are also facing a changing geopolitical environment and increased global technological competition. In this context, it is essential that Europe embraces innovation and seizes the opportunities offered by this technological revolution, as highlighted in the Draghi report on European competitiveness. It calls on the European Union to move beyond a fragmented and overly cautious approach to innovation and adopt a genuine common industrial and technological strategy.

Luxembourg has sought to position itself as a pioneer of such an approach by integrating its national strategies on artificial intelligence, quantum technologies and data into a coherent government-wide initiative aimed at accelerating the country's digital sovereignty. Data is the raw material of digital innovation, artificial intelligence enables value to be extracted from it, and quantum technologies promise to push the current limits of information processing, security and analysis.

Science plays a central and irreplaceable role in this dynamic. Research is the foundation on which disruptive innovations are built. As Minister for Research and Higher Education, I am proud to see how Luxembourg has built a dynamic and attractive research ecosystem. Since the beginning of this century, we have invested consistently and strategically to strengthen the capacities of our institutions, attract talent and encourage interdisciplinary research, which is essential for responding to the major challenges of our time.

Although the world has changed, our vision for Luxembourg 2030 – a sustainable knowledge society where research and innovation drive economic and societal

development – remains unaltered. It inspired the first national research and innovation strategy and is reflected in this update, which considers recent developments, particularly in digital innovation, while continuing to build on and consolidate the scientific expertise that has been developed.

This strategy will continue to evolve in the coming years in line with strategic and scientific developments to ensure that public investment in research and innovation, which the government is committed to maintaining at a high level, continues to contribute to boosting our economy, improving the quality of life of our citizens and strengthening our digital and technological sovereignty.



Stéphanie Obertin
Minister for Research
and Higher Education

INTRODUCTION

Since the beginning of the new millennium, successive Luxembourg governments have invested heavily in research and innovation, making them the cornerstones of their vision for the country's future. As a result, an attractive and fertile research ecosystem has emerged and has gained international recognition in a number of fields.

To consolidate these achievements and to accompany research and innovation activities in such a way that they contribute to the implementation of the Luxembourg 2030 vision of a sustainable knowledge society, the first national research and innovation strategy was adopted in December 2019. This strategy defined four research priority areas considered as particularly important for the country's societal, ecological and economic development. It also laid the groundwork for a regulatory framework and governance conducive to the targeted development of the research ecosystem.

The 2023-2028 government programme assures the continuity of these efforts. In it, the government commits to "pursuing the ambition of supporting the economic, social and ecological development of our society through a strong and consistent commitment to higher education and research". The government programme also provides for regular adaptation of the national research and innovation strategy, while maintaining and developing the four major research priority areas and placing an emphasis on the field of artificial intelligence. In addition, the government is committed to promoting innovation in order to position Luxembourg at the forefront of new technologies, particularly in the digital field, on a long-term basis.

This latter commitment resulted in the adoption in May 2025 of national strategies for data, artificial intelligence (AI) and quantum technologies. To align public efforts, the government has adopted a whole-of-government approach, integrating its strategies on cutting-edge technologies in a coherent and cross-cutting manner

within the framework of the strategic initiative "Accelerating Digital Sovereignty 2030". The common thread running through these three strategies is provided by six cross-cutting enablers, one of which is the stimulation of research and innovation, both in the public and the private sector, in order to solve complex societal challenges. The activities and priorities defined in this context will also be reflected in this strategy and will form an integral part of the sub-areas defined within the four major research priority areas.

In addition to these evolutions in new technologies and digital sovereignty, the higher education and research landscape is also marked by other important developments. These include the growing strategic role of research in the defence sector. Increased investment in defence-related research and innovation reflects a desire for technological sovereignty, which is essential for preventing future conflicts and protecting critical infrastructure. In this context, and given the geopolitical environment, research security considerations are also of increasing importance.

This strategy therefore aims to reflect these developments, while maintaining the governance principles and framework conditions as well as the four research priority areas defined in 2019.

RESEARCH FOR LUXEMBOURG 2030

HOW TO FULFIL THE MISSION

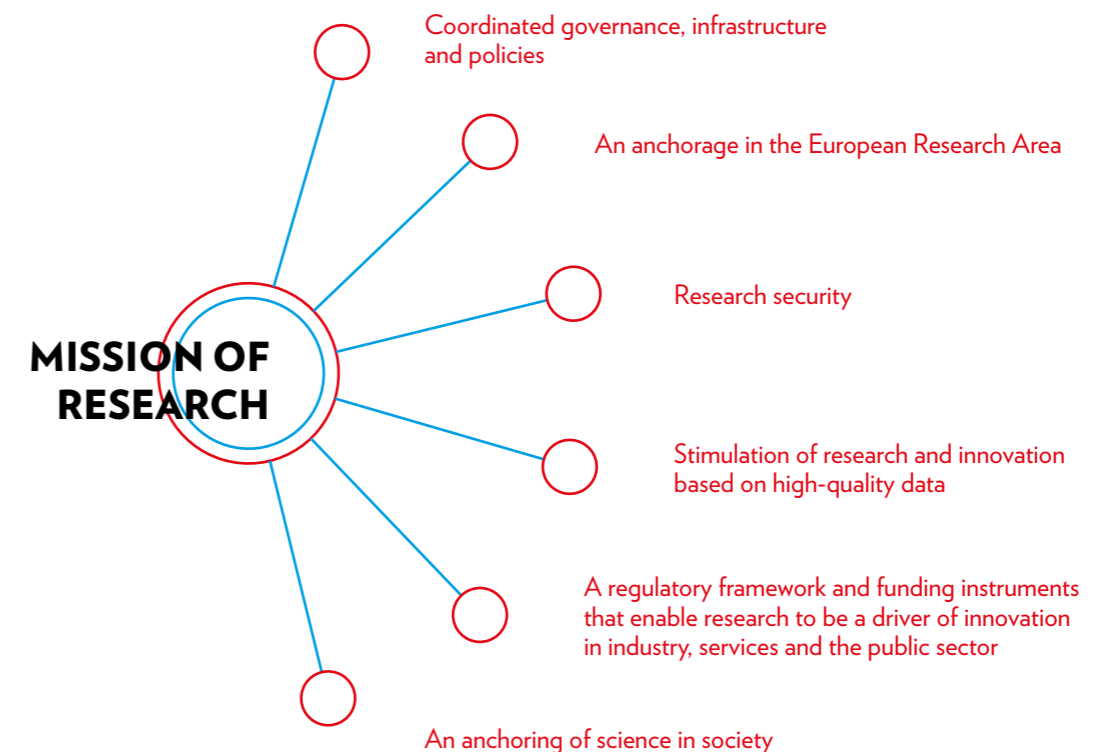
Luxembourg's vision for 2030, which inspired the development of the research and innovation strategy in 2019, remains unchanged and is also reflected in the strategic initiative "Accelerating Digital Sovereignty 2030". By 2030, Luxembourg aspires to become a country of digital and technological innovation centred on people, agility, sustainability and international collaboration.

The 17 Sustainable Development Goals of the United Nations, which aim to address the challenges we face globally, including those related to poverty, inequality, climate change, environmental degradation, peace-building and peacekeeping, and access to justice for all, will continue to serve as our guidelines.

We will also be guided by the European Commission's political guidelines for the period 2024-2029, which are structured around six main priorities aimed at making the European Union stronger, safer, more prosperous and more competitive in the face of global challenges. These priorities are inspired by the reports published in 2024 by Mario Draghi and Enrico Letta, which call for urgent action to strengthen the EU's competitiveness and sovereignty.

The science, research and innovation sector will continue to be an integral part of this vision. It must train and attract the talent that a knowledge-based society needs, while valuing diversity. It must also contribute to ensuring a high standard of living, a safe and eco-responsible environment, an innovative education system, better healthcare for the population, an economy that is conducive to innovation and start-ups, and a better understanding of Luxembourg society in all its diversity. Public research has the ambition to serve citizens, the economy and the State by ensuring that innovation moves beyond the laboratory and becomes embedded in the real economy. In this context, particular emphasis will be placed on creating added value for the economy and society by promoting the dissemination of knowledge, open innovation and social impact. In this way, science, research and innovation can play a decisive role in achieving Luxembourg's vision for 2030.

To be able to fulfil this mission, the following elements are crucial for the research and innovation sector:



COORDINATED GOVERNANCE, INFRASTRUCTURE AND POLICIES

Created in July 2019, the Strategic Steering Group (SSG) is a key instrument to ensure better coordination between the main players in public research in Luxembourg and to optimise the effects of synergy and complementarity between institutions. Chaired by the Ministry of Research and Higher Education (MESR), it is composed of executive representatives of the University of Luxembourg, the three public research centres and the Luxembourg National Research Fund (FNR). The SSG has contributed to the updating of this strategy and will continue to monitor its future development. In addition, the committee will strive to take initiatives to encourage collaboration and coordination between the four research-performing institutions, such as shared and coordinated infrastructure, models for cooperation between institutions, and a common approach and sharing of best practices in research security.

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 to reflect the different facets of the mission described in this strategy.

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. Luxembourg has invested in the development of a state-of-the-art digital infrastructure, including Tier I to Tier IV data centres, cloud solutions and the Meluxina supercomputer. The development of national high-performance computing (HPC) infrastructure, including the facilities of public research institutions supplemented by the Meluxina supercomputer developed in Luxembourg as part of the European High Performance Computing Joint Undertaking (EuroHPC), will continue to play an important role. This will be complemented by a new EuroHPC supercomputer optimised for artificial intelligence, MeluXina-AI, and the associated Luxembourg AI Factory. In addition, a new EuroHPC quantum computer, MeluXina-Q, will integrate quantum computing capabilities into the existing MeluXina supercomputer. These infrastructures will be essential tools for research institutions, which will actively contribute to activities in this area.

Furthermore, Luxembourg will continue to support the Integrated Biobank of Luxembourg (IBBL) of the Luxembourg Institute of Health (LIH) and the Luxembourg Clinical and Translational Research Centre (LCTR-Fuerschungsklinik Lëtzebuerg), a national research infrastructure bringing together clinicians, researchers and patients with the aim of translating research results into tangible therapeutic and diagnostic

solutions. Luxembourg will host the Genome EDIC platform, which aims to provide secure, federated access to genomic and health data through a decentralised architecture based on national nodes that store data locally while ensuring controlled cross-border use.

Space-related research infrastructures, such as LunaLab and the dusty thermal vacuum chamber, are essential assets for research and innovation related to the space industry and must be maintained. Luxembourg will also continue to participate in European research infrastructures such as ELIXIR, DARIAH, SHARE, EATRIS and PRACE.

In terms of research culture, the government will strongly encourage and support the adherence to fundamental values, including ethics and integrity. It will continue to support the principle of Open Science in order to make research more open, international and collaborative and to bring it closer to society, while remaining mindful of the practical, financial and security implications of this approach. Efforts to establish a national scientific bibliography, in collaboration with the National Library of Luxembourg, will continue. We will also continue to strive for more attractive research careers in Luxembourg through a value reward and incentive system that recognises 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 promote gender equality in public research and to make diversity and inclusion a priority. The government thus aims to position Luxembourg as a particularly attractive research ecosystem for the next generation of bright talents, women and men.

ANCHORING IN THE EUROPEAN RESEARCH AREA

A small research ecosystem such as ours cannot function in isolation. Cross-border collaboration, particularly with other European Union member states, is central to excellence in research and innovation. As mentioned above, this strategy is in line with the European Commission's policy guidelines for the period 2024-2029. These priorities, which are inspired by the reports of Mario Draghi and Enrico Letta, aim to ensure the economic growth and competitiveness of the European Union by developing a circular and resilient economy, focused on research and innovation, while strengthening its technological sovereignty and security. This strategy fully endorses these objectives. To achieve them, it is essential to continue building a strong, attractive and forward-looking European Research Area (ERA). Luxembourg will actively contribute to the implementation of the ERA and will continue to support the participation of research institutions in the framework programme for research and innovation, Horizon Europe. National research and innovation activities will aim to support European initiatives, such as the European Commission's Strategy on Artificial Intelligence in Science and the research and innovation activities of the Quantum Europe Strategy.

Beyond Europe, Luxembourg will remain open to research partnerships with countries sharing the same principles and values.

RESEARCH SECURITY

International cooperation is at the heart of excellence in research and innovation. However, given the current geopolitical situation, researchers and research institutions are increasingly exposed to risks when collaborating internationally, whether these risks relate to the leakage of sensitive knowledge and technologies, foreign interference or malign influence, or the misuse of research results. Limiting these risks is becoming all the more important in the context of growing research and innovation activities in the field of defence.

In May 2024, the Council of the European Union adopted a Recommendation on enhancing research security, aimed at providing guidance on measures that Member States, the European Commission and research institutions could take to address research security risks arising from international cooperation. In line with this recommendation, research security procedures will be strengthened in Luxembourg. Greater attention will be paid to risk mitigation procedures and measures to raise awareness of research security risks among the academic community, while respecting academic freedom and the autonomy of research institutions and without compromising the principle of openness in the research environment.

RESEARCH AND INNOVATION BASED ON HIGH-QUALITY DATA

In line with the National Data Strategy, Luxembourg aims to stimulate research and promote innovation based on high-quality data. It aspires to create a dynamic research ecosystem based on data excellence by establishing a robust national infrastructure that ensures the reproducibility and reusability of research data. At the same time, the country is committed to developing data spaces that promote sharing and collaboration between the various players in the ecosystem, while establishing mechanisms to encourage researchers to share their data according to the FAIR principles, i.e. Findable, Accessible, Interoperable and Reusable. These data spaces provide a clear structure enabling actors from the same or different sectors to share, exchange and collaborate on data more effectively, while complying with applicable norms and standards.

The Luxembourg National Data Service (LNDS) will continue to play a key role in this context by facilitating value creation from the secondary use of data and by supporting the reliable sharing and reuse of public sector data.

Luxembourg will also seek to position itself as a central hub for international data exchange and as a centre of excellence for data-driven innovation and value creation. While at the international level, given its size, it is often unable to compete in terms of data volume, it will rely on its expertise in the field and its centralised and efficient data governance to facilitate and accelerate access to data and, as a result, its valorisation in a trusted environment. It will actively participate in the creation and possibly the hosting of common European data spaces.

To this end, Luxembourg's regulatory framework guarantees a centralised, unified and efficient governance for the management and reuse of public sector data in a secure processing environment. With a view to harmonisation, the Government will ensure that, in the framework of the implementation of common European data spaces, the procedures and designation of the Luxembourg Data Authority are aligned with the system established by the Law of 19 December 2025 creating the Government Commission for Data Sovereignty. This centralised governance benefits the research ecosystem by providing efficient, secure and harmonised access to data for reuse.

RESEARCH AS A DRIVER OF 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. For research to become a driver of economic diversification and innovation in industry, services and the public sector, it is essential to have an appropriate regulatory framework in place.

The government will continue to encourage public-private and public-public partnerships, including through the funding instruments of the Luxembourg National Research Fund (FNR). Calls for joint projects between public research organisations and companies will be organised in collaboration between the FNR and the Ministry of the Economy on the basis of a multi-year plan, with the possible contribution of other ministries depending on the themes chosen.

The government also aims to increase the number and quality of new companies whose value proposition is based on research results produced in Luxembourg. To this end, a coherent approach for the transfer of intellectual property from research institutions to start-ups will be developed. An important role in this context will be played by the Deep Tech Lab (DTL), announced as part of the strategic initiative "Accelerating Digital Sovereignty 2030". The DTL aims to stimulate the economic valorisation of Deep Tech research activities in Luxembourg by supporting and facilitating the development of innovative solutions. It will bring together national expertise in cutting-edge technologies, in particular related to artificial intelligence and quantum technologies, and contribute to efforts to attract, retain and develop talent.

ANCHORING SCIENCE IN SOCIETY

On its way towards establishing Luxembourg as a leading knowledge society, the government also aims to firmly anchor science in society and to foster its 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 policy-making.

MISSION LUXEMBOURG 2030

WHERE TO INVEST

As highlighted above, the government intends to continue providing substantial support for research and innovation as a driver of the country's economic, societal and ecological development, in line with its 2023-2028 government programme. It will therefore continue to invest in a targeted manner in public research with the aim of developing and consolidating the research ecosystem to enable it to produce excellent scientific results, make it visible internationally and attractive to talented researchers, and at the same time serve the country's medium- and long-term objectives, whether ecological, societal or economic. This Research and Innovation Strategy outlines the areas in which investment is considered important in order to achieve this dual objective.

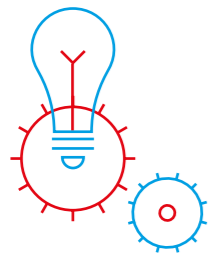
The National Research and Innovation Strategy will mainly be implemented through the funding programmes of the Luxembourg National Research Fund (FNR), especially through the multi-annual thematic research programme CORE, whose priority areas will be aligned with the present strategy, but also through talent-attraction programmes, such as PEARL and AT-TRACT. Research institutions may also be called upon to contribute to specific missions in strategic areas, such as the flagship projects defined under the strategic initiative "Accelerating Digital Sovereignty 2030" (see section on Accelerating digital sovereignty through artificial intelligence).

The present strategy does not distinguish between fundamental and applied research, as both types of research will be supported in the priority areas. It should also be noted that these 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 that receive substantial block grants from the government. All these institutions will develop or have developed, within the framework of their autonomy, institutional strategies that are of course expected to take into account the framework provided by the national research and innovation strategy, but which can and should also set institutional priorities that extend this framework in a meaningful way.

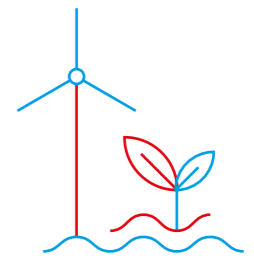
FOUR INTERDISCIPLINARY PRIORITY AREAS TO PREPARE LUXEMBOURG FOR THE FUTURE

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 country's societal, ecological and economic development. These areas are not considered to be separate and independent from each other, but rather as areas that mutually influence each other, so that the sub-themes that define each area may also have ramifications into other areas. The implementation of the research strategy will therefore place particular emphasis on interdisciplinary projects, which take into account that each of the four major priority research areas will benefit from results and projects situated in one or more of the other areas. The four chosen research priority areas should ensure that, beyond GDP growth, Luxembourg can warrant for a continuous and sustainable development of its population's well-being, including in particular health, environmental and educational factors.

**INDUSTRIAL
AND SERVICE
TRANSFORMATION**



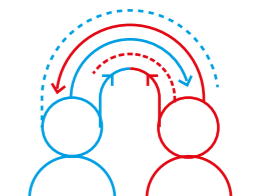
**SUSTAINABLE
AND RESPONSIBLE
DEVELOPMENT**

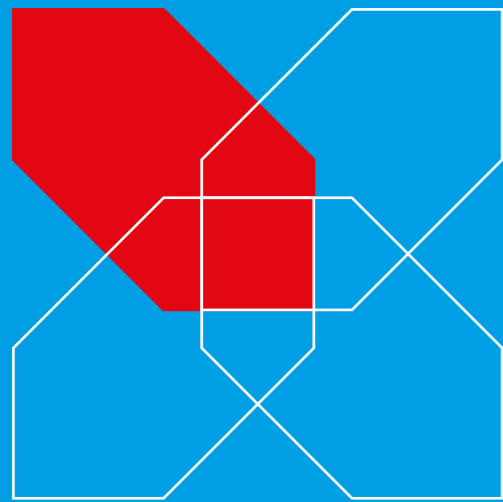


**PERSONALISED
HEALTHCARE**

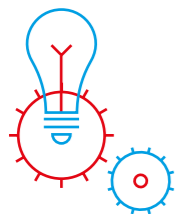


**21st CENTURY
EDUCATION**





INDUSTRIAL AND SERVICE TRANSFORMATION



Luxembourg aims to become a knowledge-based economy focused on data exploitation, using digitalisation as a catalyst to diversify its economic base and create high value-added services. This transformation requires a solid scientific foundation to guide innovation and ensure competitiveness, resilience and sustainability in a rapidly changing industrial and tertiary sector.

Research in this priority area will strengthen Luxembourg's strategic industrial fields, such as advanced materials, space technologies, automation and robotics, while integrating artificial intelligence, quantum technologies and advanced data analysis as cross-cutting catalysts. These technologies will accelerate modelling, simulation and optimisation processes, improve automation and open up new opportunities for industrial engineering and service innovation.

In order to build a trustworthy, human-centred technological ecosystem, Luxembourg must address challenges related to materials, hardware, software, communication and data technologies, while ensuring security and trust in environments where technology increasingly interacts and collaborates with humans.

The recent development of digital twins in areas such as smart cities, smart energy management and climate systems is promoting the emergence of a new generation of cyber-physical cognitive systems. These systems are increasingly user-centred and promote human-machine collaboration, which is essential for the next industrial revolution. New autonomous collaborative robotics and adaptive intelligent technologies must understand human factors. Coupling AI with cyber-physical systems and digital twins opens up new possibilities for predictive maintenance, real-time optimisation and resilient industrial processes, paving the way for smarter and more sustainable production environments.

These future systems require next-generation computing and communication systems, as well as cybersecurity measures that are essential for a data-driven economy, but which protect privacy in an increasingly connected world.

Luxembourg will advance next-generation wireless networks, including terrestrial mobile, radio and satellite networks, supported by AI-based optimisation and software-defined architectures for systems beyond 6G. These efforts will enable programmable and distributed infrastructures connecting devices, edge resources and the cloud, improving efficiency, reliability and security across the edge-cloud continuum. Applications such as connected mobility, smart industry and critical services will benefit from these capabilities. At the same time, Luxembourg will strengthen its role in the field of high-performance computing through the infrastructure of the European joint undertaking EuroHPC, promoting research on exascale systems, related architectures and energy-efficient data centres. This includes optimisation at all levels of the computing stack, from algorithms to workflow planning and data transfer, while promoting sustainability and open software practices.

Particular emphasis will also be placed on the development of quantum technologies. Luxembourg's quantum technology strategy, published in May 2025 as part of the strategic initiative 'Accelerating Digital Sovereignty 2030', sets out concrete measures and objectives aimed at making quantum technologies a driver of scientific excellence and technological progress in Luxembourg. It identifies quantum computing and algorithms, quantum communication networks and (post-) quantum cryptography as key research priorities. The development and adoption of these technologies will have a major impact on the evolution of autonomous systems, robotics, next-generation computing and communication systems, space telecommunications and materials science, and will thus have a considerable impact on industrial and service transformation. In line with these orientations and objectives, the present strategy integrates quantum technologies into the section entitled 'Future computing and communication systems' (see below).

Software engineering is integrated as a new sub-domain in this strategy, with a focus on the development of secure, reliable and sustainable software for critical sectors such as finance, autonomous systems and mobility. It promotes AI-augmented engineering and AI-based engineering sciences, while addressing the challenges posed by AI-based systems, generative AI and agentic systems. Research in the field of sustainable software engineering investigates how to improve energy efficiency, optimise resource use and, as a result, reduce

carbon emissions throughout the software lifecycle. The research ensures that scientific results and software systems can be reliably reproduced and validated, thereby promoting transparency and trust in today's complex AI-based environments. Software must also contribute to sustainable societal development by incorporating principles of fairness and compliance with regulations such as the GDPR and the European Regulation on Artificial Intelligence. Research examines how quantum and hybrid quantum/classical software systems are designed, implemented and tested in accordance with ethical and socio-technical considerations.

Today, Luxembourg has solid expertise in scientific instrumentation and advanced materials characterisation, enabling the study of matter at both the atomic and macroscopic scales and supporting applications ranging from environmental sciences to biotechnology. These capabilities open up opportunities in the fields of quantum technologies, environmental monitoring, health diagnostics and space research. Furthermore, research in the field of materials science and technology must go beyond the functionality of materials and also include sustainability throughout the process of sourcing, processing, use and disposal.

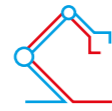
Research in the field of space telecommunications, Earth observation and space resources focuses on next-generation sensing technologies and integrated multiscale systems, combining high-resolution local measurements with large-scale remote sensing platforms. Combining these data streams with AI, machine learning and big data analytics enables real-time monitoring, predictive modelling and decision-making for complex space and Earth systems. Luxembourg will also advance technologies for the exploration and use of space resources, from prospecting to production, including tools for identifying and extracting resources on the Moon, Mars and asteroids. Furthermore, sustainability is at the heart of space research, with zero-waste concepts and circularity in space environments, and these innovations have direct applications on Earth.

Research and innovation in fintech/regtech focuses on implementing regulatory compliance and developing advanced methods for analysing the impact of regulatory changes to ensure that financial institutions can adapt effectively to changing legal frameworks. This includes modelling financial data using innovative models and calibrating them, as well as implementing robust

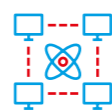
statistical techniques for estimating financial models. These capabilities are essential for risk management, pricing and forecasting in complex financial ecosystems. Transformative technologies such as AI are playing an increasing role in fraud detection, credit scoring and personalised financial services, while digital identity wallets are becoming essential for secure, user-centric financial ecosystems. By combining AI-based analytics with compliance automation and identity management, Luxembourg can strengthen trust, transparency and resilience not only in the financial sector, but also in the eGov sector, thereby improving the efficiency and transparency of public services.

Strengthening national data infrastructures and integrating advanced data analysis using high-performance computing will be essential to maintaining Luxembourg's leadership in these areas. These infrastructures will also enable Luxembourg to join, or even lead, European initiatives such as EDIC (European Digital Infrastructure Consortium), in particular Genome EDIC, which Luxembourg is preparing to host.

By integrating sustainable, cutting-edge technologies and advanced data capabilities into industry and services, Luxembourg will not only adapt to global technological changes, but will actively shape them, thereby promoting sustainable growth and the resilience of its economy.



Autonomous and intelligent systems and robotics for earth and space



Future computer and communication systems, quantum computers and networks



Software engineering



Space telecommunications, earth observation and space resources



Materials science and technology



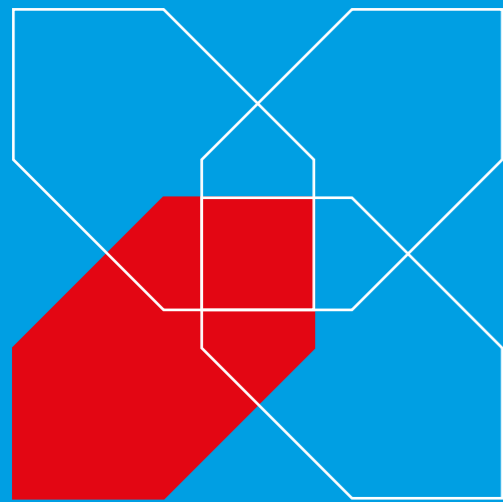
Fintech/Regtech and transformative applications of technologies



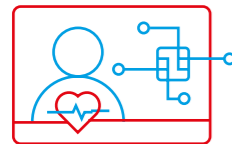
Fundamental tools and data-driven modelling and simulation



Trusted data-driven economy and critical systems



PERSONALISED HEALTHCARE



Health is a key indicator of societal well-being, and Luxembourg aims to offer excellent healthcare to its population while positioning itself as a leader in the adoption of cutting-edge technologies in the field of health. In particular, the country aspires to be one of the world's pioneers in the field of data-driven personalised digital medicine. This involves using genomics, advanced data analysis and artificial intelligence to tailor prevention, diagnosis and treatment to individual needs. This paradigm shift means that healthcare no longer follows a 'one size fits all' approach, but instead seeks precision solutions that improve patient outcomes and quality of life.

To achieve this ambition, the country needs biomedical research that directly benefits patients and strengthens the foundations of an innovative, sustainable and effective healthcare system. Translational medicine will play a central role in bridging the gap between laboratory

discoveries and clinical applications, ensuring that scientific advances translate into tangible improvements in patient care. Research conducted in Luxembourg will therefore focus on integrating clinical data, genetic information and digital health technologies to accelerate innovation and provide patient-centred solutions. One of the main catalysts for this vision will be the development of a national genomic data platform, providing secure, interoperable and ethically managed access to genomic information for research and clinical use.

This vision of health goes beyond biological and medical dimensions to include socio-economic and behavioural factors, taken into account throughout the lifespan. By adopting a holistic perspective, Luxembourg seeks to emphasise prevention, early intervention and behavioural change as key elements of personalised healthcare. Research will explore how lifestyle, environment and social determinants interact with biological factors, enabling more comprehensive strategies to be put in place to improve population health.

To this end, links with other fields, particularly social and environmental sciences, public health and health economics, are essential to deepen understanding of the onset and progression of disease. This interdisciplinary approach will accelerate growth in the field and foster

collaboration between biomedical research and other areas, including monitoring exposure to chemicals (such as persistent organic pollutants, endocrine disruptors and plant protection products) and pollution (air, noise, etc.).

Health economics will play a key role in assessing the cost-effectiveness, resource allocation and sustainability of personalised healthcare solutions. Research should explicitly consider socio-economic factors and the influence of built and natural environments to ensure that health policies and interventions are both effective and equitable.

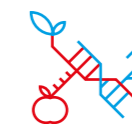
A complementary priority is the evaluation of health system performance, which examines how financing, purchasing and delivery arrangements affect equity, quality and efficiency. This theme includes observational and interventional research and aims to develop methods that translate research directly into patient impact through innovative and advanced clinical trials and the application of advanced causal inference techniques using observational data. By linking policy evaluation to clinical innovation, Luxembourg will ensure that health system reforms are evidence-based and aligned with patient needs.

This topic also requires highly interdisciplinary research approaches involving ICT and biomedicine experts in order to promote mutual understanding of needs and ensure that technological solutions are tailored to the needs of biomedicine. Such collaboration will enable the secure secondary use of health data to monitor health system performance and quality of care, while supporting innovation in digital health tools and AI-based analysis. By combining ICT expertise and biomedical knowledge, Luxembourg can create integrated and reliable solutions that improve patient outcomes and strengthen the resilience of its health system.

Improving individual health is the main expected impact, but this does not depend solely on data. Societal, economic, legal and regulatory aspects of digital health must also be taken into account to ensure the effective use of digital health data in the Luxembourg healthcare system.



Complex biomedical systems – data and models



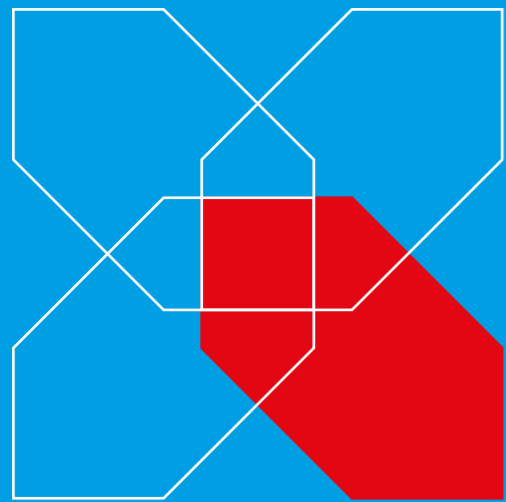
Precision medicine, including environmental, lifestyle and socio-economic factors



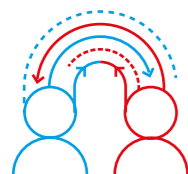
Understanding, preventing and treating the health-disease transition



Data-driven healthcare



21st CENTURY EDUCATION



Education and training remain a cornerstone of a society's well-being, as they shape employment opportunities, civic engagement and the functioning of the economy. Throughout the 21st century, education will undergo profound changes as a result of multiple factors. Rapid digitalisation is accelerating the creation of new job profiles while rendering others obsolete. Upskilling and reskilling are therefore becoming essential for Luxembourg citizens. This pace of technological development requires continuous monitoring of the skills gap and rapid adaptation of education and training systems to dynamic skill profiles.

Technology-assisted learning and assessment have evolved over the past two decades into an interdisciplinary field linking educational psychology, pedagogy and digital innovation. They emphasise the data-driven integration of technological tools into effective teaching

and assessment methods. In a context of rapid technological change, particularly in AI, IoT, virtual reality and connectivity, these technologies offer opportunities to transform education and thus provide more personalised services. However, they also raise challenges such as ethical concerns, barriers to adoption and the risk of a digital divide.

The workforce of tomorrow will need to be equipped with a dynamic mix of transversal and emerging skills, including analytical and creative thinking, technological knowledge, adaptability and resilience, as well as social and intercultural skills. Lifelong learning is evolving from a model focused on updating existing skills to one that requires the acquisition of entirely new skills in a short time frame, reflecting fundamental changes in career paths. These challenges are in addition to existing priorities of providing high-quality, equitable education to a diverse and multilingual population of pupils and learners.

Learning in a multilingual and diverse society requires inclusive educational approaches that view cultural and linguistic diversity as an asset. Schools and training programmes must integrate language awareness and intercultural skills alongside basic academic and digital skills, so that diversity becomes an asset rather than a barrier.

er. Technology-assisted learning can help achieve this goal by reducing language barriers, enabling equitable access to resources, and offering personalised learning pathways tailored to each individual's prior knowledge, skill levels, and needs.

AI is transforming technology-assisted learning and assessment by enabling personalised learning experiences through the creation of content tailored to individual needs and progress. It supports teachers by automating lesson plans, tests and multimedia resources, while providing learners with instant feedback and alternative explanations through intelligent tutoring systems. Furthermore, generative AI can improve accessibility through real-time translation and language assistance, create immersive simulations for hands-on training, and facilitate formative assessment, making education more engaging, inclusive, and effective.

As automation and AI reshape job profiles, the ability to learn continuously and adapt quickly is becoming essential. Skills upgrading and retraining are no longer optional, but are essential strategies for individuals and organisations to remain competitive, ensuring that workers can engage in lifelong learning and thrive in an economy characterised by rapid technological and structural change.

In addition, Luxembourg aims to position itself as a leader in the field of adult education by developing research programmes and technical platforms that, on the one hand, analyse the skills gaps and needs of the Luxembourg workforce and, on the other hand, recommend skills enhancement and retraining measures to address them.



Innovative digitally enhanced learning and assessment environments



Learning in a multilingual and diverse society



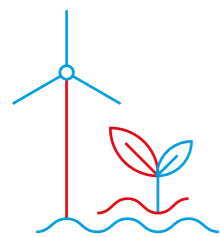
Equality of educational opportunity



Adult education, up / re-skilling and lifelong learning



SUSTAINABLE AND RESPONSIBLE DEVELOPMENT



Luxembourg fully endorses the United Nations 2030 Agenda and its Sustainable Development Goals. The country's research activities will actively contribute to the achievement of these goals, in line with the ten priority areas of the 3rd National Plan for Sustainable Development. This commitment is reflected in four key research areas that address the ecological, social, economic and regulatory dimensions of sustainability.

Digital transformation and sustainability are closely linked. Emerging technologies such as artificial intelligence, big data analytics and smart systems offer powerful tools to accelerate the ecological transition. Digital solutions enable real-time monitoring of energy consumption, predictive maintenance of infrastructure and optimisation of resource use across all sectors. They also support the development of smart grids, intelligent mobility systems and precision agriculture, all of which

contribute to reducing emissions and increasing resilience. At the same time, digitalisation must be guided by ethical principles and strong governance to ensure that technological progress serves environmental goals without compromising privacy or social equity.

Sustainability is not only a national challenge, but also a global responsibility. Luxembourg recognises that societal impact and international cooperation are essential to achieving meaningful progress. Research will therefore focus on how policies and innovations can strengthen social cohesion, reduce inequalities and promote inclusive growth. Luxembourg will actively collaborate with its European and international partners to share knowledge, harmonise standards and develop common solutions for climate change adaptation and mitigation, biodiversity protection and sustainable finance. These partnerships will amplify the country's contribution to global sustainability efforts while strengthening its role as a hub for responsible innovation.

In the context of climate change, Luxembourg aspires to become a model country for the green transition, with a focus on energy efficiency, renewable energies, renewable hydrogen, carbon capture and storage (CCS) as well as carbon capture and utilisation (CCU) and carbon dioxide removal (CDR). Research will focus

on smart energy management and sustainable urban development, integrating renewable energies, environmental health and circularity models. The integration of renewable energy sources into smart grids as well as sustainable and circular construction and sustainable mobility concepts will support this transition.

Research and innovation in the field of resilient ecosystems and agrosystems aims to ensure sustainable food production, biodiversity conservation, the increase of carbon storage and adaptation to climate change in the face of increasing environmental pressures and their impact on public health. This priority requires integrated approaches combining ecological sciences, precision agriculture and health sciences. Research will focus on developing climate-smart agricultural practices, while leveraging AI and IoT for real-time data analysis and circular bioeconomy models that reduce waste and optimise resource use. Interdisciplinary collaboration between agronomy, environmental sciences, health and socio-economic research is essential to design solutions that are not only environmentally sound, but also economically viable and socially inclusive. By encouraging innovation in these areas, Luxembourg can strengthen food security, mitigate climate risks, enhance emergency preparedness and response, and support the transition to sustainable and resilient societal systems.

New platforms, such as the Data-Driven Energy Transition (D2ET) initiative, will avoid duplication of effort and the adoption of isolated solutions by providing a shared environment where researchers can contribute data, models and scenarios. Models for agriculture, forestry, water management and extreme event prevention can thus be developed.

Research will promote the connection of national data platforms to pan-European platforms such as the Destination Earth (DestinE) initiative, which offers services based on holistic digital models of our planet. These innovations will strengthen Luxembourg's capacity to protect its population from emerging risks related to pollution, climate change and ecosystem degradation. Advanced monitoring and control systems using real-time sensors, satellite and remote sensing technologies, combined with big data analysis, will enable rapid risk assessment, early warning and effective mitigation of environmental problems.

Socially sustainable development is particularly important for Luxembourg society, which is characterised by its diversity and multilingualism. Research will focus on migration and social cohesion, exploring the social consequences of demographic change, energy transition and labour market developments. Issues of cultural identity, cultural heritage and national belonging will also be key, with increased collaboration between research institutes and cultural organisations being encouraged with a view to preserving and promoting heritage, including its digital aspects.

There is a need to rethink the nature of information technology in order to reduce its environmental impact, particularly with the use of AI. Luxembourg will promote economic sustainability through innovation in sustainable finance and the promotion of bioeconomic models linked to the life cycle of essential raw materials. These approaches aim to reduce resource consumption and environmental impact while promoting inclusive and forward-looking economic growth.

In addition, research should provide a better understanding of how Luxembourg can strategically strengthen its capacities in the fields of science, education and innovation. The aim is to leverage Luxembourg's innovation potential to increase national productivity while promoting inclusive and sustainable economic transformation. Research must therefore provide solid data and develop innovative methods to ensure the efficient allocation of resources and strengthen Luxembourg's capacity to seize opportunities related to technological progress, digitalisation and the ecological transition. This involves understanding how innovations are encouraged and adopted, and leveraging science and research to optimise these processes in order to maximise their impact.

Responsible development in a rapidly digitising world requires a robust legal and ethical framework. Research will focus on the regulation and ethics of a data-driven society, ensuring privacy-friendly use of data, addressing the implications of disruptive technologies such as artificial intelligence and quantum technologies, and implementing cybersecurity 'by design'. Luxembourg will work to adapt the national and European legal framework to support data-driven decision-making, personalised healthcare and environmental protection in a digitalised context. These efforts aim to provide legal certainty for citizens and businesses in order to unlock

the modernising potential of technological progress for the benefit of society and to strengthen democratic governance.

Through these integrated initiatives, Luxembourg seeks to position itself as one of the most advanced societies in terms of digitalisation and sustainable development, combining innovation, inclusiveness and resilience for future generations. The research results will also aim to contribute to strengthening democracy and maintaining public trust, and will lay the foundations for a smart, sustainable and data-driven economy and society.



Ecological development:
resilient eco- and
agrosystems, energy
efficiency and smart energy
management



Economic and industrial
development: green
and sustainable finance /
circular economy /
innovation and productivity



Societal development:
migration and social
cohesion / cultural identities,
cultural heritage and
nationhood



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

ACCELERATING DIGITAL SOVEREIGNTY THROUGH ARTIFICIAL INTELLIGENCE AND QUANTUM TECHNOLOGIES

This strategy is fully aligned with Luxembourg's artificial intelligence (AI) strategy, published in May 2025 as part of the strategic initiative "Accelerating Digital Sovereignty 2030". Through this initiative, the government aims to keep Luxembourg at the forefront of new technologies and to strengthen its digital sovereignty.

Artificial intelligence is considered a key enabling technology that should be used in each of the four main research priority areas. Research and innovation activities are considered essential to support the country in the rapid adoption of artificial intelligence and its deployment at national level, in line with the national artificial intelligence strategy. The operationalisation of this strategy will be based on a set of flagship projects reflecting concrete sectoral ambitions in strategic areas such as finance, health, culture, space, education, skills, cybersecurity, energy, mobility and the optimisation of legislative and administrative processes. Research will be called upon to contribute to the realisation of these flagship projects by 2030.

Certain types of work in artificial intelligence will be particularly important in achieving the above-mentioned objectives of accelerating digital sovereignty, namely:

Excellence in trustworthy, sustainable and secure AI

The country will focus on responsible AI by systematically integrating ethical, legal and social dimensions into its projects. It will develop AI audit frameworks, certification and ethical guidelines that will help to maintain fair and responsible AI systems. The emphasis will be on frugal AI with lightweight models that require fewer computing and energy resources. AI security will be a priority, with the development of tools to detect vulnerabilities and counter cyber threats.

AI for software engineering and software engineering for AI

Artificial intelligence is set to revolutionise software engineering by automating code generation and verification. At the same time, software solutions will power the next generation of AI solutions. These AI-based software solutions that power AI can then be applied to a wide variety of fields. Luxembourg will systematically focus on artificial intelligence for the development of software solutions.

AI as a catalyst for research innovation

The country aims to systematically use artificial intelligence in scientific discovery in order to accelerate advances in various disciplines through the use of AI. It will aim to support the development of specialised AI systems capable of generating new hypotheses, analysing complex experimental data, automating laboratory processes and modelling phenomena that are too complex for traditional computational methods. For a small country like Luxembourg with limited resources, this will accelerate scientific discoveries and leverage the resources deployed.

Although quantum technologies cannot be applied as broadly as AI in the four main research priority areas, they also form a pillar of tomorrow's digital transformation and are set to contribute significantly to Europe's digital sovereignty. As outlined in the Industrial and Services Transformation section, the development of post-quantum cryptography (PQC) and next-generation quantum communication technologies is indeed essential in order to ensure that information can be securely exchanged at both European and global level. In addition to this ambition, Luxembourg aims to participate in the development of quantum algorithms through the future MeluXina-Q infrastructure of the EuroHPC network, which will also support research and development efforts for disruptive European technologies.

RESEARCH AND INNOVATION FOR DEFENCE

In line with Luxembourg's Defence Industry Strategy, the government aims to promote local research and innovation in the field of defence and to support the development of skills, knowledge and technological innovations within Luxembourg research institutes and companies, in order to ensure the adaptability and renewal of defence capabilities in the face of evolving threats.

Research and innovation projects directly related to the field of defence will be supported through specific calls for projects in collaboration between the FNR, the Directorate of Defence of the Ministry of Foreign and European Affairs, Defence, Development Cooperation and Foreign Trade and the Ministry of the Economy.

Based on the existing skills and know-how in Luxembourg, a particular focus will be placed on the fields of materials and production technologies, automated and autonomous systems, cybersecurity, space technologies, military logistics and mobility, and circularity for defence. Data valorisation, artificial intelligence and quantum technologies will play an essential role as cross-cutting technologies and services.

The defence budget allocated to public research will ensure lasting economic and societal benefits for the country. The government will make sure that defence-related research activities are eligible for defence funding.

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

The country has the ambition to leverage the global impact of its national efforts by systematically reviewing research results with a view to their potential use and transfer in the context of Luxembourg's development cooperation efforts. Luxembourg is one of the countries with the highest per capita contribution to development cooperation, and many of the challenges that development cooperation policy tries to address can benefit from the technologies and results produced by the research ecosystem.

The government will therefore continue to encourage the research ecosystem to contribute to Luxembourg's development cooperation efforts, including through calls for joint projects between the Cooperation Directorate of the Ministry of Foreign and European Affairs, Defence, Development Cooperation and Foreign Trade and the FNR.

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

From the outset, the national research and innovation strategy was designed not as a fixed and unalterable document, but rather as an ongoing process. The current version of the strategy is the result of an update exercise, taking into account new national strategies on data, artificial intelligence and quantum technologies, and other recent developments, such as the increased focus on defence-related research and innovation.

The general principles underlying the initial strategy and the four interdisciplinary research priority areas that form its backbone have remained unchanged, and the sub-areas have only been adapted in specific cases.

The strategy will continue to be adapted regularly in the future, in consultation with the Strategic Steering Group and governmental, economic and societal stakeholders. A more in-depth review of the research priorities within the four priority areas could take place following an external evaluation of the FNR's CORE programme, which is the main funding instrument underpinning this strategy.



THE GOVERNMENT
OF THE GRAND DUCHY OF LUXEMBOURG
Ministry of Research and Higher Education

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