ROMANIA LASER VALLEY

DEVELOPMENT SCENARIOS

WORLD BANK GROUP

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List of Abbreviations

Acronyms	Explanation
ADR	Regional Development Agency
ALPhANOV	Technology transfer center
ARPI	Advanced Photonics Research Institute
BICs	Business Incubation Centers
BIOCEV	Biotechnology and Biomedicine Center of the Academy of Sciences and Charles University in Vestec
CEA	Alternative Energies and Atomic Energy Commission
CELIA	Center for High Intensity Lasers and their Applications
CERN	European Organization for Nuclear Research
CESTA	Center for Scientific and Technical Studies in Aquitaine
CETAL	Center for Advanced Laser Technologies
CIR	Research Tax Credit
CITT	Centre for Innovation and Technology Transfer
CNRS	National Center for Scientific Research
CONICYT	National Commission for Scientific and Technological Research
CRADAs	Cooperative Research and Development Agreements
CS1	One Scientific Researcher
CTBT	Comprehensive Nuclear Test Ban Treaty
EC	European Commission
ELI	European Extreme Light Research Infrastructure
ELI-ALPS	Extreme Light Infrastructure-Attosecond Laser Science
ELI Beamlines	Extreme Light Infrastructure-High-Energy Beam Science
ELIBIO	Electronic System Interacting with Biology
ELI-DC	Extreme Light Infrastructure-Delivery Consortium
ELI-ERIC	Extreme Light Research Infrastructure - European Research Infrastructure Consortium
ELI-NP	Extreme Light Infrastructure-Nuclear Physics
EPO	European Patent Office
ERDF	European Regional Development Fund
ERRIS	Engage in the Romanian Research Infrastructures System
ESFRI	European Strategy Forum on Research Infrastructures
ESO	European Southern Observatory
EU	European Union
EU2020	Europe Strategy for Growth and jobs 2010–2020
EUR	Euro
FDI	Foreign Direct Investment
FNADT	National Fund for Territorial Development
FP7	Framework Program 7
FZU	Czech Institute of Physics

GCCI	Gwangju Chamber of Commerce and Industry
GDP	Gwangju High-tech Industrial Park
GERD	Gross Domestic Expenditure on Research and Development
GHIP	Gwangju High-tech Industrial Park
GIST	Gwangju Institute of Science and Technology
HIFI	High Field Initiative
HiLase	High Average Power Pulsed Lasers
HiPER	European High Power Laser Energy Research Facility
HPC4Mfg	High Performance Computing for Manufacturing
ICF	Inertal Confinement fusion
ICT	Information and Communications Technology
IDA	Inter-communal Development Association
IFIN-HH	National Institute for Physics and Nuclear Engineering Horia Hulubei
IGSS	Institute for Spatial Sciences
INFLPR	National Institute for Physics of Lasers, Plasma and Radiation
INFP	National Institute for Earth Physics
INOE	National Institute for Optoelectronics
IOGS	Institute of Optics Graduate School
IP	Intellectual Property
IPO	Industrial Partnerships Office
IR	Infrared Laser
ISS	Institute of Space Science
IZEST	International Center for ZETTA-Exawatt Science and Technology
KOPTI	Korea Photonics Technology Institute
LED	Liquid Electronic Display
LHC	Large Hadron Collider
LIL	Laser Integration Line
LLNL	Lawrence Livermore National Laboratory
LMJ	Laser Megajoule
LVI	Laser Valley Initiative
LVOC	Livermore Valley Open Campus
MeV	Million Electron Volts
NIEP	National Institute for Earth Physics
NIMP	National Institute for Material Physics
NNSA	National Nuclear Security Administration
PATZ	Interjurisdictional Plan
PETAL	PETawatt Aquitaine Laser
PhD	Doctor of Philosophy

PNCD National Plan for Research and Development
PRAM Parameter Random Access Memory
PW Petawatts
PwC PricewaterhouseCoopers
PYLA Training Center for Optics and Photonics
R&D Research and Development
RDI Research, Development, and Innovation
RIFR Research and Innovation Framework in Romania
RO-PTO Romanian Patent and Trademark Office
SATT Society for Accelerating Technology Transfer in the Aquitaine Region
SERI State Secretariat for Education and Innovation
SME Small and Medium-Size Enterprise
SRIF Science Research Investment Fund
STAR Space Technology and Advance Research Program
TW Traveling Wave
UAMGA Urban Activation Movement of Gwangju Area
VLT Very Large Telescope

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Executive Summary

Romania invested about EUR 300 million in building the world's largest science infrastructure dedicated to the fundamental study of light-matter interaction in the ultra-relativistic regime. Of an unprecedented[1] scale, the Extreme Light Infrastructure – Nuclear Physics (ELI-NP) is expected to bring significant advances to basic sciences and introduce major breakthroughs in the application of oncology treatment, medical and biomedical imaging, fast electronics, and new methods of nuclear-waste processing. The ELI-NP is one of the three[2] pillars of the "landmark" European Extreme Light Infrastructure (ELI), the first world laser research infrastructure, resulting from a coordinated effort by a multinational scientific community. Launched in 2007, after 36 months of preparation, ELI was brought to organizational and scientific maturity and is expected to start operations in 2019. The preparatory phase involved about 40 research and academic institutions from EU member states. The ELI will be governed and operated as a single, distributed international laser user facility of pan-European dimensions for the investigation of light-matter interactions at the highest intensities and shortest time scales.

The ELI-NP offers a singular opportunity for knowledge and commercial and spatial spillovers, particularly in Măgurele, where is located, and more generally in Romania, for several reasons. First, its location is in an already well-established research hub, and its open-access policy can reinforce a virtuous circle of excellence in research and development (R&D) in Romania. This will likely have an appeal of its own, which may attract other players to the location (e.g., universities, private-sector technology companies, service providers, etc.). Second, ELI-NP can trigger economic benefits from research externalities (hiring local researchers including Romanian researchers in the production of new fundamental and applied research and hiring local university students). Third, ELI-NP can lead to commercial applications of research through selling, licensing, or contracting technology services, intellectual assets, and related knowledge into spinoff creations and R&D collaboration. Fourth, ELI-NP can lead to a multiplier effect from linkages with knowledge-intensive sectors (based on the supply of goods and services to the research facility and associated activities). Fifth, the Romanian research sector can increase its visibility, thus contributing to a better integration in the European research area. With its open-access policy, the ELI-NP facility could provide the possibility to create an international pole of excellence related to science and technology.

These expected outcomes constitute the basis of the Romanian Government's "Laser Valley-Land of Lights" initiative (LVI)[3]. Although not yet defined, the LVI represents a development vision aimed at integrating R&D into regional and local development strategies to boost economic development based on science and technology. However, the articulation of this vision and its implementation pose significant challenges.

The objective of this report is to provide initial evidence to help the policymakers conceptualize the development vision for LVI. The report suggests potential pathways by framing the enabling conditions for the occurrence of the spillovers that could emerge from the ELI-NP research infrastructure and by identifying the inhibiting conditions that could prevent the achievement of the expected effects.

1 The ELI-NP hosts two machines, a very high intensity laser, where beams from two 10 PW lasers are coherently added to obtain intensities on the order of 1,023–1,024 W/cm2 and the most brilliant tunable gamma-ray beam machine currently available in the world.

2 The ELI is based on three specialized and complementary facilities, known as the "three ELI pillars:" (i) high-energy beam science (Prague, Czech Republic) devoted to the development and usage of dedicated beam lines with ultra-short pulses of high-energy radiation and particles reaching almost the speed of light; (ii) attosecond laser science (Szeged, Hungary) designed to conduct a temporal investigation of electron dynamics in atoms, molecules, plasmas, and solids at the attosecond scale; and (iii) the extreme light infrastructure-nuclear physics pillar under implementation in Măgurele (near Bucharest, Romania), which will focus on laser-based nuclear physics.

3 www.laservalley.ro or www.landoflights.ro

The report first reviews the R&D and innovation environment in which ELI-NP operates and assesses the framework conditions at the national and local levels in which ELI-NP operates to allow the identification of the enabling and inhibiting factors for the occurrence of knowledge and commercial spillovers. The review covers the framework conditions for research excellence, science-industry collaboration, and business innovation at both the national and local levels. Second, the report provides a comprehensive territorial perspective for the Laser Valley initiative and stresses the existing catalysts and inhibitors that affect the development of the initiative from a spatial and urban perspective. Third, the report reviews the international cases of seven large science infrastructures similar to ELI-NP and their local effects. In addition, the report identifies the opportunities and challenges that the LVI is likely to encounter. Fourth, the report suggests three possible development paths for LVI based on selected intended outcomes and highlights the conditions for each scenario for success. Although these scenarios differ in terms of outcomes, they have ELI-NP in common as an anchor science infrastructure. These scenarios overlap to a certain extent and evolve and emerge from each other. The final development path depends on the existence of the enabling conditions, the players, and their dynamic interactions.

- **Scenario A:** ELI-NP as an "enclave". This is the basic scenario. As one of ELI's pillars, ELI-NP operates with minimum interaction with local organizations (research organizations or firms). The science infrastructure is utilized mainly by fly-in/fly-out visiting scientists selected based on the scientific merits of their project proposals with little to no collaboration with researchers from other local research organizations. Spillovers are focused on service provision to the foreign and local scientists that will have R&D collaboration and experiments at ELI-NP. Such spillovers are mainly spatial spillovers (housing, accommodations, and transport). Overall, the preconditions for this scenario require some support but appear to be achievable. Some recommendations for attention by decision makers would include:
    - (i) ensuring the necessary funding for maintaining the ELI-NP in operation,
    - (ii) ensuring that regulatory requirements are in tune with the needs of ELI-NP to efficiently and accessibly bring international scientists to Măgurele and to maximize the number and quality of the research outputs,
    - (iii) developing a set of accommodation and transportation options for visiting researchers and the expanded local workforce that will be working with them, and
    - (iv) undertaking planning activities for public utility provision in the Măgurele area.

- **Scenario B:** Laser Valley as a "knowledge ecosystem". The expected outcome of this scenario is the creation of new knowledge through joint research work and collaboration within the geographic boundary of the Măgurele/Bucharest area among the different local research organizations and firms and with ELI-NP having a catalytic role. This scenario assumes knowledge spillovers to the local research community and universities and spatial spillovers derived from service provision to local and foreign scientists. Although ambitious, it has good prospects given Măgurele's current position as a strong pole of research in Romania. However, it is held back by several national and local factors. The following intermediate outcomes and lines of action are suggested in addition to those discussed under Scenario A: further improving the research base and conditions for research excellence and collaboration by improving the scientific governance, funding and monitoring and evaluation (M&E) of the research in the physics domain (especially atomic and subatomic research), incentivize collaboration between local and international scientists, attract the diaspora in research collaboration, enable open access, etc. In addition, interventions are needed to improve the accessibility, amenities, and public utility provisions to the Măgurele area.

- **Scenario C:** Laser Valley as an "innovation ecosystem". The outcome of this scenario is the integration of the new knowledge created by and around ELI-NP and its exploitation for value creation through commercialization and linkages. In this scenario, commercial spillovers (spinoffs and backward linkages) are added to the knowledge spillovers under Scenario B. Scientific research successfully leads to commercial spinoffs, either channeled through existing companies or through startups located in or around Măgurele. Backward linkages are fostered for suppliers to ELI-NP and associated initiatives (maintenance, services, and suppliers). Spatial spillovers are expected. This is a very ambitious scenario that requires a concerted effort on a number of fronts to ensure the preconditions for success are in place in addition to those discussed under Scenarios A and B. They include interventions to improve the science-industry collaboration and technology transfer and to enable startup creation and technology transfer. Finally, ambitious spatial plans will require active initiatives to secure sufficient land and to administer it consistently with the objectives of Laser Valley (to avoid urban sprawl and speculation). Transport plans for connectivity to Bucharest, the airport, and the wider region may also need to be enhanced.

Finally, the report provides insight for the governance arrangements that need to be put in place to lead the way ahead. The complexity and ambition level of the outcomes envisaged for the Laser Valley development scenarios dictate the most appropriate governance arrangements. Each development path suggested above has different stakeholders that need to coexist, collaborate, and coevolve to achieve the shared outcomes. They include research organizations, firms, local authorities, central government and line ministers, associations, and citizens. Their role increases in complexity as the ecosystems evolve and the need for coordination becomes absolutely critical. 1.

Chapter 1

Extreme Laser Infrastructure – Nuclear Physics and the Laser Valley Initiative

1. Extreme Laser Infrastructure – Nuclear Physics and the Laser Valley Initiative

1.1 Background

The European Commission has placed innovation at the heart of the Europe 2020 strategy and allocated resources from its regional development funds (ERDF) to support innovation investments as part of the Research and Innovation Strategies for Smart Specialization (RIS3). The RIS3 is a novel approach to regional economic and social development promoted by the EU, which is specifically designed to address the issues of economic competitiveness, growth, and social cohesion as outlined in the Europe 2020 strategy. The approach is based on the principle that the discovery of well-defined domains for specialization in a region or country (e.g., of research and innovation areas in which it could excel and have comparative advantages) may trigger economic advancement in that region or country. Research infrastructures are well placed to play an enabling role in the context of RIS3. They may form environments that act as incubators for the development of entrepreneurial cultures and may be hotspots that may facilitate the development of regional hubs where good science, technology, talent, and entrepreneurship may cluster and have a significant socio-economic regional impact.

The European extreme light research infrastructure (ELI) is one such project. The ELI project is a "landmark" project selected by the European Strategy Forum on Research Infrastructures (ESFRI) and included in the European Road Map for Research Infrastructure. Established as a major element of competitiveness of European research, once implemented, ELI will be the first world laser research infrastructure resulting from a coordinated effort by a multinational scientific community. Launched in 2007, after 36 months of preparation, ELI was brought to organizational and scientific maturity. The preparatory phase involved about 40 research and academic institutions from EU member states.

The ELI project is expected to operate as a single, distributed international laser user facility of pan-European dimensions for the investigation of light-matter interactions at the highest intensities and shortest time scales. The project is based on three specialized and complementary facilities, known as the "three ELI pillars:"

(i) high-energy beam science (Prague, Czech Republic) devoted to the development and usage of dedicated beam lines with ultra-short pulses of high-energy radiation and particles reaching almost the speed of light,

(ii) attosecond laser science (Szeged, Hungary) designed to conduct a temporal investigation of electron dynamics in atoms, molecules, plasmas, and solids at the attosecond[4] scale; and

(iii) the extreme light infrastructure-nuclear physics pillar under implementation in Măgurele (near Bucharest, Romania), which will focus on laser-based nuclear physics. A fourth pillar could be further developed; however, the location is not yet decided.

The extreme light infrastructure-nuclear physics (ELI-NP) pillar located in Măgurele, Romania, is a unique laser research infrastructure on an unprecedented scale in the laser area. Dedicated to the fundamental study of light-matter interaction in the ultra-relativistic regime, The ELI-NP is expected to bring significant advances to basic sciences and major breakthroughs in the application of oncology treatment, medical and biomedical imaging, fast electronics, and new methods of nuclear-waste processing. It will host two machines, a very high intensity laser, where beams from two 10 PW lasers are coherently added to obtain intensities on the order of 1,023–1,024 W/cm^2 and the most brilliant tunable gamma-ray beam machine currently available in the world. When operational, the ELI-NP facility will generate laser and gamma beams with unique characteristics suited to perform frontier laser, nuclear, and fundamental research. Moreover, ELI-NP is expected to employ over 200 full-time researchers and engineers (including about 60 PhDs) and be visited by many external researchers selected by an international committee based exclusively on the quality of the research proposals.

4 ELI White Book, p. 494.

1.2 Location Choice

The localization of ELI in Central and Eastern Europe was purposely targeted to utilize the scientific and technological potential of the new EU member states, accelerate their integration in the European research area, and trigger improvements of the national research infrastructure in the region. The ELI project also envisages providing new educational and training perspectives for the younger generation of students and scientists in the fields of laser, laser-matter interaction, and photonics.

Within Romania, Măgurele is an obvious fit for the ELI-NP infrastructure given its "long tradition as a pole of excellence in Physics, the only site in Romania and in all South–East Europe with such a concentration of research, educational and technological facilities in all major fields of Physics and related domain."[5] Indeed, the Măgurele area already hosts an important cluster of well-established public research institutes and educational facilities specialized in physics sciences that generate about 30% of the research output in Romania, which are the following:

(i) National Institute for Physics and Nuclear Engineering "Horia Hulubei" (IFIN-HH);

(ii) National Institute for R&D for Physics of Lasers, Plasma, and Radiation (INFLPR), and their affiliated Institute for Spatial Sciences;

(iii) National Institute for Material Physics;

(iv) National Institute for Optoelectronics (INOE);

(v) National Institute for Earth Physics; and

(vi) Faculty of Physics (University of Bucharest).

Annex 1 provides information about the activity of these institutions. The ELI-NP facility is built on the premises of the IFIN-HH, the leading research institute in Romania.

1.3 Phases in Implementation

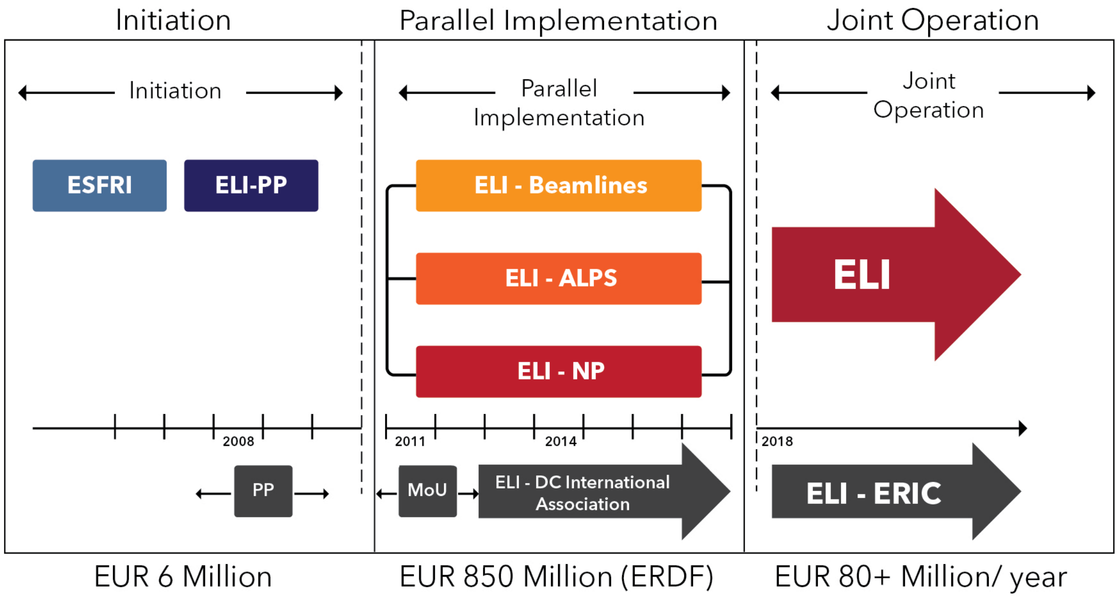
Currently, ELI is in the implementation phase in all three locations (Table 1). For ELI-NP, this phase includes the construction of the building, the installation of the laser and gamma beam equipment, and the testing of the equipment for proper functioning in the operationalization phase. The building construction phase was finalized in 2016, while the installation and full commissioning of the equipment are expected to be finalized by 2019. The implementation is 85% funded from the ERDF through the Sectoral Operational Program "Increase of Economic Competitiveness" and 15% funded from the national budget.

Once the implementation stage is finalized and facilities become operational, the ELI pillars will be operated jointly by the ELI European Research Infrastructure Consortium (ELI-ERIC), a legal entity whose main task is to establish and operate the full scope of the infrastructure. In addition, ELI will be set up as an ERIC according to Council Regulation (EC) No 723/2009 of 25 June 2009 on the community legal framework for ERIC. After the implementation phase of ELI-DC (delivery consortium) ends in 2018–2019 and the operational phase begins, the beamlines, equipment and infrastructure, experimental capabilities, and human resources will be available for request for access from researchers or firms (see Annex 2 for a list of exploitable technologies and services offered by ELI-NP). It is estimated that the annual operating costs for ELI will amount to EUR 80 million, of which EUR 29 million will be for ELI-NP (including re-investments). Romania is expected to contribute significantly[6] to the operational costs as a founding member of the future ELI-ERIC. Additional contributions are expected from other partners and countries showing interest in the facility.

5 ELI White Book, p. 494.

6 Romania expressed its commitment to support at least 30% of the operational costs of ELI-NP and to increase this share in the case in which the contributions of the participant countries and revenues from grants cannot cover the remaining 70%.

Table 1. ELI Phases[7]



1.4 Expected Impacts

The ELI-NP is expected to produce new knowledge in the field of nuclear physics, which is important for human understanding. In addition, the science facility offers a singular opportunity for development of the Măgurele area and for Romania for several reasons. First, its location is in an already well-established research hub, and its open-access policy can reinforce a virtuous circle of excellence in R&D in Romania. This will likely have an appeal of its own, which may attract other players to the location (e.g., universities, private-sector technology companies, service providers, etc.). Second, ELI-NP can trigger economic benefits from research externalities (hiring local researchers including Romanian researchers in the production of new fundamental and applied research and hiring local university students). Third, ELI-NP can lead to commercial applications of research through selling, licensing, or contracting technology services, intellectual assets, and related knowledge into spinoff creations and R&D collaboration. Fourth, ELI-NP can lead to a multiplier effect from linkages with knowledge-intensive sectors (based on the supply of goods and services to the research facility and associated activities). Fifth, the Romanian research sector can increase its visibility, thus contributing to a better integration in the European research area, and with its open-access policy, the ELI-NP facility could provide the possibility to create an international pole of excellence related to science and technology.

These expected effects constitute the basis of the "Laser Valley-Land of Lights" Initiative (LVI). The LVI represents a development vision aiming at integrating R&D into regional and local development strategies to boost economic development based on science and technology. However, the articulation of this vision and its implementation pose significant challenges. The expected economic benefits described above are not likely to occur unless enabling conditions are met in terms of a conducive framework for research and innovation and spatial and territorial development. In the absence of such conditions, the ELI-NP research infrastructure may become an "enclave" with minimum economic spillovers.

Against this background, the European Commission invited[8] the Romanian Government to consider the risks that may jeopardize the expected economic benefits from the massive investment in the ELI-NP research infrastructure and to take mitigating measures. Since the beginning of the discussions on ELI-NP as a major research infrastructure project, the European Commission invited the Romanian authorities to set up the appropriate framework that reinforces the linkages of the project with the research sector, education system, business environment, and local development.

7 ELI project website.
8 Letter 27/07/2012.

Commitments made by the government in 2012 included taking measures to create the conditions for the following:

(i) to transform ELI-NP in a knowledge-based economy cluster fostering regional and national competitiveness,

(ii) to strengthen the integration of the infrastructure into the local socio-economic environment,

(iii) to ensure the financial support for the operational phase, especially in the context of the severe underfunding of the research system, and

(iv) to monitor the compliance of the research infrastructure with the state aid rules.

1.5 This Report

This report provides initial evidence to help the policymakers conceptualize the development vision for ELI-NP in more detail. The report suggests potential pathways in the implementation of this vision by framing the enabling conditions for the occurrence of the spillovers that could emerge from the ELI-NP research infrastructure and by identifying the inhibiting conditions that could prevent the achievement of the expected effects.

First, the report reviews the R&D and innovation environment in which ELI-NP operates and assesses the framework conditions at the national and local levels in which ELI-NP operates to allow the identification of the enabling and inhibiting factors for the occurrence of spillovers. The review covers the framework conditions for research excellence, science-industry collaboration, and business innovation at both national and local levels. Second, the report provides a comprehensive territorial perspective for the LVI and stresses the existing catalysts and inhibitors that affect the development of the initiative from a spatial and urban perspective. Third, the report reviews the international cases of the large anchor science infrastructure similar to ELI-NP and their local effects and identifies the opportunities and challenges that the LVI is likely to encounter. Fourth, the report suggests possible development paths for LVI based on selected intended outcomes and highlights the conditions for each scenario for success. Finally, the report provides suggestions for the next steps.

Chapter 2

Research and Innovation Environment for ELI-NP

2. Research and Innovation Environment for ELI-NP

This chapter provides an overview of the research and innovation environment in Romania based on the effectiveness framework developed by the World Bank.[9] The objective is to assess the framework conditions at the national and local levels in which ELI-NP operates to allow the identification of the enabling and inhibiting factors for the occurrence of spillovers. The review of the R&D sector was mainly done through desk research and analysis of available public data and builds on the findings of the World Bank Functional Review for R&D and Innovation (2011). The framework conditions at the national and local levels are further assessed by investigating the opinions of the researchers involved in ELI-NP or in research activities that are closely connected to the ELI-NP science domain. These opinions were captured by the survey[10] implemented in 2017 (Annex 11) and by face-to-face interviews.

2.1 Effectiveness of the R&D and Innovation Framework

The assessment of the environment around ELI-NP uses the R&D effectiveness framework assessment developed by the World Bank (Correa, 2014). The effectiveness framework assessment is used to assess the extent to which policy output results in expected outcomes. Described in Box 1, the intermediate outcomes include (i) research excellence, (ii) science-industry collaboration, (iii) business R&D and firm startups, and (iv) non-R&D innovation and technology adoption. To fully cover the ELI-NP environment, the assessment is complemented with the spatial dimension, which is investigated in Chapter 3.

Box 1. Assessment Framework

Research Excellence. Research excellence comprises four elements, including (i) access to the research infrastructure, (ii) availability of researchers, (iii) access to research funding, and (iv) the governance regime. As represented in Figure 1, the first three elements are "inputs" that are dependent on the EU and Romanian Government, among other outside stakeholders, as well as the capability to recruit talented researchers for ELI-NP. Moreover, ELI can create an effective governance regime that maximizes the likelihood of knowledge exchange. In addition to world-class research capabilities and infrastructure, these include continuous education and training, workshops, and international conferences. Institutions can also provide opportunities and develop supporting guidelines that enable researchers to engage in research and application-oriented partnerships (see below). Clear guidelines and policies are essential to govern the disclosure, patenting, and licensing of derivative technologies to the industry as well as the establishment of new, derivative spinoff companies (Phan and Siegel 2006). Institutions can also create policies that encourage collaboration and govern the use of facilities, equipment, and other infrastructure elements by outside researchers, students, and firms from the region and abroad. Finally, institutions can foster a culture that embraces and balances open scientific dialog with entrepreneurial thinking (Audretsch 2014).

9 Public Expenditure Reviews in Science, Technology and Innovation, Paulo Correa.

10 A total of 1,130 online invitations were sent to researchers directly involved in ELI-NP activities or closely connected to ELI-NP; 224 responses were received, and 57% of these respondents work in Măgurele, while 43% work in research organizations and firms elsewhere in Romania.

Science-Industry Collaboration. Several factors affect successful knowledge exchange among research organizations and the industry, including incentive regimes for individual researchers (and the research organizations themselves), public-private research collaboration, and the availability of physical infrastructures, such as science parks. Further, organizational intermediaries (illustrated in Figure 1) are the specific mechanisms through which research institutions and industry partner. Myriad types of intermediaries exist from engineering research centers (Ponomariov and Boardman 2010), technology transfer offices (Bradley et al. 2013a), and proof-of-concept centers (Bradley et al. 2013b) to large-scale pre-competitive research and translation consortia, such as IMEC (Debackere and Veugelers 2005).[11]

Business R&D and Startups. It is critical to understand demand-related elements associated with industry and startup R&D as well as their commercial success. Examples include environmental factors for business success, R&D investment motivations, and services and resources required for a startup. An awareness of the demand factors provides valuable context not only for better understanding of the potential application of derivative technologies within the industry but also for guiding an applied industrial research agenda (Audretsch et al. 2015; Hagedoorn et al. 2000). Further, the industry provides critical capabilities and resources important for technology development and commercialization. The availability of local suppliers that provide technical support, equipment and parts, and other engineering and technical services to ELI-NP constitutes an important factor in maximizing the effects and integration of ELI-NP into the local economy (backward linkages).

Non-R&D Innovation, Technology Adoption, and Policy. Many environmental factors affect the exchange and effects of new knowledge; knowledge exchange occurs within the context of regional and national innovation ecosystems that may support or detract from potential application and commercialization. The efficacy of an innovation ecosystem depends on the presence of relevant financial, human, and technological resources, specialized services (legal, accounting, etc.), dense social networks among institutions, and a supportive policy and regulatory environment, among other facets (Claryesse et al. 2014). Other specific elements include quality manufacturing extension services, access to metrology and quality improvement services, and credit availability. Further, successful innovation ecosystems coevolve to encourage and support both older and emerging industries (Saxenian 1994).

Spatial Aspects. Spatial aspects of any research enterprise affect their existing and future influence. Given that tacit knowledge exchange generally occurs locally, economic geography and the proximity of various industries within the region where a research facility is located are critical determinants of the extent to which it can be commercialized (Saxenian 1994). Further, land acquisition and development potential are critical. The expansion of existing research facilities and collaboration infrastructure, such as science parks and shared workspaces, depend on the availability of land. Finally, physical infrastructure from utilities and ultra-high-speed broadband to international airports and roads is critical to the development of a successful research enterprise, such as ELI-NP (Lugar and Goldstein 1991).

11 IMEC is an industry-led, pre-competitive R&D consortia located in the Flanders region of Belgium. Established in 1982 in close partnership (and co-located) with the Catholic University Leuven (K.U. Leuven), IMEC has grown to be a world-class microelectronics consortium with 1,000 in-house researchers and staff work with more than 500 guest researchers from international and local industrial and university partners. Seventy percent of its approximately €250 operating budget comes from its industrial partners, including local firms (that enjoy discounted participation fees).

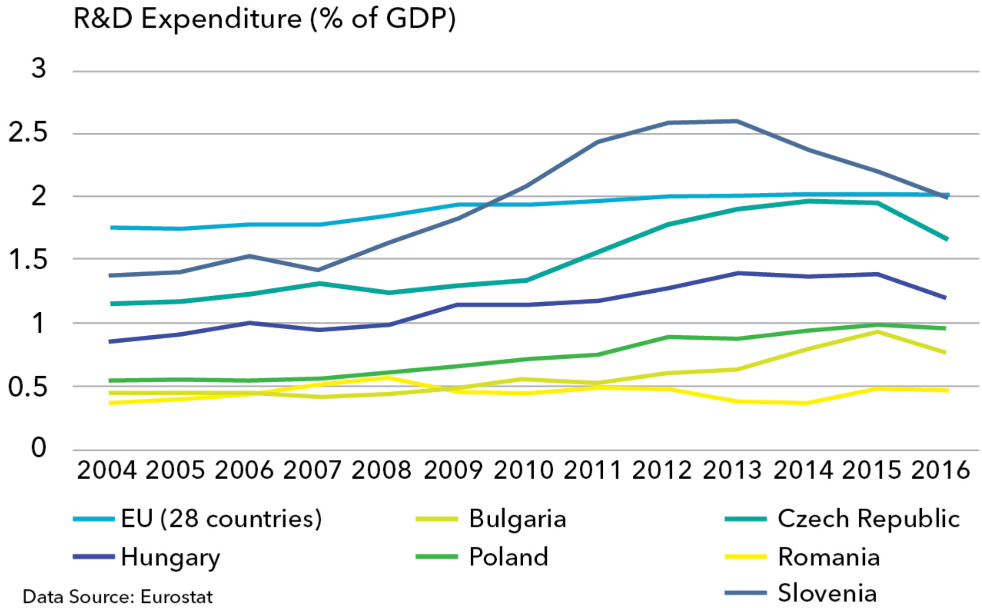
2.1.1 Research Excellence

Research excellence in Romania is affected by low and unpredictable funding, low supply of human resources, and poor incentives under which researchers operate.

Funding

The Romanian R&D system remains heavily underfinanced. In 2016, the gross domestic expenditure on R&D (GERD) was the second lowest among all the EU member states (0.48% of GDP compared to an EU average of 2.03% of GDP) and among the lowest[12] in Europe during the last decade (Figure 1). It was below the expected levels, given its economic development path (Figure 2). The highest level of R&D expenditure was reached in 2008 before the economic crisis, at only 0.52% of GDP (or EUR 39.4/inhabitant as compared with the EU average of 2.03% of GDP (or EUR 588 EUR/inhabitant). The reductions in GERD public expenditures were driven not only by fiscal constraints stemming from reduced growth in the context of the financial crises but also by a deliberate policy to decrease the spending in R&D despite commitments made in the context of negotiating the EU accession in 2007 and the EU2020 targets.[13] The government commitment of reaching 1% of public R&D expenditure by 2020 as part of the EU 2020 strategy has become a remote target, unless a significant increase in budget allocation of at least 44% from the current level will be made over the remaining period.

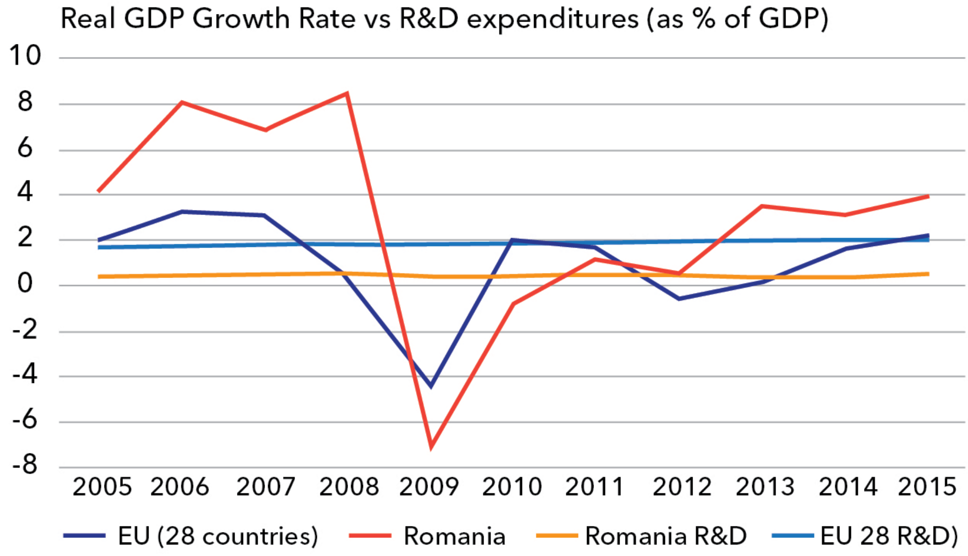
Figure 1. Research and Development Expenditure



Data Source: Eurostat

12 Except for 2008 and 2009.
13 Target for 2020 is 2% (1% from government contribution).

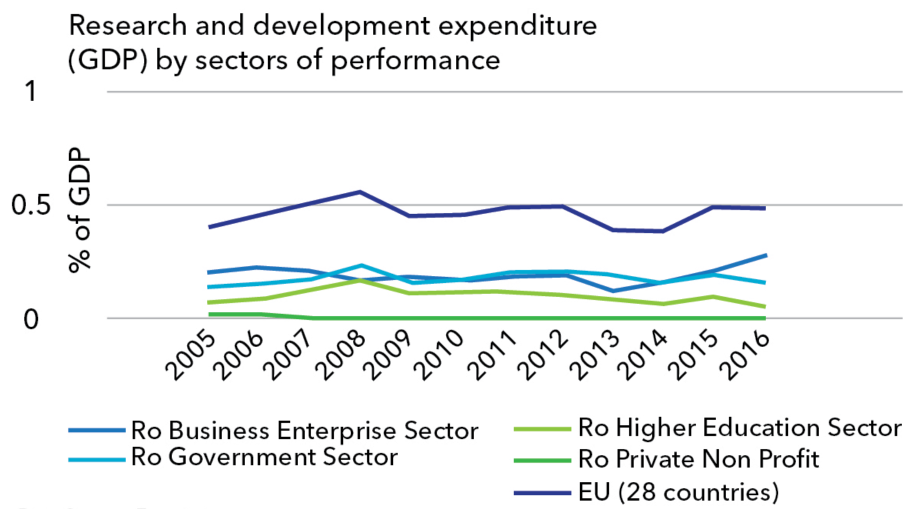
Figure 2. Real GDP Growth Rate vs. R&D Expenditures



Data Source: Eurostat

The R&D expenditures are predominantly in the government sector in contrast to the overall EU (EU 28) average or top innovation countries. Although at low levels, throughout 2006–2016, the main part of the R&D expenditure in Romania was in the government sector and reached 42% of the total R&D expenditures in 2016. It was followed by the business sector (38%) and funds from abroad (19%; Figure 3). Funding by higher education was small at about 1.7%, while funding from the private non-profit sectors was negligible. In contrast, the main R&D expenditure in EU countries was in the business enterprise sector, and its R&D intensity rose from 1.1% of GDP in 2005 to 1.3% in 2014 and 2015, an overall increase of 18.2%. The second largest sector performing R&D was the higher education sector, whose intensity increased 23.1% between 2005 and 2014 to reach 0.48% of GDP before falling marginally in 2015. Among the EU member states, in 2015, business-funded R&D accounted for more than three-fifths of the total R&D expenditure in Slovenia (69.2%), Germany (65.8%), and Sweden (61%).

Figure 3. Research and Development Expenditure by Sectors of Performance



Data Source: Eurostat

The main sources of funding from abroad have been the European Union Research Programs 2007-2013 Framework Program 7 (FP7) and Horizon 2020 (2014–2020). However, Romania's performance by 2014[14] was behind countries such as Hungary, Poland, or Czech Republic both in terms of the success rate in signed agreements and the share of EU budget attracted. About EUR 143.44 million[15] was attracted by 2014. Among the 28 EU countries in all FP7 signed agreements, Romania ranked 19th in terms of budget share and 18th in terms participation in all signed agreements. A total of 5,291 eligible proposals were submitted in response to the 487 FP7 calls issued over 2007–2013, involving 6,878 applicants from Romania (representing 1.32% of the total EU applicants) and requesting EUR 1,654.99 million of the EC contribution (0.85% of the EU). The small and medium-size enterprise (SME) performance and participation were also lower (13.89%) than that of the 28 EU member states and the SME applicant success rate of 20.19%. Their success rate in terms of the EC financial contribution of 9.27% was lower than the corresponding overall EU rate of 20.12%. Out of the 2,355 RO SME applicants requesting EUR 475.8 million, 327 (13.89%), only 239 applicants successfully signed a grant agreement in an amount of EUR 44.09 million (9.27%).

The main instrument for public funding for R&D, the National Research, Development and Innovation Plan. The current Plan for 2015–2020[16] (PNCDIII) provides the utilization of about RON 15 billion in support of five strategic objectives (Box 2), however its implementation started only in June 2016. The main part of the public funding is competitive. Under the PNCD II, this part was severely affected by the unpredictable budget cuts, forcing the public research institutes toward subsistence strategies. Project budgets were lowered and no budgetary appropriation was allowed from one year to another. Although no impact assessment was done to analyze the effects of this practice on the efficiency and effectiveness of the research projects, it could be easily assumed that the quality and outcome were affected. The limited funds for R&D are allocated across a fragmented research and innovation system, which lacks rigorous and regular evaluation mechanisms for assessing the institutional research performance.[17] According to recent estimates[18], over half of public funding was allocated via institutional funding, with the rest being allocated via project-based funding. However, there are very few or no 'competitive' components within institutional funding, meaning that institutional funds are not allocated based on institutional research performance (bur rather on the number of researchers, students, etc.)

In addition, the European Regional Development Fund (ERDF) finances programs that support RDI, as part of the Operational Program for Innovation and Competitiveness 2014–2020. Out of the total allocation of around EUR 894 million for the 2014–2023 implementation period, only about EUR 178 million is allocated for the Bucharest-Ilfov region, which Măgurele is part of, with an additional EUR 11 million performance bonus. The EUR 189 million is further split by individual measures as shown in Table 2.

14 FP7 Monitoring Report (data as of 2014).
15 FP7 Monitoring Report (data as of 2014).
16 Approved by GD 585/2015, amended in 2017.
17Chioncel, M: del RIO Country Report 2017
18 Ibid

Box 2. PNCD III (2014-2020)

1. **Development of a national R&D system** (max. 35% of the budget allocated):
    - 1.1 Human Resources: supporting doctoral and postdoctoral projects; young researchers, reintegration of Romanian diaspora, and mobility; and awards for excellent scientific results;
    - 1.2 Institutional Performance: supporting public research organizations and research business cooperation;
    - 1.3 R&D Infrastructure: supporting investments in regional, national, and pan-European research infrastructure;
    - 1.4 Support: supporting the development of competency centers, evidence-based policy analysis and management, access to scientific literature, and science communication.
2. **Increasing the competitiveness of the Romanian economy through RDI** (max. 10% of the budget allocated):
    - 2.1 Competitiveness through RDI: supporting experimental demonstration and technological service, technology transfer projects, projects outsourcing research to public R&D partners, innovation vouchers, innovative solutions, technological platforms, and cluster development;
    - 2.2 Technology Transfer Support: supporting technology transfer broker offices.
3. **European and international cooperation** (max. 20% of the budget allocated): supporting participation in international research projects to facilitate the mobility of researchers and their access to programs and research institutions that are not available in Romania.
4. **Fundamental and frontier research** (max. 15% of the allocated budget): supporting the development of niche areas in which basic Romanian research has a competitive advantage and in which there is a critical mass of researchers.
5. **Research in areas of strategic interest** (max. 20% of the allocated budget), support program run by institutions with a scientific coordinating role in areas of strategic interest for development of research institutions and national components in areas of strategic interest for Romania:
    - 5.1 Nuclear physics and high-power laser research, particularly related to the ELI research infrastructure;
    - 5.2 Participation in projects and activities in atomic and subatomic physics (CERN, EURATOM, FAIR, CEA, and F4E);
    - 5.3 Space Technology and Advance Research (STAR program);
    - 5.4 River-Delta-Sea system research program, particularly in connection with the Danubius Research Infrastructure.

Table 2. OP Competitiveness Allocations for the Bucharest-Ilfov Region 2014–2020

Measure	Total (Euros)
R&D Infrastructure (public)	€103,055,324
R&D Infrastructure (private, including scientific parks)	€11,250,000
RDI activities in public research centers including networking	€4,424,789
RDI activities in private research centers including networking	€27,432,165
Technology transfer and cooperation between universities and SMEs	€36,597,212
Research and innovation by SMEs	€6,250,000

Source: The World Bank calculations

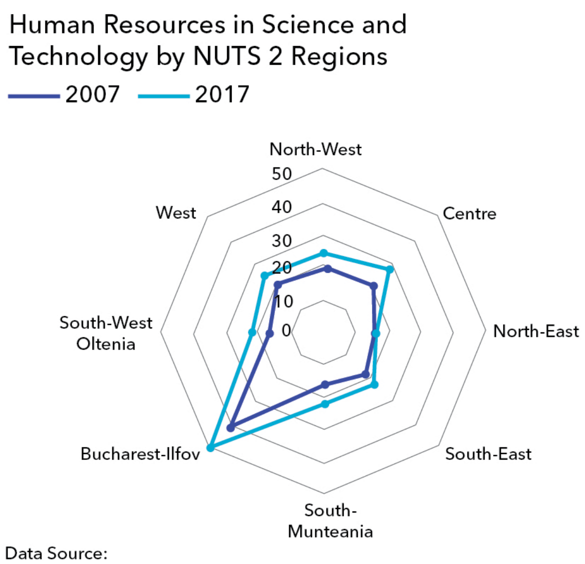
Human Resources

Romania faces a shortage of highly skilled human resources, notably in the scientific disciplines which are key for R&D and innovation, policy measures to attract and retain highly skilled human resources remain insufficient, with negative impact on the scientific performance of the Romanian public R&D sector and the private sector at large.

The availability of researchers in Romania is limited in comparison to other EU member states. Human resources in science and technology as a share of the active population[19] reached 27.7% in 2017, about half of the overall EU average of 46.6%. However, the availability of human resources by regions shows a concentration of 49% in Bucharest and the Ilfov region (that includes the Măgurele area), which exceeds the EU a

verage (Figure 4). Similarly, the number of researchers is highest in Bucharest and the Ilfov region, reaching 0.85% of total employment. Doctoral students in science and technology fields as a percentage of the population aged 20–29 years old is 0.2%, less than half of the EU average of 0.5%.

Figure 4. Human Resources in Science and Technology by NUTS 2 Regions

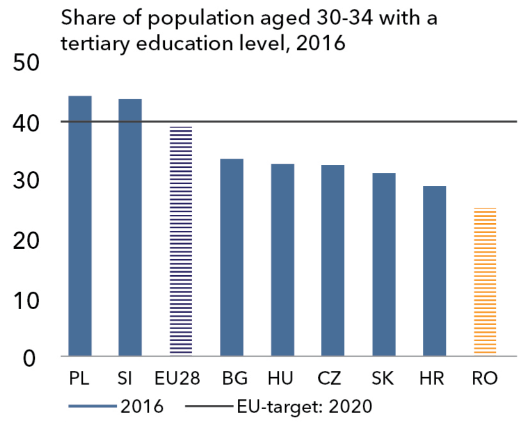


19 Active population in the 25–64 age group.

There are also shortages in key occupations, including information and communication technology (ICT) and science and engineering professionals and technicians (European Commission, 2014a). For instance, Romania ranked 26 in the EU28 in 2015 regarding the number of graduates in the field of computing per thousand population aged 25-34[20]. Beyond the emigration of highly skilled labor, institutional shortcomings in the Romanian educational system have led to insufficient numbers of highly skilled workers. Tertiary education attainment (30–34 years old) has not increased since 2015 and has remained at 25.6% in 2016, the lowest in the EU. While Romania's target of 26.7% by 2020 is achievable, this remains a low percentage compared with the EU average of 39.1% in 2016 and the EU 2020 target of 40% (Figure 5). Romania also lags peers in the number of graduate students per population aged 20–29 in science, technology, engineering, and mathematics (STEM) disciplines (Figure 6). Skill shortages also exist in skilled manual occupational groups, including machinery mechanics and repairers; cooks; car, van, and motorcycle drivers; and workers in the garment and related trades, partially reflecting the low development of vocational training and technical school [21]education. Difficulties in finding skilled staff have important implications for private-sector growth.

Tertiary education attainment (30-34 years old is the lowest among EU contries)

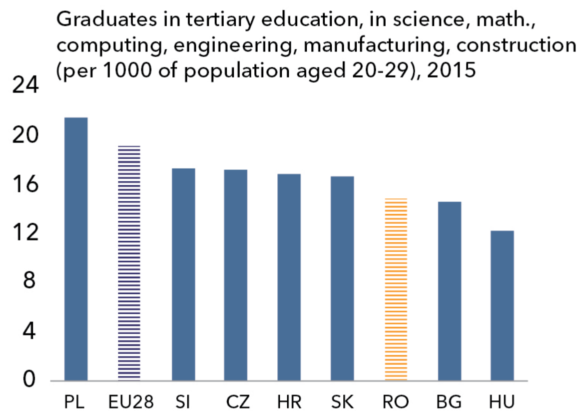
Figure 5. Tertiary Education Attainment (30-34 years old)



Data Source: Eurostat

Tertiary education outcome in STEM disciplines is among the lowest in the EU

Figure 6. Tertiary Education Outcome in Science, Technology, Engineering and Mathematics (STEM) Disciplines



Data Source: Eurostat

The drastic cuts in the funding of most research programs led to substantial 'brain drain,' while the research career prospects of new PhD graduates are under question. Romania has one of the largest scientific diaspora among the EU countries, with an estimated 15,000 researchers working abroad. Funded from the European Social Fund, the newly trained PhD researchers experience difficulties in finding jobs in Romania and become contenders to enlarge the diaspora. The "production" of PhDs has not been matched by career opportunities in R&D or in higher education. Therefore, PhD researchers decide to leave Romania or to work in jobs for which they are overqualified.

Attracting and retaining top researchers and highly qualified technicians is also one of the most severe problems reported by the survey's respondents. About 47% of them believe that attracting and maintaining top-level researchers is problematic. This perception increases to 55% when referring to attracting top technicians. In their view, the factors that explain this situation are the unpredictability of funding, the lack of incentives and opportunities offered by the Romanian research organizations, and the difficult and uncertain process to recognize studies and experience abroad, etc.

Due to the unpredictable funding, recruitment by public research organizations remains mostly closed. The interviews with public research organizations revealed that, during the last decade, they faced a gap in human resources turnover because the old generation of researchers retired and because the employment of new researchers was at low levels and could not cover the needs. In the case of Măgurele, the supply of specialists in physics decreased, as the University of Physics was not

20 Source: Eurostat
21In 2016, VET accounted for only 1% of total public expenditures on education.

as attractive as it had been in the past. The university considers that the situation has stabilized in the last years, as around 130 students graduated from the university. However, the number of people applying is still low, which has consequences on the quality of students admitted.

The job opportunities for young researchers appear to be transparent.[22] The vacancies must be publicly announced at least 30 days in advance. The selection panels include research staff who must hold a scientific title equal to or higher than that required for the vacant position. The examination must be approved by the scientific council of the institution both in terms of content and process, and the content of the application file is mandatory.

Mobility and job opportunities for researchers are transparent in the EU. EURAXESS, the European platform for researchers, entrepreneurs, universities, and businesses, covers mobility opportunities for researchers and entrepreneurs. The platform centralizes and publishes the vacancy announcements[23] in research from all EU member states.

Infrastructure

The research infrastructure was updated in the last years, mainly using EU funds; however, the drastic budgetary cuts affected their full utilization. As per the registry[24] of the existing infrastructure, the country has 1,407 research infrastructures with 76,506 research services, 61 technological services, and 19,851 pieces of equipment. Most of the research involved in or close to ELI-NP considers that the quality of the equipment is up to international standards (82%) and is operable (86%) and accessible (91%). The funding cuts affected the smooth implementation of research projects and may have led to the underutilization of recently built research infrastructure.

Romania has updated the road map to prioritize investments in research infrastructure. The roadmap strategy was published in 2008 and was recently updated by end 2017. The R&D and Innovation Strategy adopted in 2014 stated a series of principles to bring coherence to the prioritization of such investments, but its associated program, the National R&D Program III, has allocated a considerably lower budget than the initial commitments.

Access to the infrastructure of other research organizations is constrained; however, it is not clear whether this is by regulation or practice. The interviews with the researchers revealed that researchers from other organizations cannot use the research facilities. Moreover, researchers from the same institution that are not part of the project research team have restricted access. Institutes do not report having a transparent system for monitoring use of infrastructure and report little to no income generated from supply of high tech services to private entities.

Governance of Public Research Organizations

Four areas of challenges and possible government interventions to improve the performance of RDI were identified during the 2011 World Bank Functional Review and are still relevant. Some of these recommendations are addressed in the National Plan (NP3), such as the measures for developing RDI activities in the private sector, attracting highly skilled researchers from abroad, investing in the development of large-scale R&D infrastructures, strengthening the link between research organizations and enterprises, training researchers and engineers in issues related to industrial and intellectual property (IP) rights, and better monitoring and consolidating the public research sector. The specific actions are planned to be implemented with financing from both ERDF 2014–2020 and the state budget under NP3 (2015–2020).

First, a preeminent task is to strengthen the governance of the RDI system. This requires broader understanding in that it is a national system, which comprises a variety of stakeholders and distinct activities, which together contribute to (or break) the value chain. The public R&D is highly fragmented with 48 national R&D public institutes, 65 institutes and centers of the Romanian Academy and over 102 HEIs[25].

22 Law 319/2003.
23 On April 8, 2017, https://www.euraxess.gov.ro/jopbs/search/country/Romania/1062/field_research_field/, there were 59 vacant positions in Romania.
24 http://erris.gov.ro
25 The number of HEIs (56 public and 46 private universities) has rapidly increased since the early 1990s and these organizations

High-level government oversight of the system is needed to promote its enhanced integration and functioning, ensure the participation of relevant stakeholders in policy making, determine more focused national priorities for the allocation of scarce R&D resources, and enforce transparent accountability for performance. Second, the performance of R&D activities within the public sector itself needs to be strengthened by better aligning incentives, funding, performance monitoring, and research priorities regarding the agreed national priorities. Third, there is no public policy to effectively promote innovation and to transfer R&D into innovation in the private sector. This requires more attention to the commercialization of publicly funded research and appropriate IP legislation. It also requires a coherent and targeted program of early stage technical and financial assistance to startup firms applying innovation stemming from Romanian R&D so that a greater proportion of such research outputs result in economic activity gains and value added within the country. Fourth, there is a need to increase the level of the private-sector R&D in a framework of well-defined IP rights and targeted tax and regulatory actions to improve the climate for the private-sector RDI and attraction of R&D intensive foreign direct investment (FDI).

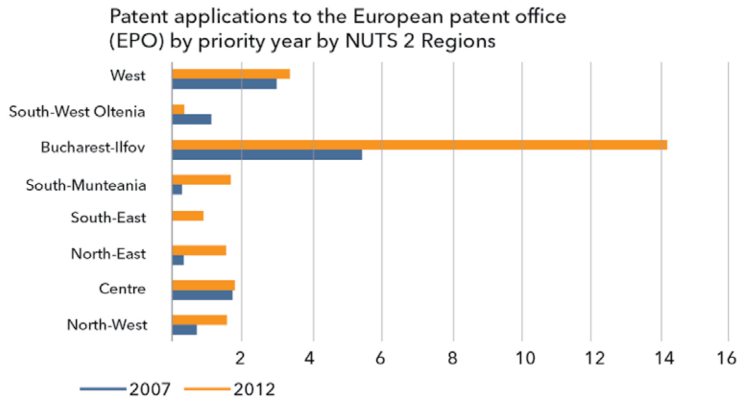
2.1.2 Science-Industry Collaboration and Technology Transfer

Science-industry collaboration is modest in Romania. Researchers, especially from public research institutes and universities, do not have incentives to patent or commercialize. The number and quality of services provided by the technology transfer organizations is low, and the financial schemes to support joint research projects are limited.

Intellectual Property

The volume and quality of scientific output is low. The number of international scientific publications in 2016 was about 182 per million of population, less than one-third of the EU average performance of 494 per million of population. However, the number of the most cited publications among the 10% most cited increased in 2014 to 5.1, half of the EU average of 10.6. Romania also ranks relatively low in terms of public-private scientific co-publications (19 in 2018) and even more worrying is the declining performance since 2012[26]. Although it increased ten times during the last decade, the number of patent applications to the European Patent Office (EPO) is still low in comparison with peer countries and the EU average (Figure 8). In 2016, there were 102 applications from Romanian researchers. The large majority of them are from researchers from the Bucharest-Ilfov region that includes the Măgurele research area (Figure 7). The patents granted by the United States Patent and Trademark Office were 2.35 per million inhabitants, much lower than the EU average of 53.4 per million inhabitants.

Figure 7. Patent Applications to the EPO by Priority Year by NUTS 2 Regions

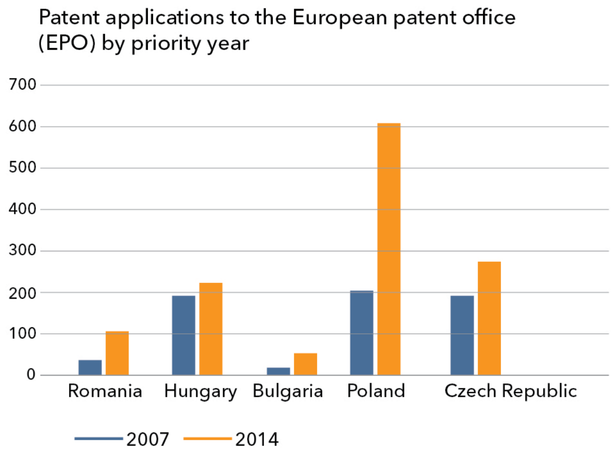


Data Source: Eurostat

tend to have similar activities/programmes. Source; Chioncel, M; del Rio, J-C, RIO Country Report 2017: Romania, EUR 29169 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-81280-4

26 The share of public-private scientific co-publications as % of total number of publications amounted to 0.6% in 2015. the country experienced a sharpt decline since 2012. Source: European Commission, DG Research and Innovation, Data: Eurostat

Figure 8. Patent Applications to the EPO by Priority Year



The legal framework for IP comprises several pieces of legislation that have unclear or contradictory statements on invention ownership and its transfer. The World Bank Functional Review (2011) identified[27] the following issues:

- *The knowledge and awareness of IP may be insufficient.* There is an overall lack of substantive knowledge and awareness on the IP regulatory framework and its effect on the commercial exploitation of the RDI results. Because of the lack of understanding of the fundamentals of IP protection, public entities and institutions are thus at risk of losing the ability to exploit valuable commercially viable assets on various market sectors and at a significant scale. A manual of good practices regarding the inventions was developed by USFICDI[28].
- In addition, the survey revealed that researchers were unaware of the following[29]:
    - The fact that RDI results are subject matter protected by a system of IP laws[30] and intertwined applicable provisions, sometimes entirely ignoring pieces of legislation with influence on the protection and commercial exploitation of the RDI results.[31]
    - How public entities and institutions may become legal owners of various IP rights in the RDI results and the steps necessary to follow to secure full legal protection for all IP-protected subject matter.
    - All means by which the public entities and institutions may exploit the RDI results commercially, including but not limited to the benefits that the individual researchers are entitled to and may receive due to their RDI activities.
- Practices regarding the ownership of the RDI results are inconsistent among the public stakeholders. Various public entities and institutions employ different practices when dealing with IP ownership arising out of RDI activity performed by their employees or researchers. While some of the interviewed subjects acknowledged that their employer applied to obtain a patent for a patentable subject matter that they invented, others mentioned that they applied directly and obtained such a patent in their own name. None of the persons interviewed were aware or made any reference to any contractual provision regulating such ownership.

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27 An updated assessment is necessary to reflect the legal amendments introduced since the time of the review. The legislation covered is listed in Annex 7.
28 https://uefiscdi.ro/Publicatii-1
29 One researcher mentioned that he would undoubtedly ask for private legal assistance and representation should he be challenged with a legal matter concerning his rights with respect to the RDI results.
30 The Law on Patents, the Law on Utility Models, the Law on Topographies of Semiconductor Products, the Law on Plant Varieties, the Law on Ornamental Designs, the Law on copyright, the Law on Trademarks, and the Law on Scientific Research and technological Development.
31 Such as the Law on Copyright, which may protect an entire class of RDI results: documentation, studies, plans, drawings, diagrams, pictures, audio recordings, software, databases, etc.

These practices run the risk that the public entities and institutions will fail to legally secure and exploit the RDI results Moreover, our review of the provided employment and research agreements revealed that:

- There is confusion regarding the types of contracts that qualify as having an *"inventive mission"*[32] and the agreements are generically called *"research agreements."*
- Some of the contract clauses are not compliant with the applicable IP provisions regarding ownership and assignment.

- *Legal ownership of the RDI results is unsettled.* The central piece of legislation governing the RDI sector, the Law on Scientific Research and Technological Development, does no more than simply state that, in the absence of specific contractual provisions regulating the ownership of the RDI results, the general provisions of the various IP laws apply.[33] Thus, while undoubtedly a step forward compared to an older version that provided that the entity financing the RDI activity and the entity performing the RDI activities were co-owners of the RDI results, this law still lacks the "teeth" necessary to effectively foster the creation and commercialization of RDI results. Moreover, by leaving the ownership of the RDI results to be settled by contract, it runs the risk of creating inconsistent practices in the field and thus having a deterrent effect on private venture capital funds interested in financing RDI activities because they are used to predictability and consistency in the application of the laws in the field.
- *The Law on Scientific Research and Technological Development needs improvements.* One of the notable omissions of this law is the fact that it fails to include, among the RDI results, the rights existing before a submission of a patent or a utility model application[34] with the Romanian Patent and Trademark Office (RO-PTO)[35] and the rights existing after the application is submitted to the RO-PTO but before the patent or the utility model certificate is issued. In addition, the above referenced law warrants,[36] subject to contract, participation in the benefits arising from exploitation of the RDI results to persons involved in the RDI activity, which is not subject to the system of IP laws. This provision is unclear with respect to how participation in the benefits is warranted, given that a contract is essentially the result of mutual negotiations between the parties. Moreover, such a provision poses a significant burden to identify the subject matter in each contract, which may not fall under the IP regulatory framework.
- The IP laws regulating the RDI results need to be amended and harmonized. Various IP laws regulate the ownership and assignment of RDI results differently.[37] The relevant laws are the:
  (i) Law on Patents and the Regulation on Patents,
  (ii) (Law on Plant Varieties and the Regulation on Plant Varieties,
  (iii) Law on Topographies of Semiconductor Products and the Regulation on the Topographies of Semiconductor Products,
  (iv) Law on Ornamental Designs and the Regulation on Ornamental Designs,
  (v) Law on Copyright, and
  (vi) Employment Inventions Bill.

Employment Regulations

The employment regulations for researchers do not provide the possibility for sabbatical years for the researcher's employment in the spinoff company through which the research could potentially be commercialized.

32 According to Article 5 (1) (a) of the Law on Patents.
33 Article 5 (2) and Article 75 (1) of the Law on Scientific Research and Technological Development.
34 Or other similar protectable subject matter.
35 Article 45 of the Law on Patents specifically provides for the right of the inventor to freely assign the right to obtain a patent before submitting an application with the RO-PTO to get a patent. The same type of regulation applies to utility models (Article 20 of the Law on Utility Models) and to ornamental designs (Article 38 (2) of the Law on Ornamental Designs).
36 Article 5 (4) of the Law on Scientific Research and Technological Development.
37 A detailed review of such inconsistencies is covered by the World Bank Functional Review 2011.

The survey[38] implemented in the researcher's community revealed other challenges besides the regulatory barriers suggested above. The awareness of the practical process for a spinoff is limited (17%) primarily to those researchers who worked abroad and managed doctoral programs. The factors listed by the researchers who have not been involved or are not aware of any spinoffs are the poor management of the institutes and general lack of entrepreneurial culture, the regulations, the limited funding, the lack of incentives for researchers, and the heavy bureaucracy.

Technology Transfer Offices, Science and Technology Parks

Romania has a network of 49 organizations[39] that are accredited by the Ministry of Research and Innovation to perform technological transfer support activities (11 have provisory accreditation). There is no information regarding their performance concerning the commercialization of the research outputs. However, the rather limited number of spinoffs and patents in Romania indicates that these organizations focused more on providing consultancy services for supporting firms to develop their production and better market their products, rather than technology commercialization. The assessment done in 2016 by the Ministry of Regional Development and Public Administration states[40] that these organizations have not been able to generate sufficient revenues from the services provided.

2.1.3 Business Innovation

Entrepreneurship, Startup, and Scale Up

The micro, small, and medium-size enterprises (MSMEs) are largely predominant in the Romanian enterprise sector (Table 3). Of the 460,000 enterprises operating in industry and services, 88.5% are micro-enterprises, 11.1% are SMEs, and 0.4% are large firms.[41] The business density is 56% lower than the rest of EU, of about 23 enterprises per 1,000 people.

Table 3. Enterprise Sector in Romania (2010-2015)

No. Employed	2010	2011	2012	2013	2014	2015
From 0 to 9 persons	397,901	356,008	372,569	383,257	403,444	405,493
From 10 to 19 persons	24,869	26,947	27,041	27,424	26,816	26,475
From 20 to 49 persons	15,189	16,294	16,496	16,003	16,121	16,434
From 50 to 249 persons	7,635	8,161	8,043	7,931	7,866	8,078
250 persons or more	1,497	1,541	1,582	1,538	1,605	1,642

Romania[42] has a low volume of new firm creation and a low surviving rate of firms beyond five years. The birth rate of new firms is flat since 2011, while the survival rate among firms dropped from about 60% to about 40% over the period 2009–2014. In addition, the survey implemented by Global Entrepreneurship Monitor[43] concluded that the early stage entrepreneurial activity rate in Romania in 2014 was 11.35% of the adult working population, slightly higher than in 2013 (10.1%), and higher than Croatia, Hungary, and Poland. The share of nascent entrepreneurs decreased to 5.33% in 2014 from 7.94% in 2013 and is at similar levels as Croatia, Hungary, Lithuania, and Poland. The share of young business entrepreneurs increased to 6.17% in 2014 from 4.20% in 2013, which is the highest among the efficiency-driven economies from the European Union.

38 Annex 11.
39 http://www.research.gov.ro/ro/categorie/1065/sistemul-de-cercetare-infrastructura-inovare-si-transfer-tehnologic
40 Quoted by the Smart Specialization Strategy for Nord East Region, 2017, p. 25.
41 As of December 31, 2015. Data from EUROSTAT.
42 The Romanian Entrepreneurial Ecosystem Background Report, 2016 (EC, Horizon 2020 Policy Support Facility)
43 Global Entrepreneurship Monitor, http://gemconsortium.org/country-profile/103

Early stage entrepreneurial activity appears to be more oriented toward manufacturing and construction (31.31%), followed by the extractive sector (26.89%).

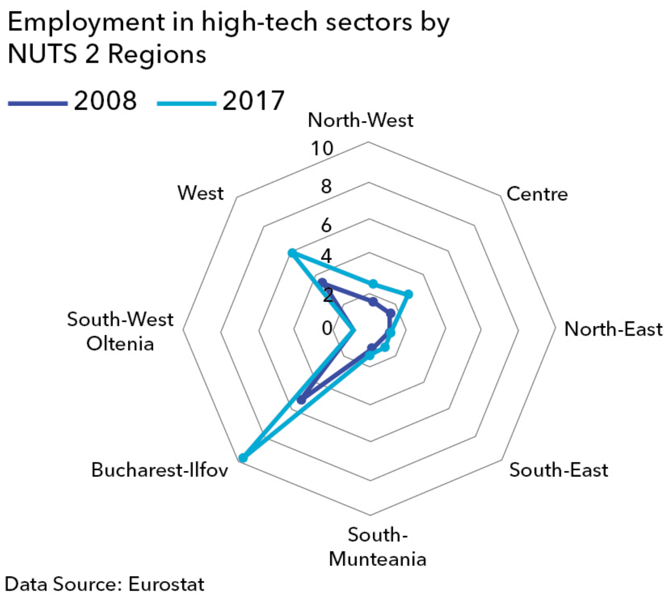
About 26% of the early stage entrepreneurs use technology that is newer than five years, and about 15.6% of them use technology that is newer than one year.[44] In contrast, about 15.7% of more established firms use technology that is newer than five years, and only 4.3% use technology that is newer than one year.

However, the number of high-growth firms in Romania increased in 2016 by 34% as compared to 2015 (from 1,169 to 1,568) at a higher rate than the EU average of 14%. The increase was highest in Cyprus (104%); however, the absolute number of high-growth enterprises in Cyprus is relatively low (48 in 2015 and 98 in 2016), followed by Romania (34%), Slovenia (29%), Spain (27%), Italy, and France (both 26%).

Early stage entrepreneurs and established firms are less innovative in Romania (in terms of new products or new markets) than peers in Poland, Croatia, and Hungary. The novelty of new products or services offered by early stage entrepreneurs is the highest in Croatia (59.3%), while in Romania, it is only 36%.

The employment in high and medium-high technology manufacturing sectors and knowledge-intensive sectors was 5.9% of the total employment in 2017, slightly higher the EU average of 5.8%. Figure 9 shows a high concentration of such employment in the Bucharest-Ilfov region (9.6% of total employment), followed by the West region (5.9%), Center region (2.8%), Northwest region (2.5%), South-Muntenia (1.2%), and Southeast region (1.1% and Northeast region at 1%).

Figure 9. Employment in High-tech Sectors by NUTS 2 Regions



44 Entrepreneurship in Romania – Country Report 2014, AnaMaria Dezsi Benyovszki, Agnes Nagy, Tunde Petra Szabo.

Access to Resources

Startups and MSMEs are not sufficiently served by the banking sector.[45] Startups do not have access to bank financing, as they lack track records and strong balance sheets to be used as collateral. Micro-enterprises tend to have informal practices and poor financial conditions (96.5% have negative equity, compared with 42.3% for all active enterprises). Moreover, SMEs are a very heterogeneous group with varied access to bank financing, although banks focus on urban areas, especially Bucharest, which account for more than one-third of SME loans on average. Overall, banks compete to serve large firms, while foreign-owned firms, which account for 5.9% of total enterprises and 44% of total value added in 2015, tend to benefit from parent companies' centralized treasuries, which often borrow from banks or bond markets outside of Romania at a lower cost than the local subsidiaries can, making them more productive.

Funding for entrepreneurship is mainly from structural funds grants. However, the financial support schemes are mainly general-purpose entrepreneurship programs.[46] Some RDI focused programs are included in the operational competitiveness programs implemented at the regional level. However, they are not designed and targeted to address the pre-seed and seed stages of the innovation process. Some programs have been funded from state budget, such as Start-up nation, however their sustainability is not clear.

The presence of business angels and venture capital in Romania is recent and less developed than in other EU countries. Several business angel networks are present, such as Venture Connect, Angel Connect, TechAngels, and Business Angels Romania. They provide both funding and matchmaking between startups and investors. Venture capital's overall investment volume in 2015[47] was of EUR 144 million into 11 firms, mainly in the form of buy-out capital. However, with only 0.09% of GDP, Romania is behind Poland (0.19%) and Hungary (0.15%) in terms of private capital investments. Co-investment schemes, with a mix of public and private funds, aimed at leveraging and decreasing the risks of the private equity investors, do not exist in Romania.

Apparently, Romania has a generous tax incentive policy to support R&D and innovation; however, its effectiveness is jeopardized by a series of factors that make it difficult to apply.[48] Several policy instruments were implemented since 2008:

- The Emergency Ordinance 200/2008 introduced a corporate tax reduction of 20% of R&D expenditure (which was later increased to 50%[49] in February 2013) and the application of the accelerated depreciation method for the equipment used for R&D activities.
- The Emergency Ordinance 32/2016 introduced an income tax exemption for R&D employees.
- The Emergency Ordinance 3/2017 introduced the exemption from corporate income tax for 10 years, both for startup companies and existing companies that exclusively carry out R&D and innovation activities.

The implementation of the legal provisions for additional deduction of eligible R&D expenses for corporate tax purposes is affected by the lack of clarity with respect to the eligible costs for which the additional deduction can be applied (such as the difficulty in differentiating the costs for research from those related to development) and by the administrative effort needed to compile the necessary documentation and address the fiscal inspectors/auditors' clarification questions. The implementation of the provisions related to the personal income tax exception for individuals involved in R&D activities is apparently affected by the difficulties and uncertainties related to the definition of eligible activities qualifying for tax deduction and the administrative compliance costs by both the R&D firms and individuals.

45 World Bank, Romania Systematic Country Diagnostic, 2018.
46 Start-ups, Scale-ups and Entrepreneurship in Romania – Horizon 2020 Policy Support Facility, 2017.
47 The Romanian Entrepreneurial Ecosystem Background Report, Horizon 2020 Policy Support Facility, 2017.
48 KPMG, Research, Development and Innovation – Tax incentives and economic growth in Romania, 2017.
49 Ordinance 8/2013.

Business Environment

The unpredictability of the business environment, a direct consequence of institutional failure, is a significant challenge to business operations, including investment decisions.[50] Firms in Romania are affected by the lack of predictability of the regulatory environment, especially fiscal-related uncertainty over the approach tax inspectors will take during their audits. The unpredictability of the business environment, a direct consequence of institutional failure, is a significant challenge to business operations, including investment decisions. While a static analysis of the business regulatory environment does not portray a negative picture (Romania is ranked 45th in Doing Business), over the past years, businesses were faced with a number of fiscal measures that were introduced and then reversed, which severely affected their ability to plan operations, including investments. While constraints to businesses activity vary depending on firm size, the unpredictability of the regulatory framework—in particular regarding taxation—is a concern for most enterprises. The high number of changes to the fiscal code (20 changes in the last two years only), the lack of consultation with the private sector, and the short time given to businesses to adapt have led to delays in investment decisions. Because of their size and scarce resources, MSMEs tend to be more affected by the regulatory burden. According to the EIB Investment Survey 2016, "political and regulatory climate" was the top factor negatively affecting the ability of firms to carry out planned investment for 47% of Romanian firms, which is lower than that in Poland (50%) but substantially higher than that in other countries in the region, such as Bulgaria (17%), Hungary (23%), or Croatia (28%).

50 World Bank, Romania Systematic Country Diagnostic, 2018.

2.1.4 Conclusion R&D and Innovation Environment in Romania

The R&D and innovation (RDI) sector in Romania is in a silent crisis. The country is diverging in innovation performance from its European peers. The European Innovation Scoreboard 2017 (Annex 6) places Romania as a modest innovator, with a declined performance by 14.1% relative to that of the EU in 2010. Romania is performing well below the average of the EU on all outcome dimensions and indicators. However, the concentration of R&D human resources, research outputs and dynamic entrepreneurship in the Ilfov/Bucharest area create good premises for ELI-NP externalities, provided that a sustained effort is made to improve the framework conditions discussed above.

Chapter 3

Spatial Dimensions of Laser Valley

3. Spatial Dimensions of Laser Valley

The objective of this section is to provide a comprehensive territorial perspective by reviewing existing enabling and inhibitor conditions that affect the development vision for the LVI. First, the chapter reviews the national, regional, and local spatial dimensions for the Laser Valley and sketches the functional profile of the LVI area. Second, it reviews the normative dimension that governs the current planning practices, with the objective to identify the constraints that hinder coherent spatial and planning exercises. Third, it assesses the level of realism of the financial perspective and administrative commitments by analyzing the structure of available and planned municipal budgets. Finally, it suggests an initial planning concept that offers a coherent planning solution for the region, including its financial and administrative rationale. Each section ends with a list of catalysts and inhibitors, drawn from the spatial and normative perspective, which affect the future development path of the Laser Valley project.

3.1 Spatial Perspectives

The exact territorial scale of the Laser Valley initiative area is difficult to determine at this stage. Each territorial scale harbors different benefits that can be capitalized upon via the Laser Valley project as the following paragraphs aim to show. In principle, larger territorial scales are more prone to produce sectoral policies, especially of the industrial and commercial type, and their associated large-scale infrastructure projects, while smaller scales lend themselves more readily to available spatial and urban planning instruments. Nevertheless, it is precisely these smaller-scale planning instruments that need to concomitantly accommodate policy formulation and prepare the project area for future large-scale investments.

The section covers national, regional, and local perspectives, as follows:

- The national perspective describes the major determinants affecting the Laser Valley project area in its broadest sense. It concentrates on the coherence of the transport networks servicing the southeastern part of Romania. Thus, the insight gained should receive scrutiny within industrial and commercial policy formulation, as it pertains to the possible economic gains derived from the privileged position of the Laser Valley project area within the country and from its high exposure to international trade.
- The regional perspective concentrates on the commuting patterns of the labor force, on firm location, and on the question of urban sprawl. In contrast with the national perspective, which focuses more on the physical infrastructure supporting the process of economic integration, the regional perspective highlights the influence Bucharest exerts on its vicinities. As it turns out, the municipalities surrounding Bucharest face the real danger of becoming an undifferentiated suburbia, which is difficult to manage and yields little benefit at a metropolitan level.
- The local perspective completes the picture by taking a closer look at matters related to accessibility and public utility provision. This perspective focuses exclusively upon the municipality of Măgurele since it is intimately linked to the development of the ELI-NP project.

3.1.1 The National Context

The Laser Valley area benefits from an extremely privileged location within the Romanian national context due to its proximity to Bucharest. Its future development path is therefore intimately linked to the opportunities available for Bucharest and its hinterland. However, capitalizing on many such opportunities requires a broader territorial perspective, aimed at assessing the national and international significance of the region. Essentially, this becomes a question of territorial competitiveness.

Hence, from a strictly geographical perspective, this macro-territorial perspective encompasses Bucharest and its adjacent municipalities in the north, the River Danube in the south, and the port of Constanța in the east. Viewed from an industrial and commercial policy perspective, such a broad focus has the benefit of including the sole functioning of the Romanian multimodal corridor, stretching from Bucharest in the west to the port of Constanța in the east.

The corridor comprises the higher-speed railway between Bucharest and Constanța, the A2 Motorway, the River Danube, and the Danube-Black Sea Canal. In principle, this corridor has the potential to transform Bucharest and its surrounding region into a direct hinterland to Constanța, which acts as the most important commercial port at the Black Sea coast. It could thereby ensure Bucharest's access to a potential market stretching from Western Ukraine and Moldova to Hungary, while integrating the capital into the wider Asian and European markets.

Nevertheless, there are some inhibiting factors currently barring this process of economic integration, as discussed below. Most of these aspects pertain to industrial and commercial policy formulation, but they have the potential to dramatically affect the Laser Valley project area in the long run. Hence, they should be considered when designing spatial and urban planning documentations within the area.

- *Rail transport is not currently regarded as a viable strategic option*, with most of the freight conveyed by road transport via the A2 Motorway. In addition to management, service provision, and pricing issues, rail transport is also plagued by a few severed links within the network. One such prominent case is the railway connection between Bucharest and Giurgiu, which has remained out of service since 2015, when a bridge over the Argeș River collapsed.
- *None of the linear connections by road, rail, and water have managed to produce discernible development opportunities for the surrounding areas over the past years.* Hence, development seems to be mainly confined to the large urban centers of Bucharest and Constanța and their immediate vicinities.
- *The navigation potential on the Danube remains underdeveloped mainly due to the weakness of the transport market and the inadequate links* to other river basins but also due to existing 'pinch points' (i.e., critical sections that prohibit the transit of vessels with a draught greater than two meters between 40 and 60 days a year). These critical sections, which cover the Lower Danube almost entirely, have not been systematically dredged to date. This inhibits the development of the Bucharest-Danube Canal, which would complete the multimodal corridor described above by providing a direct navigable connection to the port of Constanța and to the Asian markets. Furthermore, this missing link prevents Bucharest from capitalizing on the European inland waterway system, thereby thwarting its potential to develop into a major commercial hub within this system (Figure 10). In principle, there are three major operating fields in which the region might assume a leading role within a European context, thereby completing Romania's current international commercial profile: roll-on/roll-off shipments, the transfer of liquefied petroleum gas from seaports, and the shipment of heavy cargo to the Upper Danube.

Figure 10. European Inland Waterway System in 2012

Source: The United Nations Economic Commission for Europe (UNECE)[51]

51 Available at: https://www.unece.org/fileadmin/DAM/trans/main/sc3/European_inland_waterways_-4_2012.pdf [06 04 2017].

3.1.2 The Regional Context

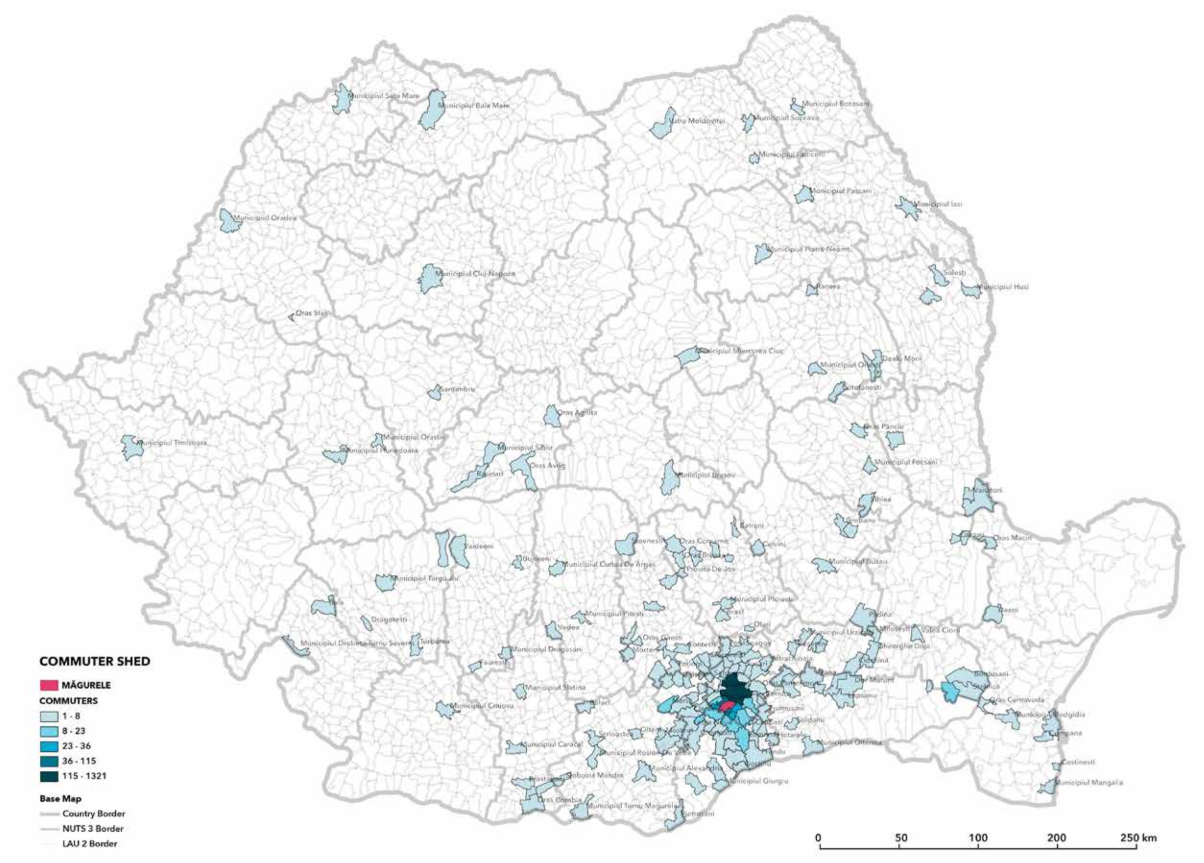
Against this national and international background, the regional perspective focuses on the influence Bucharest exerts upon the Laser Valley project area. There are three distinctive features at this scale. First, there is the commuter shed, which is indicative of a municipality's attractiveness for the labor force. However, it also simultaneously points to some shortcomings in the quality of urban life, especially in terms of housing quality and public service provision. Second, there are firm location patterns, which are representative of the business environment within the municipality. Third, urban sprawl, originating in Bucharest, produces an inefficient urban form that becomes increasingly difficult to service. Furthermore, by eroding existing land reserves, urban sprawl usually prevents consistent planning interventions and coherent real-estate projects. When combined, these three aspects become pivotal in explaining the interactions within the Laser Valley project area by highlighting the influence of Bucharest on the region.

Commuter Shed

The following illustration displays the entire commuter shed for the municipality of Măgurele, based on the 2011 census records (Figure 11). The resulting commuting pattern appears to be exceptionally large, covering almost the entire country. This seems somewhat unlikely, as commuting trips over such large distances quickly become impractical. Hence, we surmise that the more distant fringes of the commuting area are, in fact, persons who have not applied for a resident's permit within the municipality of Măgurele.

Figure 11. Total Commuter Shed for Măgurele

Source: The World Bank, based on data provided by the National Institute for Statistics (NIS).



Nevertheless, the real commuter shed for Măgurele covers an area of more than 100 km in diameter, with the city of Bucharest harboring the largest number of commuters by far. This extensive commuter shed has formed despite a feeble metropolitan public transportation system. This observation is important, as it highlights a comparatively high propensity for commuting within the population. We might therefore surmise that a functional and efficient regional public transportation system might dramatically increase the area covered by the commuter shed.

The analysis of the commuting profile within the commuter shows that out of 2,100 commuters, about 30% are R&D personnel (Figure 12). When switching focus from the type of activity to the type of profession, one is also able to observe an important share of specialists and technicians commuting daily to Măgurele, amounting to 39% and 15%, respectively, of the total number of commuters (Figure 13 and 14).

Figure 12. R&D Personnel Commuting to Măgurele

Source: The World Bank, based on data provided by the NIS.

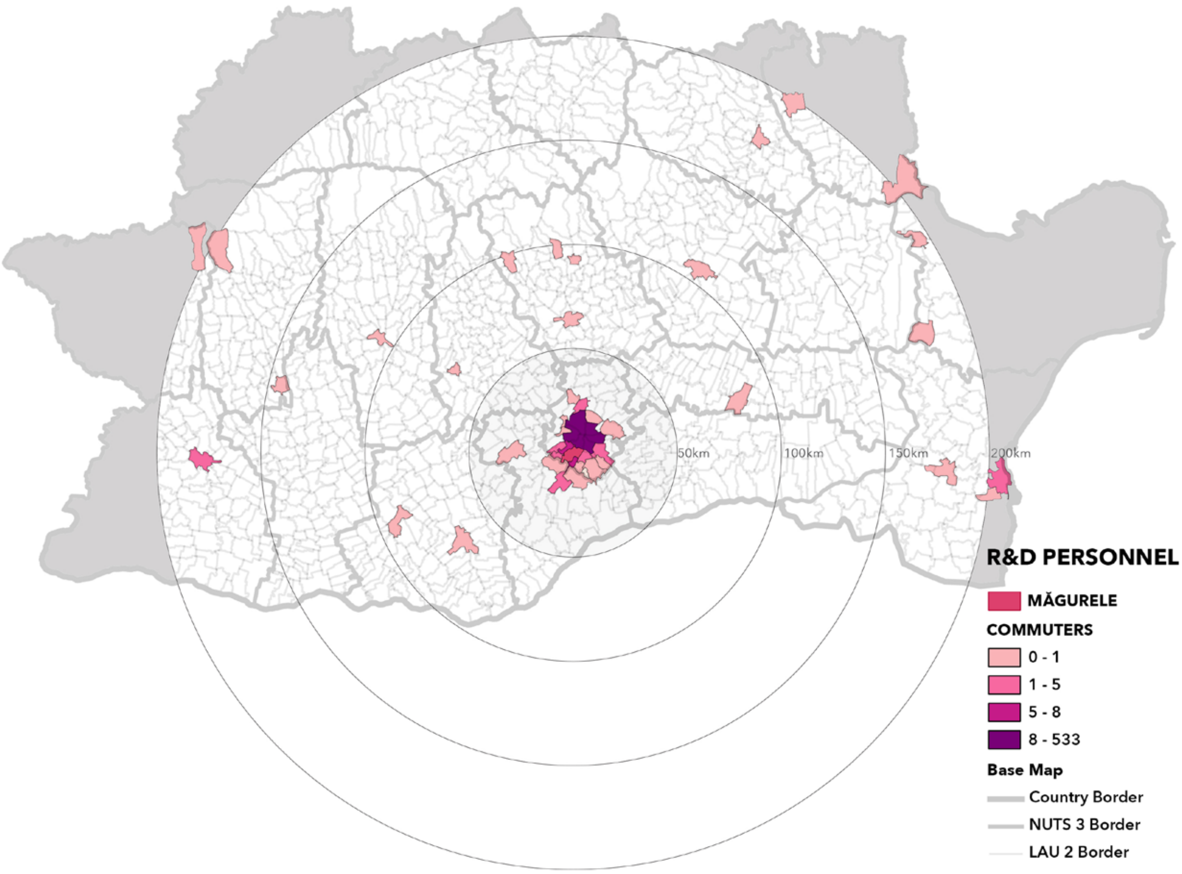


Figure 13. Specialists Commuting to Măgurele

Source: The World Bank, based on data provided by the NIS.

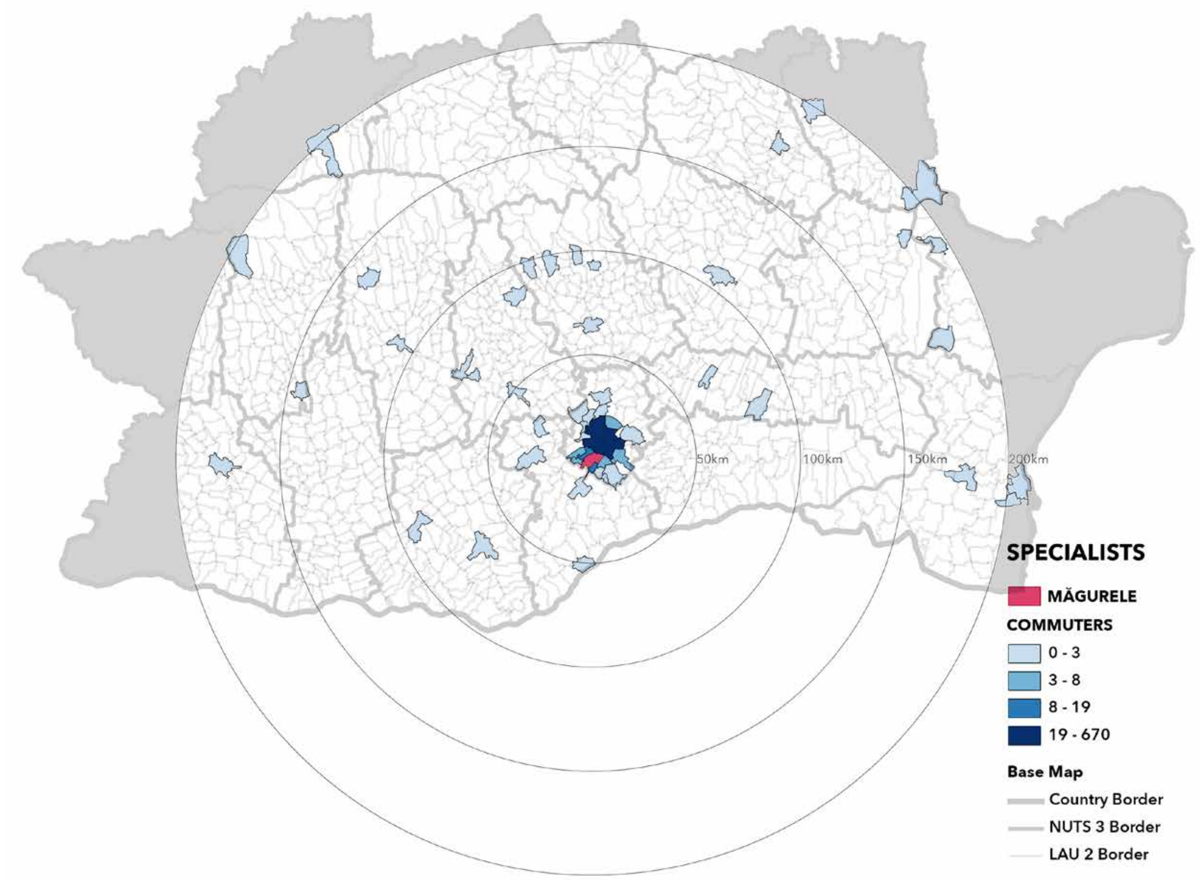
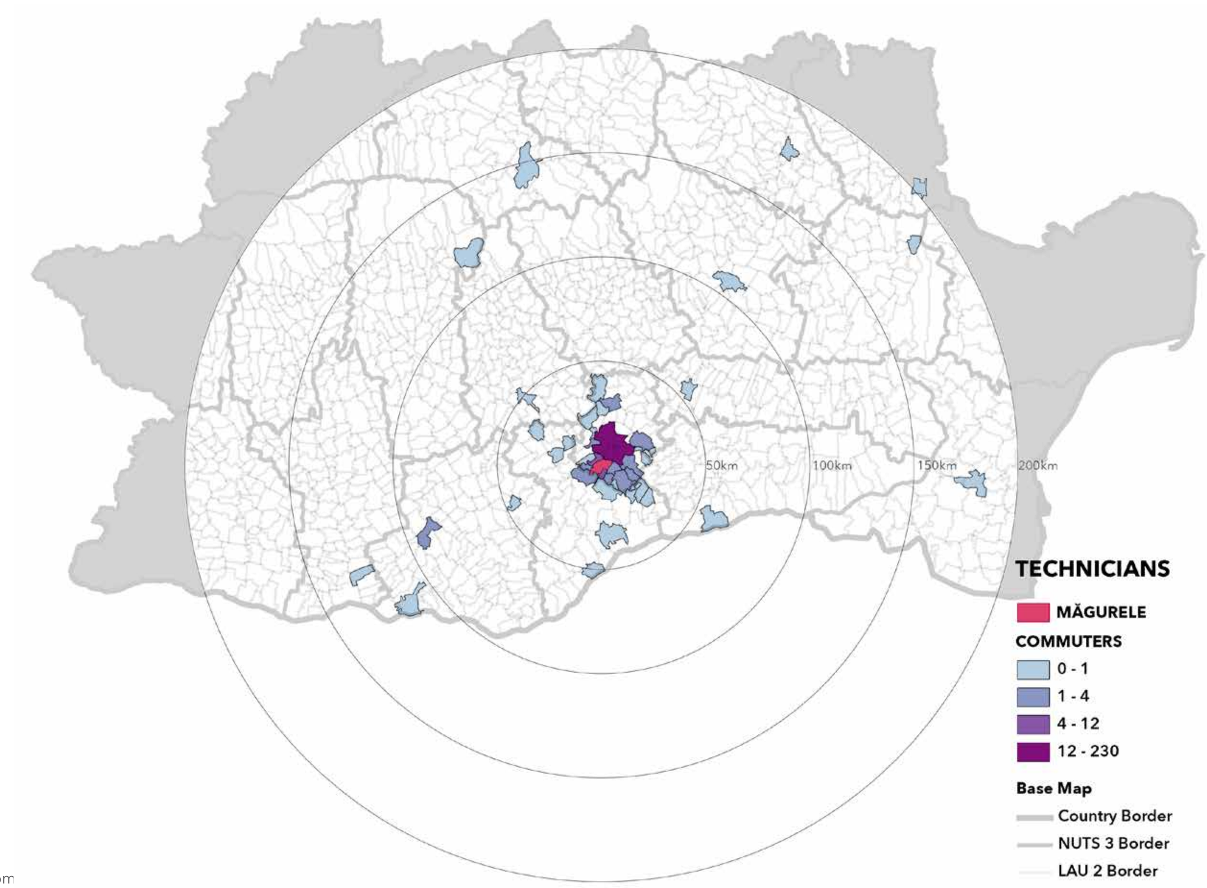


Figure 14. Technicians Commuting to Măgurele

Source: The World Bank, based on data provided by the NIS.



Additional insight can be gained through a closer examination of commuting patterns. Hence, it seems that men display a greater propensity toward commuting than women do, thus indicating a sizable commuter gender gap, which might translate into a wage gap. Furthermore, men seem to have a more balanced commuting pattern (i.e., arriving in Măgurele from almost all directions). Women, on the other hand, seem to commute primarily from municipalities located on Măgurele's western fringes. Apart from such differences, Bucharest remains the primary commuting origin for both genders. In addition, the population between 45 and 64 years of age is more prone to commuting than the other age groups within the workforce (i.e., the 16–35 and the 36–44 cohorts). Nevertheless, the youngest cohort seems to have the densest commuting pattern, almost entirely filling the area inscribed by the 50-km radius.

With respect to education, most persons working in Măgurele have gained some form of higher education degree. Again, most of them come from Bucharest. Commuters with an upper secondary degree seem to spread more evenly around the municipality, sometimes reaching and even surpassing the 100-km commuting limit.

Hence, Măgurele is essentially a commuting destination for the highly qualified workforce involved in R&D activities, thereby displaying a unique commuter profile among Romanian municipalities. Employment opportunities are therefore somewhat imbalanced, with the top share of employment being dedicated to R&D personnel, specialists, and technicians. A smaller share of commuters work within the administration. Retail ranks among the least important employment opportunities for commuters.

Firm Location

The commuter shed revealed a significant share of R&D personnel, specialists, and technicians present among commuters. It therefore became necessary to set commuting patterns in a wider context by examining the R&D industry more closely. The following paragraphs thus chart the industry at the national, regional, and local levels. In addition, Annex 8 in this report provides some additional rankings within the R&D industry, aimed at complementing the illustrations presented within this section (Tables 8.1 to 8.5).

When viewed from a national perspective, the R&D industry exhibits the highest concentrations in and around Bucharest, both in terms of employees and turnover (Figures 18 and 19). They seem to be unique across the Romanian landscape, with regional capitals lagging far behind. It is also worth noting that many of these R&D companies and institutions operate at a loss, with R&D companies and institutions residing within the cities of Pitești, Craiova, and Iași seeming somewhat unprofitable (Figure 20). The case of Bucharest is, unfortunately, still illegible at this scale, thereby requiring a finer grained perspective.

Figure 15. R&D Personnel in Romania

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.

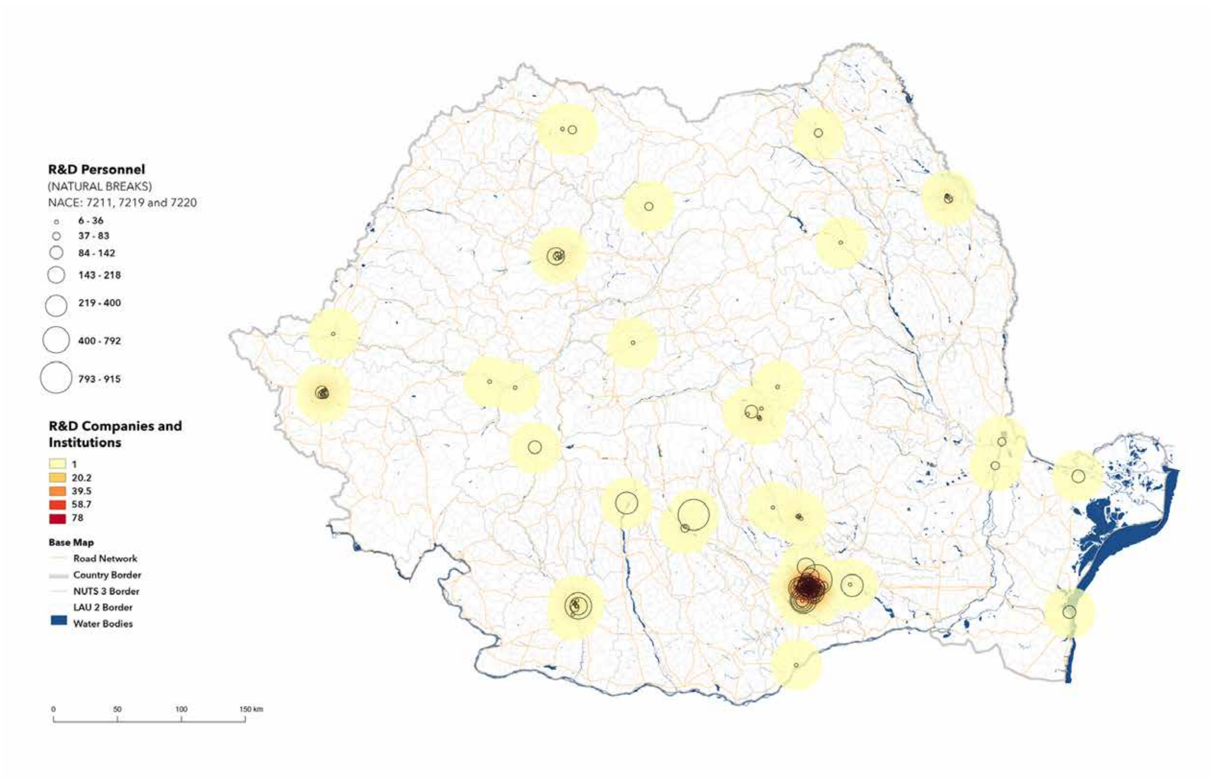


Figure 16. R&D Turnover in Romania

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.

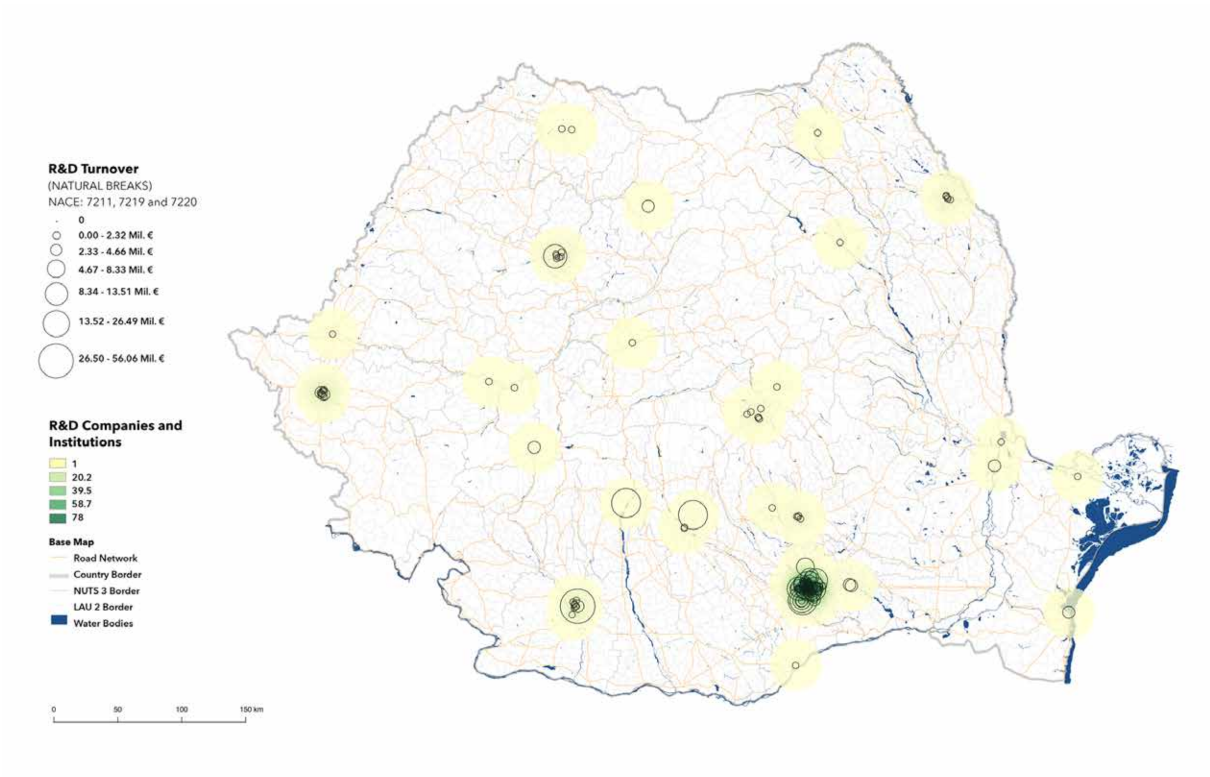
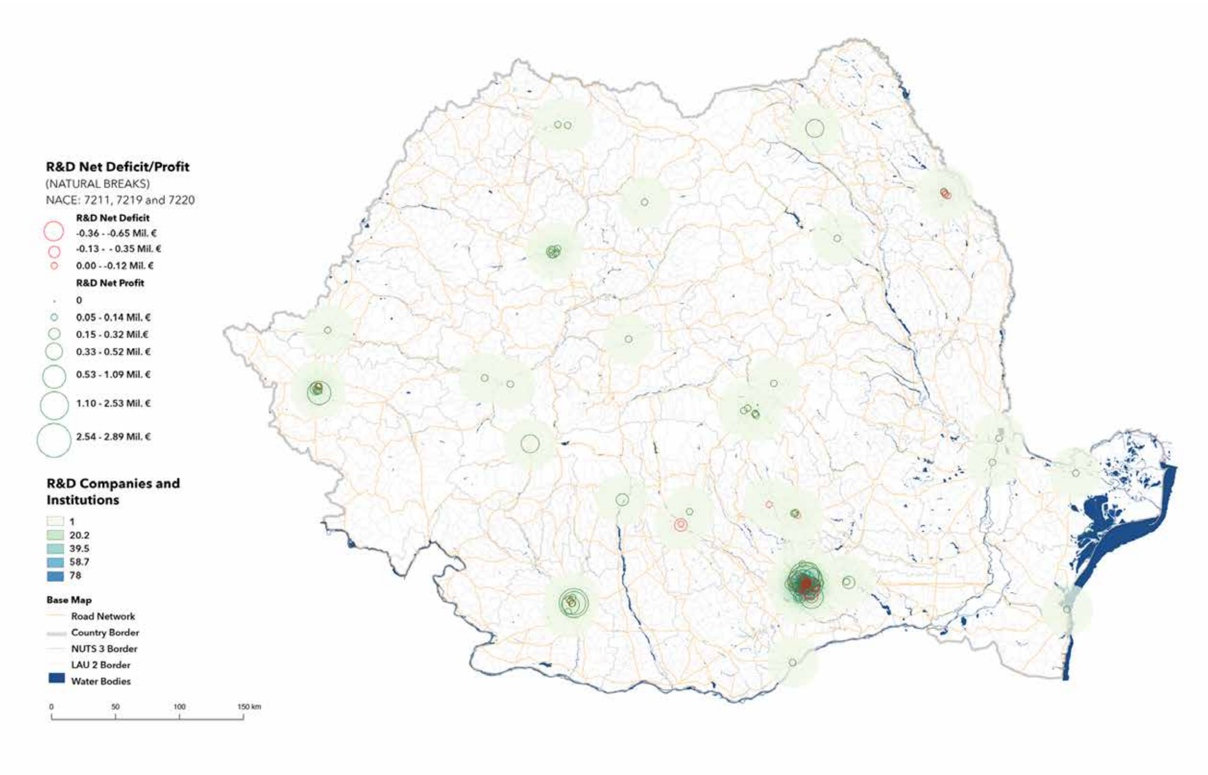


Figure 17. R&D Profits in Romania

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.



Thus, the picture sharpens when viewed from a regional perspective (Figures 18 to 20). Hence, it becomes clear that the R&D industry is primarily concentrated in the northern part of Bucharest, with the municipality of Măgurele and the former IMGB Industrial Platform being the only two notable exceptions to this rule. The relative isolation of the research platforms located within Măgurele thus becomes strikingly evident, thereby substantiating concerns related to accessibility.

The question of profitability also becomes more nuanced at this scale, with most R&D companies and institutions operating at a profit. Among them, those located within the municipality of Măgurele seem to fare relatively well.

Figure 18. R&D Personnel in the Bucharest-Ilfov Region
Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.

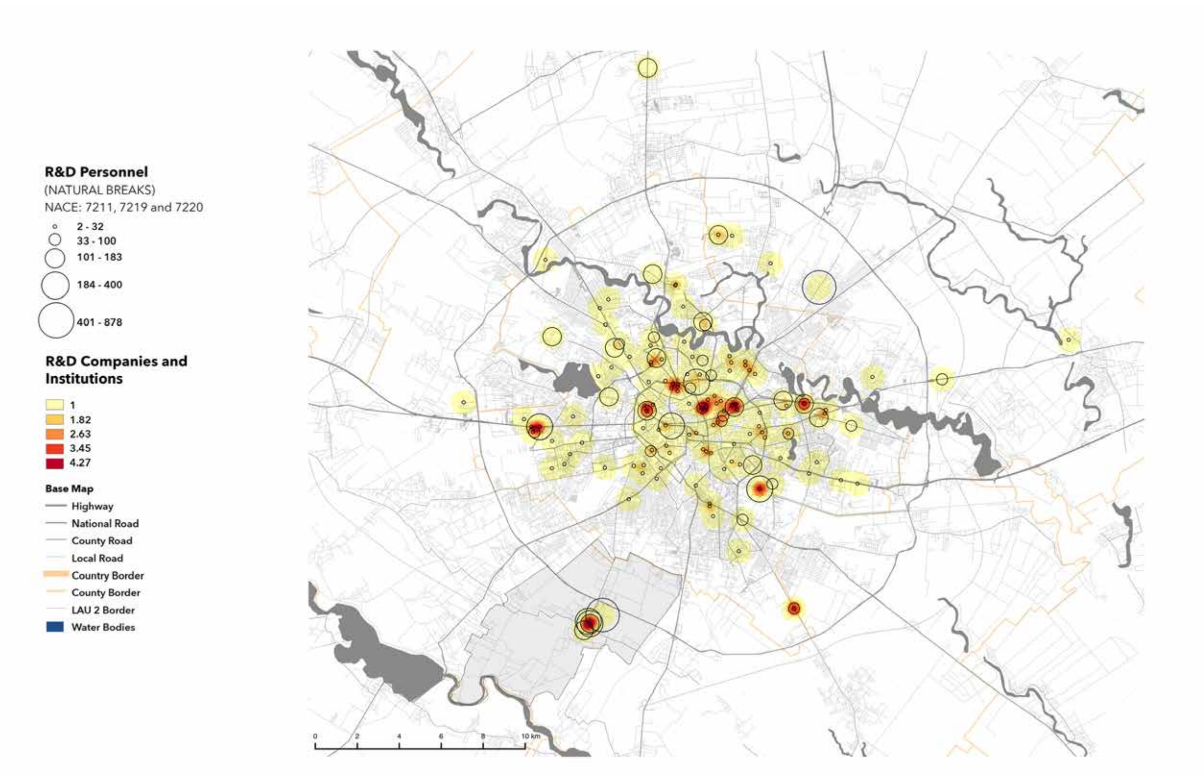


Figure 19. R&D Turnover in the Bucharest-Ilfov Region
Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.

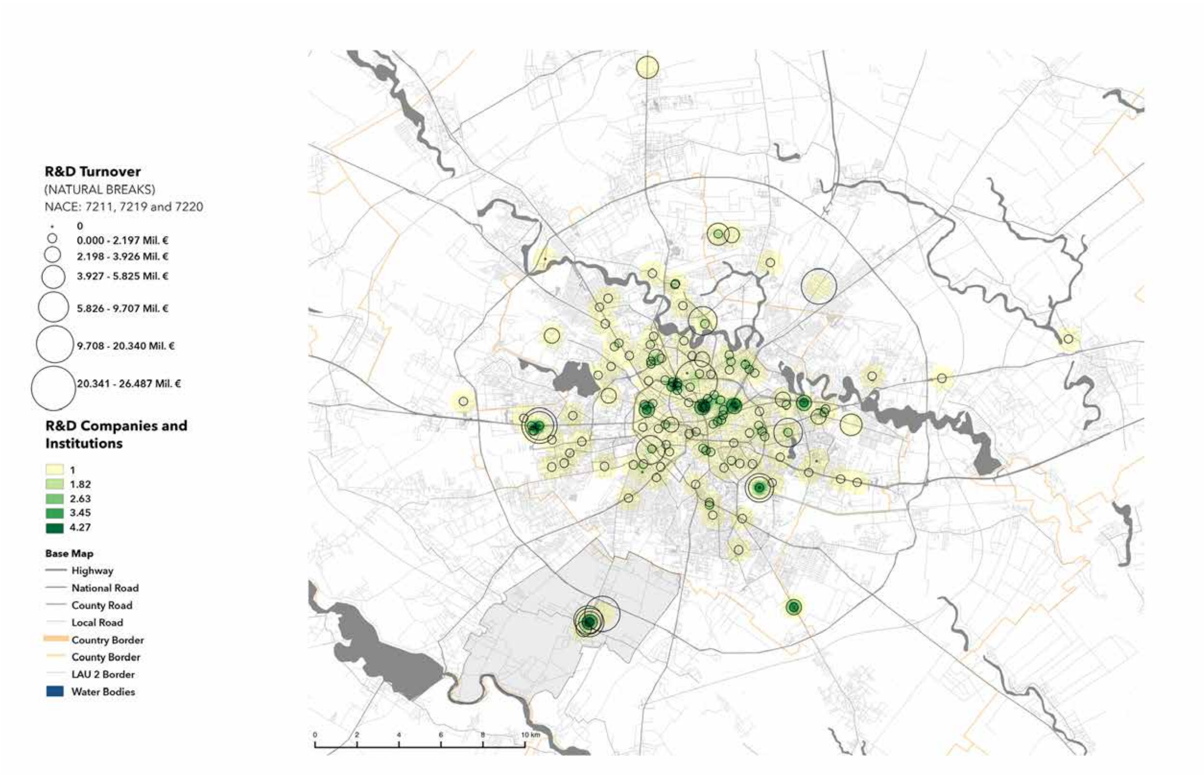
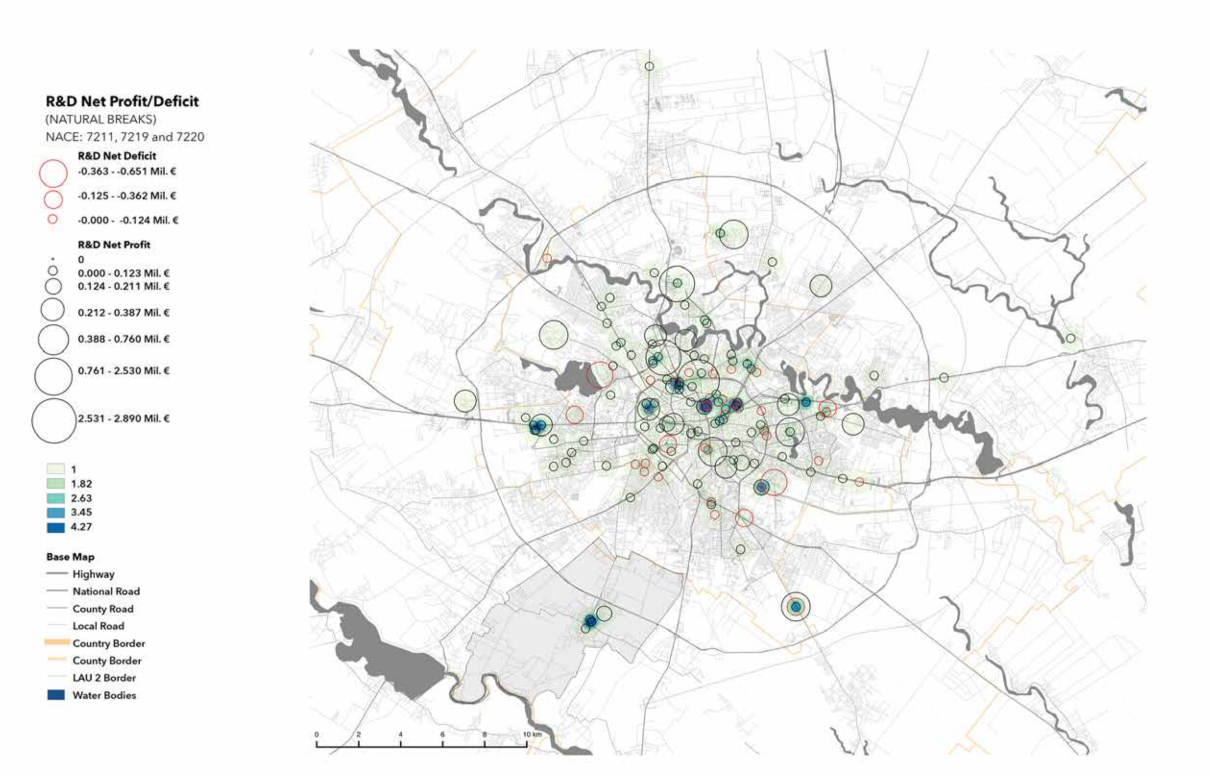


Figure 20. R&D Net Profits and Deficits in the Bucharest-Ilfov Region

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.



The local perspective further reveals the limited extent to which R&D companies and institutions have spread across the municipality of Măgurele (Figures 21 and 22). Essentially, they remain confined to the civic center and the immediate vicinity. This trait seems to be distinctive for the R&D business environment in Măgurele, especially when compared to the location patterns of other companies (Figures 23 and 24). [52]

Hence, other firms have spread more evenly across the town proper without reaching the southern part of the municipality. Furthermore, other major players within the business landscape seem to be companies operating in the field of postal and courier activities (NACE 5320) or delivery of pharmaceuticals (NACE 4773) (Annex 8, Tables 8.4 and 8.5). Nonetheless, the most important player in terms of turnover is a company that specializes in wholesale diesel distribution, which currently acts as the largest independent oil company in Romania.

52 Figures 23 and 24 also display three companies that seem to lie outside the confines of the municipality of Măgurele. These companies operate within the municipality, but their erroneous position results from working on the OpenStreetMap (OSM) base map, which, given its community development, sometimes harbors inconsistencies.

Figure 21. R&D Personnel in Măgurele

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.

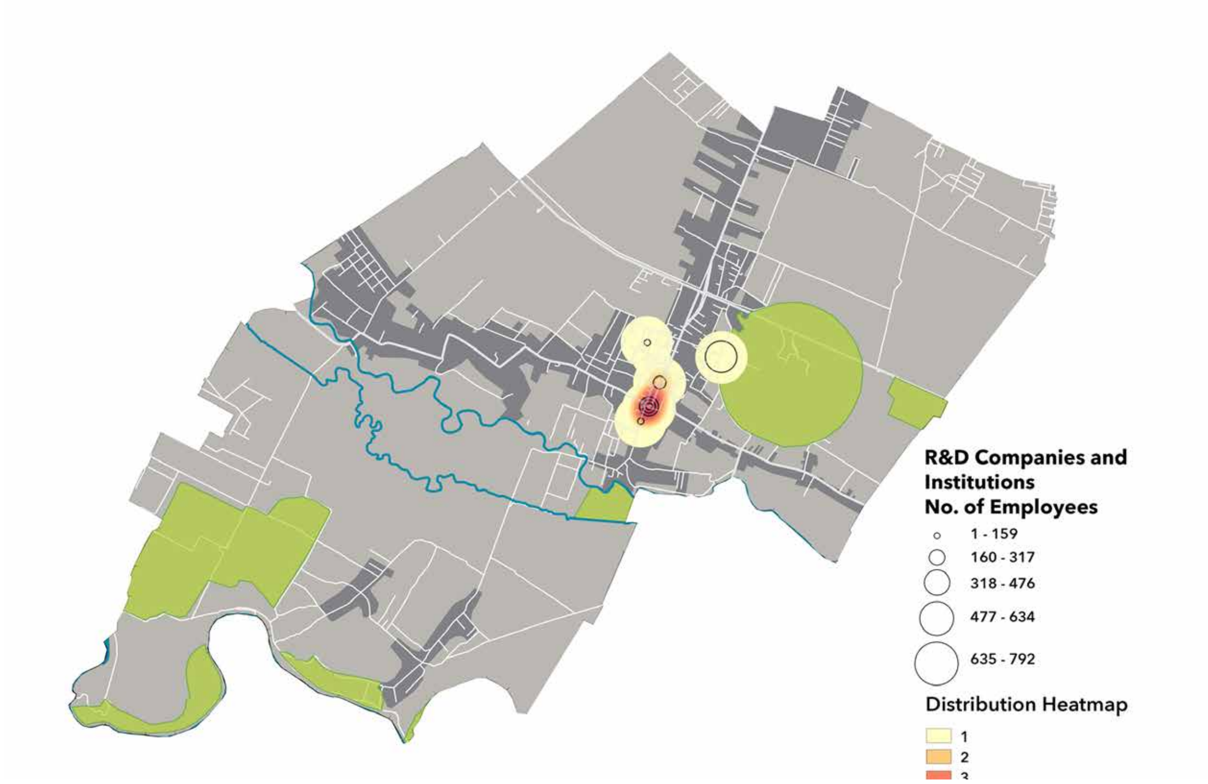


Figure 22. R&D Turnover in Măgurele

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.

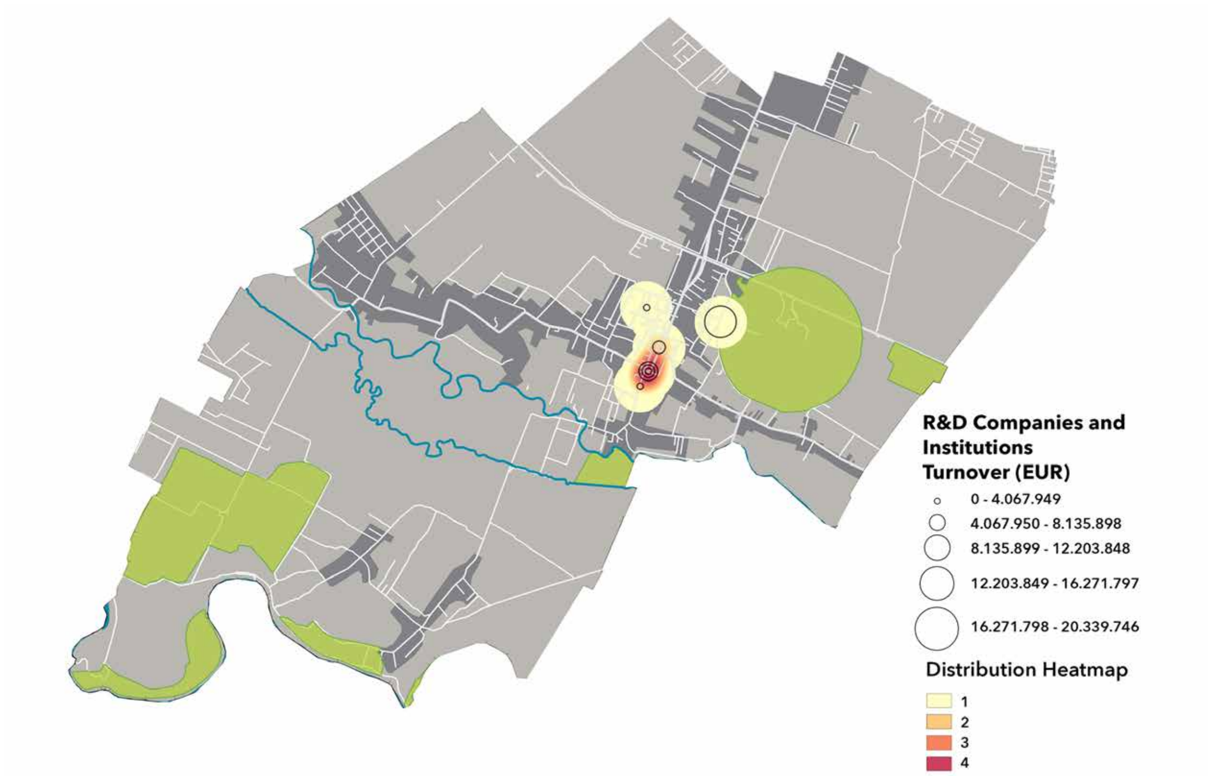


Figure 23. Employees in Măgurele

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.

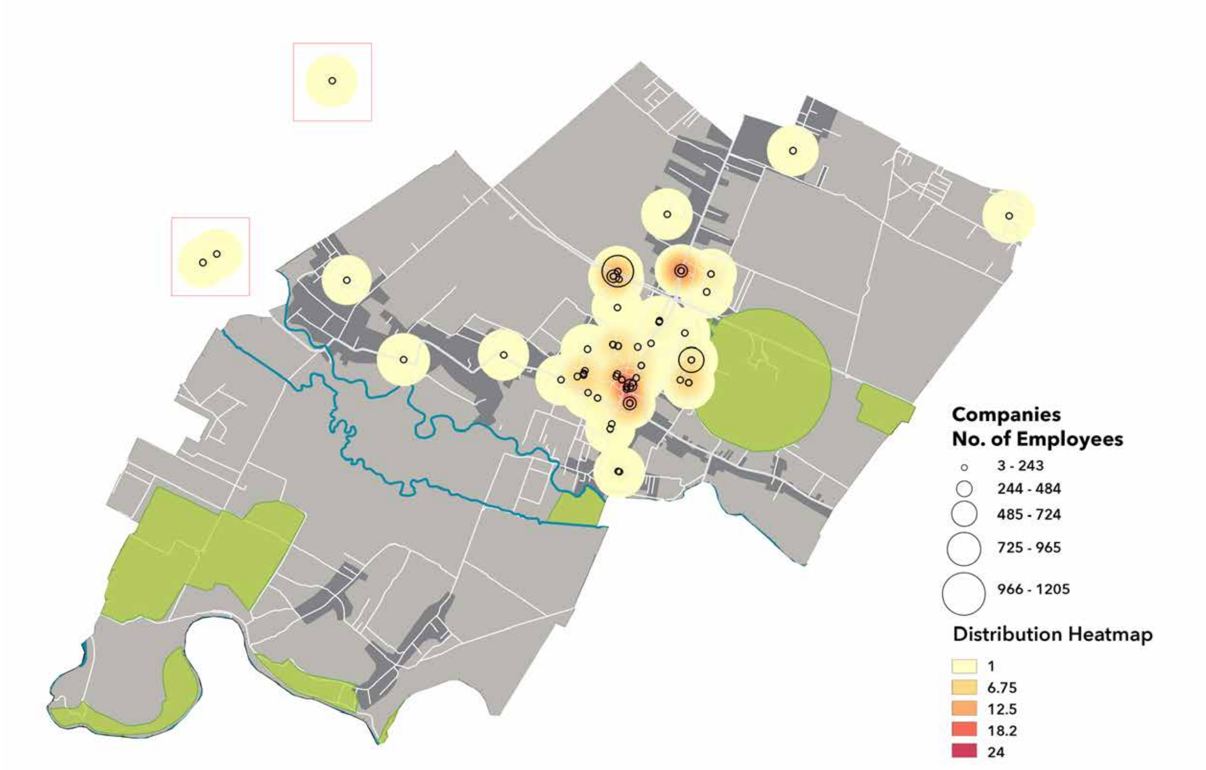
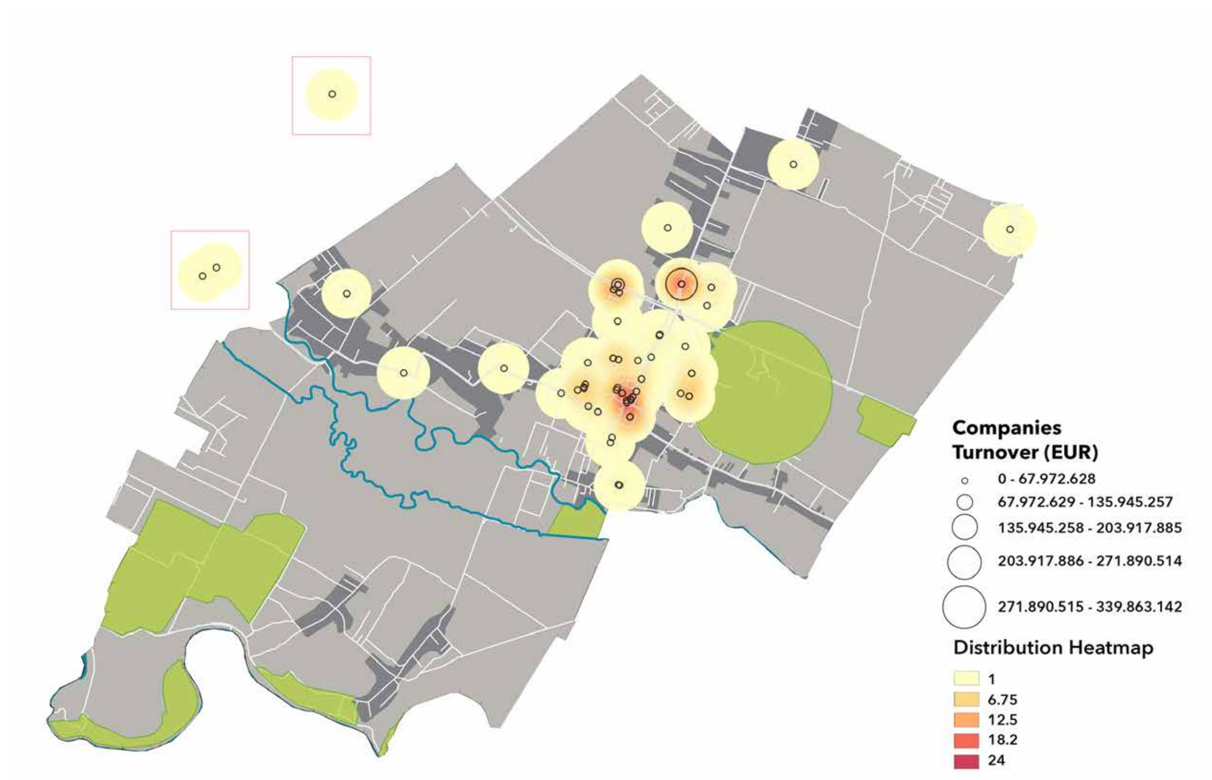


Figure 24. R&D Turnover in Măgurele

Source: The World Bank, based on data provided by Lista Firme/Borg Design S.R.L.



The apparently high concentrations of R&D companies and institutions may lead to the conclusion that Măgurele is a dynamic business environment, given the variety of firms operating at the intersection between research, pharmaceuticals, material science, and fuels (Annex 8). However, the semi-structured interviews have revealed that there is practically no interaction between the R&D companies and institutions and these other firms (Annex 11).

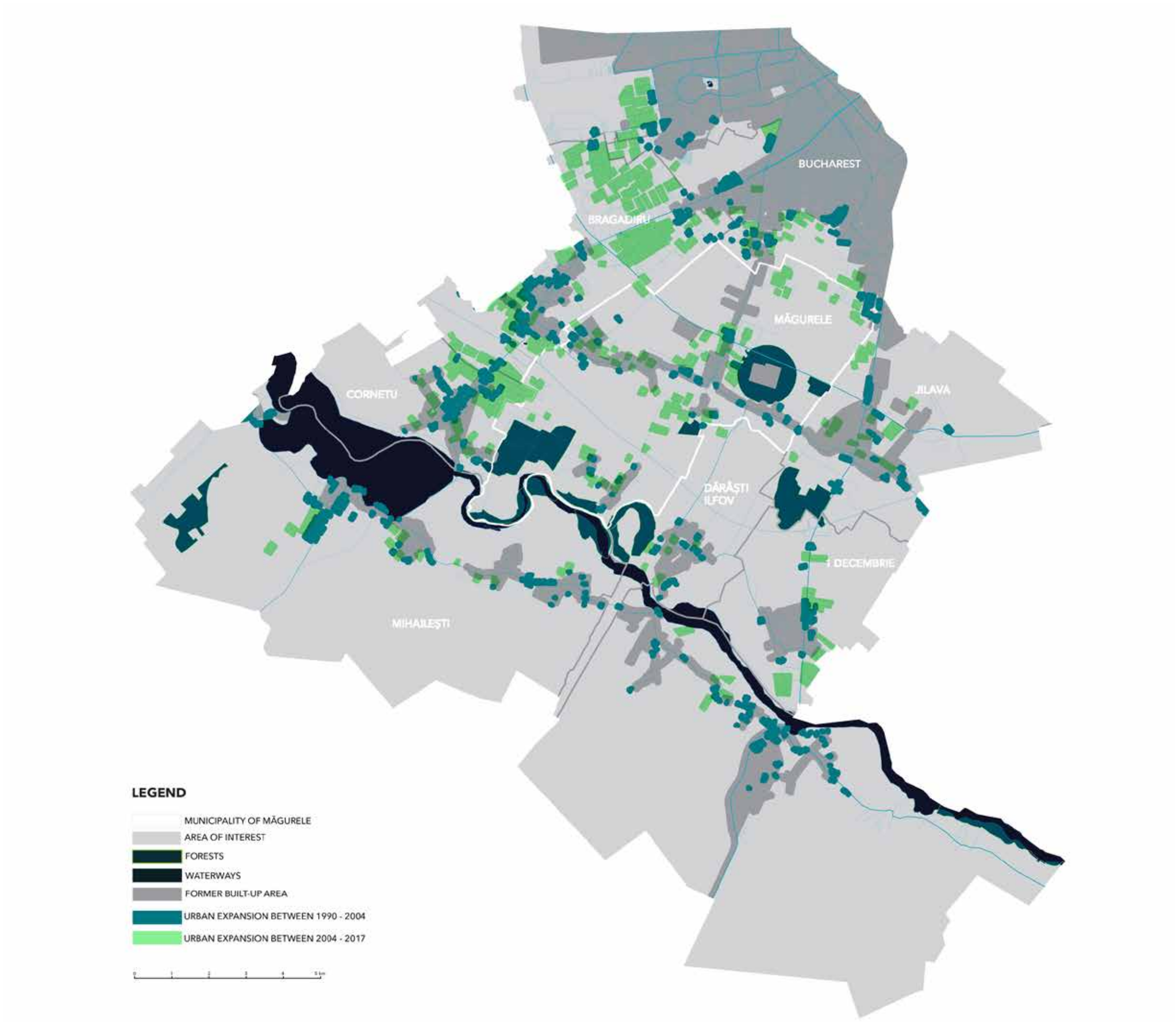
Unfortunately, it seems that the distance within the innovation chain is simply too large. Thus, research conducted on these platforms is either not mature enough for it to be commercialized effectively, or local firms are in no need of integrating the results of research within their day-to-day operations. In the first instance, if the current inhibitors related to legislation, dedicated funding, and business culture prevent most of the research results from reaching maturity, in the second instance, it is more a question of a lack of demand for innovative products. However, it is most likely a combination of these two factors that best explains the current situation.

Urban Sprawl

Another more disconcerting consequence of the immediate vicinity of Bucharest is the phenomenon of urban sprawl. The following illustration displays the effects on the town of Măgurele and its neighboring municipalities (Figure 25). To obtain a more detailed perspective on this matter, the map is accompanied by a series of satellite images depicting the changes within the urban fabric of Măgurele and Bragadiru occurring between 2004 and 2017 (Figures 25 to 29).

Figure 25. Urban Sprawl between 1990 and 2017

Source: The World Bank, based on Google Earth satellite imagery.



Dividing the post-socialist period into distinct time spans reveals the different speeds at which this process erupted throughout the entire area. Hence, while urban expansion developed linearly along the main roads until 2004, the subsequent period witnessed a massive increase in speed and breadth with new allotments starting to erode the remaining fabric. The most probable mechanism behind such a gain in speed is the highly volatile real-estate market within Bucharest, which forces households to settle for homes that are increasingly farther away from the city center.

Figure 26. Municipality of Măgurele in 2004 and 2017

Source: Google Earth satellite imagery.

Figure 27. Northern Part of Măgurele in 2004 and 2017

Source: Google Earth satellite imagery.

Figure 28. North-Western Part of Măgurele in 2004 and 2017

Source: Google Earth satellite imagery.

Figure 29. Municipality of Bragadiru in 2004 and 2017

Source: Google Earth satellite imagery.

However, one direct effect of this ongoing urban sprawl process is the rising pressure exerted on public amenities and public service provision. Furthermore, inefficient allotments of former agricultural plots have produced a highly wasteful urban form, which is characterized by a low-rise and low-density type of fabric. Hence, to produce a more efficient urban form, a greater concentration of housing units is needed as well as a more diverse public amenity portfolio.

One of the very few areas that have escaped the urban sprawl phenomenon is the immediate vicinity of the former military fort, which might house a future science park. The reason behind this apparent immunity lies in the protection area that surrounds the fort. However, once this provision becomes void, the area becomes subject to rampant sprawl, unless planning regulations can effectively shield it.

3.1.3 The Local Context

The municipality of Măgurele displays an interesting territorial profile. It lies in the immediate vicinity of Bucharest, bordering it on the southern fringe of the Fifth Sector. This privileged location ensures direct access to the qualified workforce and talent concentrations developing in Bucharest.

In addition, the Ciorogârla, Sabar, and Argeș Rivers cross the municipality. These potential blue-green corridors are comparatively less affected by human intervention than their counterparts in northern Bucharest, thereby offering ample room for a future increase in ecosystem service provision.

However, many traits of this inherent potential currently lie dormant for a variety of reasons that require special consideration from a planning perspective. One of the most prominent inhibitors is an insufficient public transportation provision, which greatly impedes commuter flows while producing traffic congestion. It is closely followed by the structure of the land that, given its high degree of fragmentation, requires additional planning interventions, such as land readjustment and land pooling, so that it can accommodate coherent real-estate investments. Finally, there is the matter of public service provision, which relies on an incomplete critical infrastructure that leaves many important areas within the municipality unserved.

Accessibility

The municipality of Măgurele benefits from a radial connection to the center of Bucharest, via Atomiștilor Street (DC 19), Bucharest-Măgurele Highway (DC 18), and Alexandria Highway (DN 6), which enters Unirii Square through its southwestern corner. Furthermore, Bucharest Ring Road (DNCB) and Bucharest Ring Railway, which act as concentric connections to Bucharest, also cross the municipality. An additional county road (DJ 401A) connects Măgurele to the adjacent municipalities of Jilava and Bragadiru.

Hence, the municipality of Măgurele should benefit, at least in principle, from a high degree of accessibility both from Bucharest and from its adjacent municipalities. This is unfortunately not the case, as traffic congestion and insufficient levels of public transportation provision plague the radial connection. Moreover, the concentric connections are either highly congested, as in the case of Bucharest Ring Road, or are inoperative, as in the case of Bucharest Ring Railway.

However, public transportation is limited to three bus lines (i.e., lines 427, 453, and 455), which connect the municipality to the Ghencea District and the Alexandria Terminal in Bucharest. Privately operated minibuses, such as lines 203, 204, 214, and 303, which connect the Institute of Atomic Physics (IFA) to the Ghencea Bus Terminal, provide additional transportation. Unfortunately, there is no line connecting the municipality of Măgurele to the center of Bucharest or to Henri Coandă International Airport.

Hence, commuters basically have three options available for them to reach their workplace. The first option is to use the public transportation system, which generally implies one or more transfers between lines to reach the city center or other districts, except Ghencea. A second option is to use minibuses. They also end their journey at the Ghencea Bus Terminal but have the advantage of a shorter cadence. Nonetheless, the transfer problem remains. The last option is to use a private car or to engage in car sharing. For the time being, most commuters prefer to commute by private car. Despite this unattractive context, the commuter shed is large, with people willing to commute 50 km and or even farther.

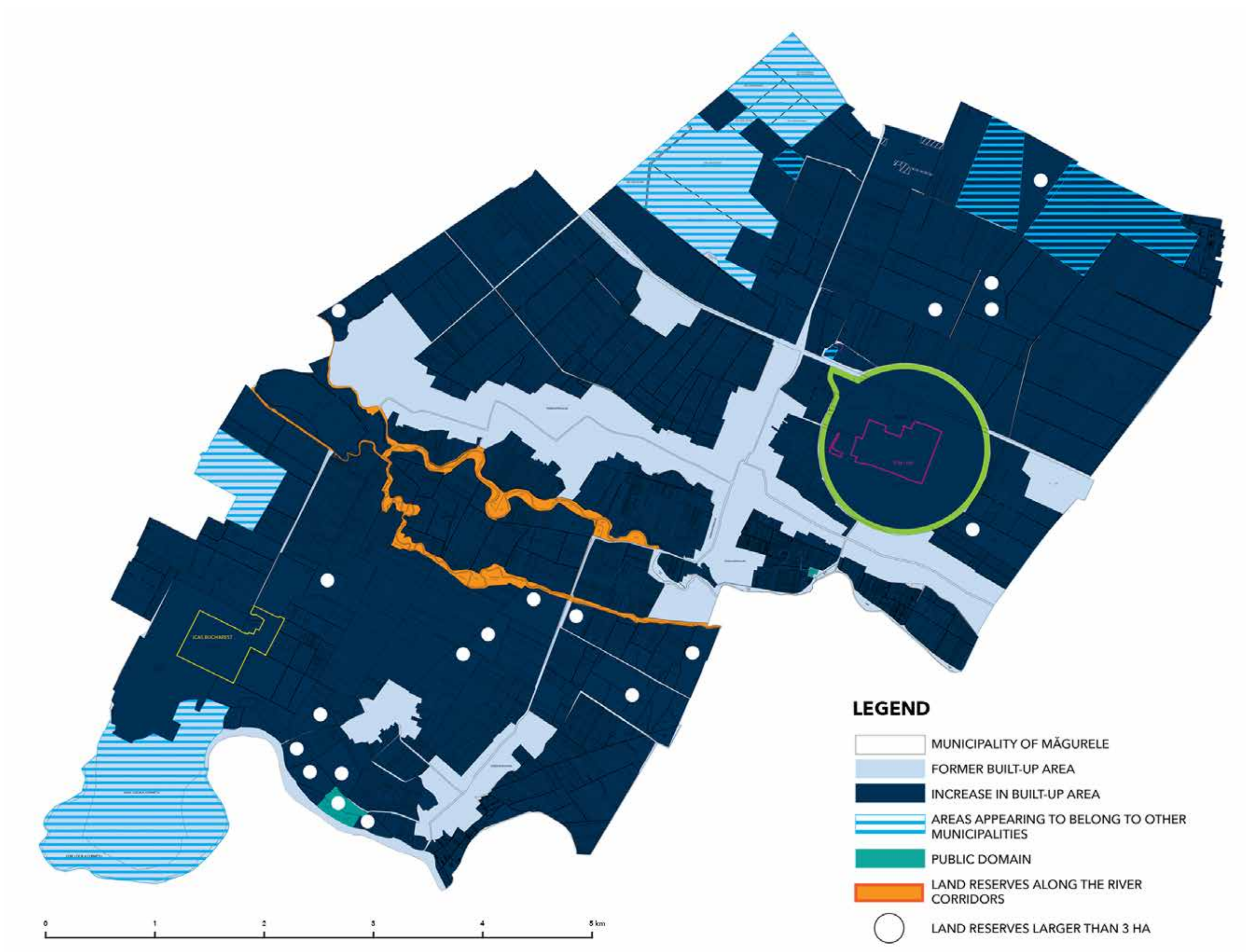
Land and Property

The following illustration depicts the land structure within the municipality of Măgurele (Figure 30). The gray areas represent the former built-up areas of the constituent settlements, (i.e., the town of Măgurele and the villages of Alunișu, Dumitrana, Pruni, and Vârteju). The remaining areas have been included in the newly contoured built-up area, thereby augmenting it by a staggering 331%.

However, some parts within the municipality of Măgurele belong to the adjacent municipalities of Cornetu, Bragadiru, Dărăști–Ilfov, and Bucharest. The semi-structured interviews have revealed that this is a common occurrence, with the municipality of Măgurele also owning land within some of these municipalities. This produces a serious planning predicament, with urban planning documentation regulating the use of land belonging to a different municipality.

Figure 30. Increases in the Built-up Area of Măgurele

Source: The World Bank, based on general urban plan for Măgurele (2014).



Little of this newly incorporated land has been built (Figure 31). To be more precise, the built areas amount to about 27% of the built-up area, a figure that translates roughly into approximately 1,000 ha. Hence, in principle, 73% would remain available for future development. Unfortunately, these remaining areas are marred by an inefficient land structure, which prevents coherent real-estate investments from reaching fruition, unless a targeted land readjustment program is initiated.

Figure 31. Built Areas in Măgurele

Source: The World Bank, based on Google Earth satellite imagery.

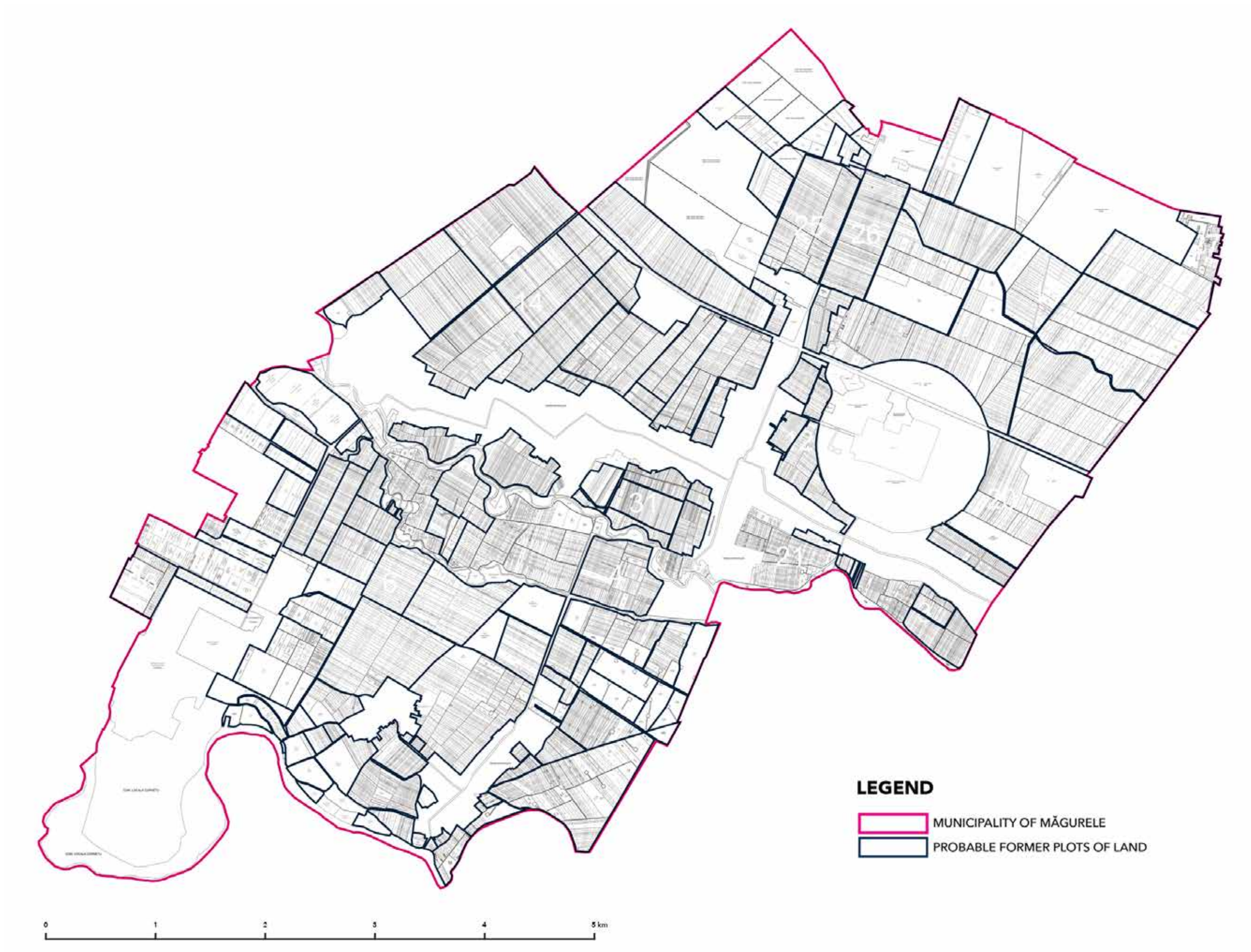
Thus, plots can be divided into three distinct size classes (Figure 32). The largest plots, ranging from about 20 ha to a maximum of 103 ha, are generally wooded areas belonging to the Bucharest Forest District. There are a few exceptions to this rule, with the most prominent one being an area of about 84 ha, belonging to the municipality of Dărăști–Ilfov. Nonetheless, this instance requires further investigation, as its status is somewhat unclear.

A second class of plots ranges from about 1 ha to about 15 ha. Most of these plots are private property, but some of them, especially the larger ones, are listed as land reserves and are located within the municipality commons. However, these land reserves should receive careful consideration, as they might form the main reservoir for pending land restitutions.

The last class of lot sizes comprises plots smaller than 1 ha. Many of them are precisely 1 ha or 0.5 ha in size. These values again point toward a rather widespread process of land restitution. Most of them are private property, albeit with some exceptions, which are listed as land reserves. Here again, the same care is required when regarding them as available.

Figure 32. Plot Structure within the Municipality of Măgurele

Source: The land cadaster.



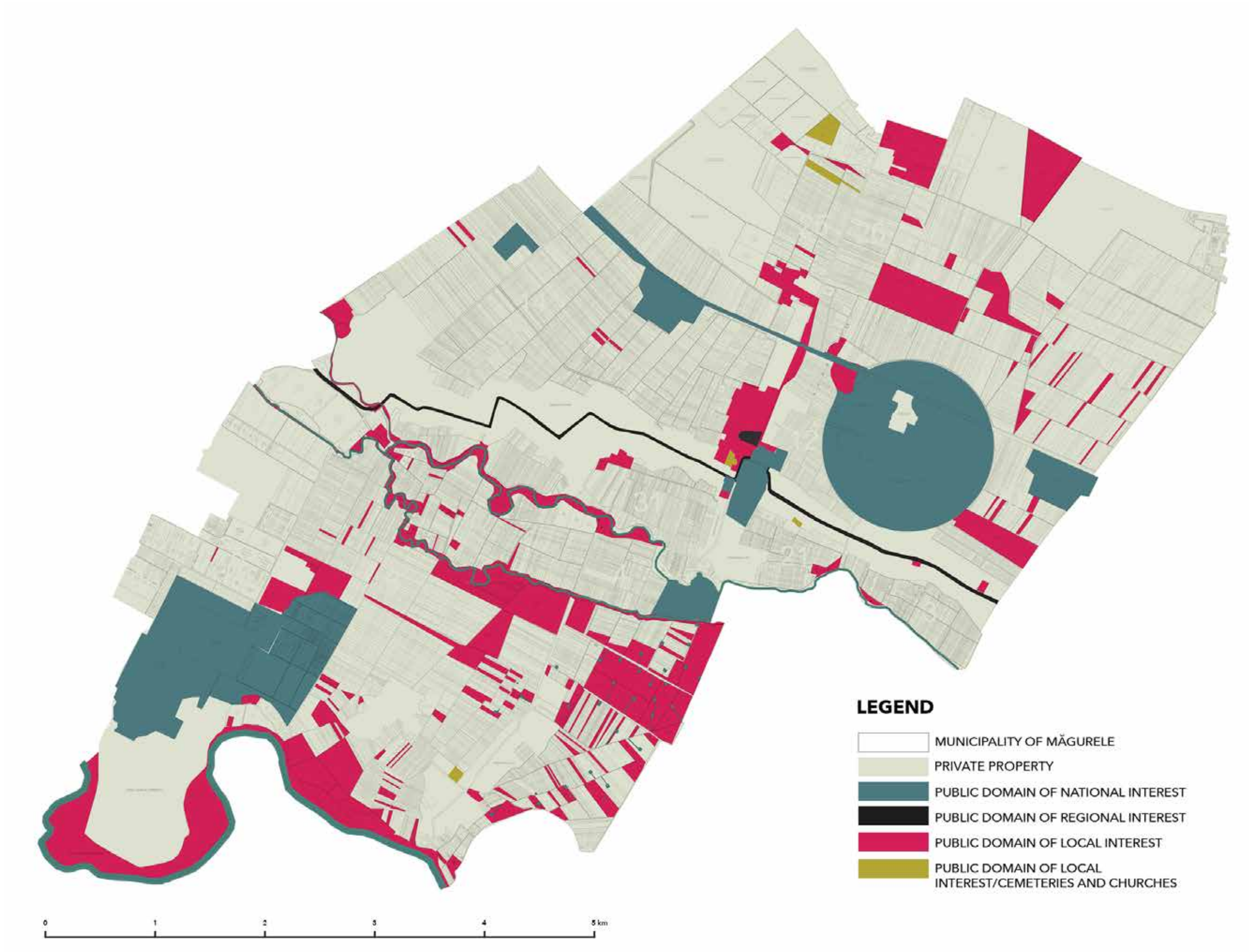
A methodological word of caution is due. Because of the limits in the legibility of the base map, we were unable to account for all plots. Furthermore, we gained access to two different sources for assessing the property structure within the municipality of Măgurele: the land cadaster and the general urban plan of 2014. They present conflicting information about the availability of land within the public domain, with the land cadaster restricting it to only two larger plots, while the general urban plan illustrates far more extensive land reserves available within the public domain (Figure 33). The question of choosing between these two sources must remain open until the municipality publishes a definitive assessment.

Hence, if one were to consider the land cadaster to be the primary source of information, while also considering the land restitution conundrum, one would conclude that the public domain is quite limited in size, with only two larger plots of about 8 ha and some 0.5 ha, respectively, available for immediate development. Both have direct access to the rivers crossing the area, with the larger plot being located on the left bank of the Argeș River and the smaller one on the left bank of the Ciorogârla River. Nevertheless, while zoning regulations covering the larger plot permit a mixture of tourism facilities and green open spaces, the smaller plot falls completely under regulations that permit housing only.

The situation changes dramatically if the general urban plan is a credible source of information. Here, land reserves are far more generous, being spread all over the municipality. At least some of these reserves would again act as restitution reservoirs; nevertheless, a fair share of available land could accommodate future real-estate investments connected to the ELI-NP program. As noted earlier, great care is needed when assessing available land reserves for immediate development.

Figure 33. Property Structure within the Municipality of Măgurele

Source: The general urban plan for Măgurele (2014) and the land cadaster.



A concise overview of these available land resources, as listed within the general urban plan for Măgurele, is listed in the Table 4 below.

Table 4. Enterprise Sector in Romania (2010-2015)

Source: The general urban plan for Măgurele (2014).

	Property	Surface (ha)	Surface (%)
1	**Municipality of Măgurele**	**4,413.86**	**100%**
2	**Total Built-Up Area**	**4,017.00**	**91%**
3	**Unincorporated Areas**	**396.86**	**9%**
4	Public Domain of National Interest (including forests, which are part of the unincorporated areas)	512.00	11.60%
5	Public Domain of Regional Interest	14.00	0.32%
6	Public Domain of Local Interest	518.00	11.74%
7	Public Domain of Local Interest (churches and cemeteries)	9.62	0.22%
8	**Total Public Domain**	**1,053.62**	**23.88%**
9	Private Property	3,360.24	76.12%
10	**Total Private Property**	**3,360.24**	**76.12%**

Regardless of the chosen source of information, it is important to give strategic real-estate investments thorough consideration, as many investment opportunities will most certainly rely on some form of property and development rights transfer. These might turn out to be costly, especially when considering the costs of critical infrastructure provision. Furthermore, it is quite likely that a comprehensive land readjustment program might soon be needed to prepare for a more efficient urban form.

Against this background, alternative land reserves should be considered as well. The selection should meet the following three criteria: first, that such land reserves are close to the municipality of Măgurele, in the sense that they offer accessible and speedy connections to the research platforms and their environs; second, that they are large enough to enable coherent real-estate development; and third, that they benefit from public utility provision.

The interviews conducted in preparation for this report have revealed a consistent land reservoir that meets all three criteria located within the Fifth Sector in Bucharest. Essentially, this reservoir consists of three large reserves, totaling some 650 ha, with the municipality of the Fifth Sector owning about 400 ha.

The first land reserve is located adjacent to Antiaeriană Street, south of the Ghencea Sports Complex, spreading over about 300 ha. The municipality of the Fifth Sector owns about a third of it (i.e., ~110 ha). The second land reserve straddles the border between the Fifth Sector and the municipality of Măgurele, stretching between the Odăi neighborhood and Progresul neighborhood on the southern fringe of the Ferentari neighborhood. It encompasses about 330 ha, of which the municipality of the Sector owns about two-thirds. The third land reserve comprises the former industrial railway connecting the Progresul Railway Station to the former ROCAR industrial platform and to the Cotroceni Railway Station and the Bucharest Ring Railway. Of immediate interest are about 8 km, comprising the railway connection of the Toporași-Răzoare sector and former ROCAR platform, totaling approximately 20 to 30 ha.

These land reserves compensate for many deficiencies exhibited by the land and property structure within the municipality of Măgurele. Thus, they are less fragmented, better endowed with public utilities, and are closer to the center of Bucharest, thereby benefiting from a better accessibility. They might therefore prove to be potent catalysts for the Laser Valley project.

Public Utility Provision

Public utility provision is uneven across the municipality of Măgurele. The critical infrastructure supporting the provision of utilities is underdeveloped, particularly within areas that have been included in the newly endorsed built-up contour of the municipality. Thus, the following illustrations depict the current situation for the road infrastructure, water supply, sanitary sewer, central gas supply system, and street lighting (Figures 34 to 38).

It is important to note that there is no comprehensive plan illustrating the entire critical infrastructure covering the municipality. We have therefore relied solely upon information provided by the Sustainable Urban Mobility Plan for the municipality of Măgurele. Nonetheless, the insight gained proved sufficient in highlighting areas that require special attention when considering future real-estate developments.

The following map displays the road infrastructure overhaul projects comprised within the Sustainable Urban Mobility Plan for Măgurele (Figure 34). There is an explicit focus on improving the road network within the town proper and the village of Vârteju, in what has essentially become a constituent part of the town. The other villages (i.e., Pruni, Dumitrana, and Alunișu) receive comparatively less attention, probably due to less real-estate pressure being exerted on them.

In addition, Atomiștilor Street (DC 19) has undergone a major overhaul operation, resulting in a four-lane thoroughfare that connects Măgurele with Bucharest-Măgurele Highway (DC 18). Unfortunately, this latter highway consists of only two lanes, thereby acting as a bottleneck for traffic.

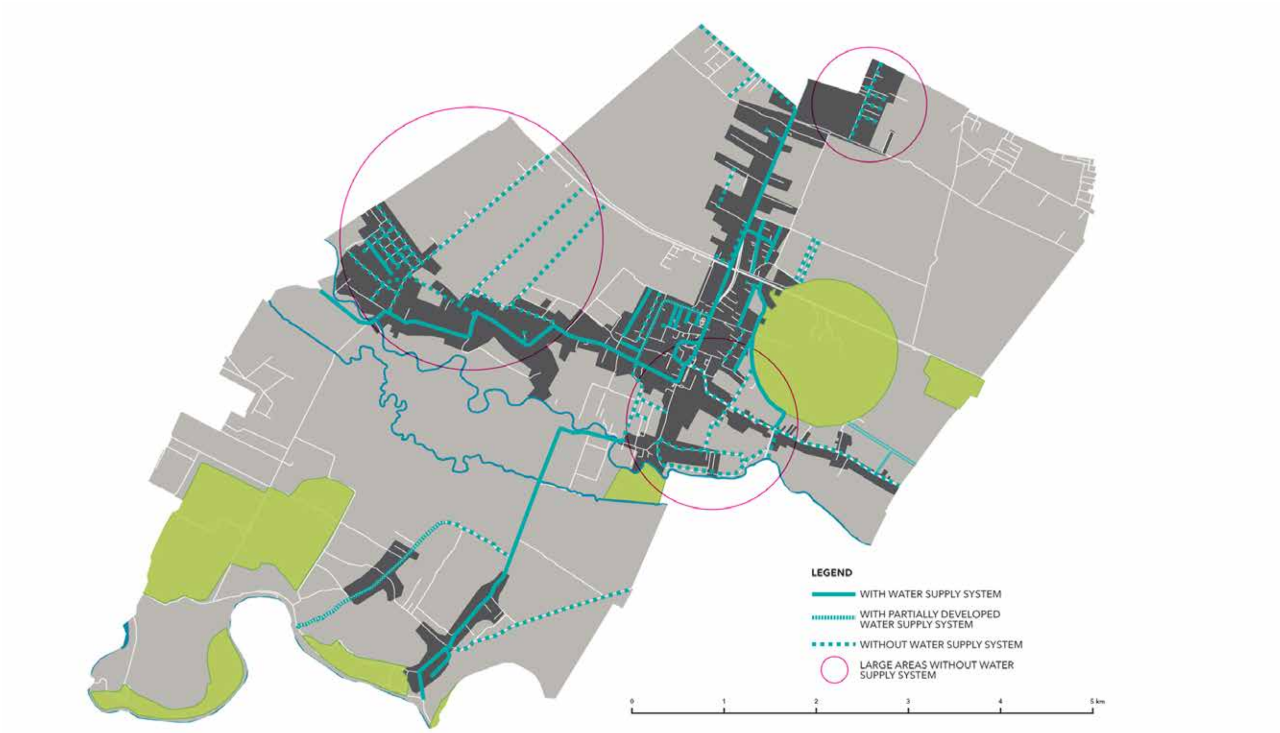
At the same time, the map also indicates an apparent incongruence between the wish to develop the science park within the former military fort and its lack of connective road infrastructure.

Figure 34. Road Infrastructure Overhaul Projects in Măgurele
Source: The World Bank, based on the Sustainable Urban Mobility Plan for Măgurele.

The same observation applies to the water supply system (Figure 35). Nonetheless, efforts to extend the water supply system seem more balanced, covering a somewhat larger area. However, the area dedicated to the future science park seems disconnected from the rest of the system. Furthermore, when comparing the map displaying the areas affected by urban sprawl, a strategy of adaptation is clear, in the sense that the water supply system closely follows new housing developments instead of preparing for future real-estate projects.

Figure 35. Water Supply System in Măgurele

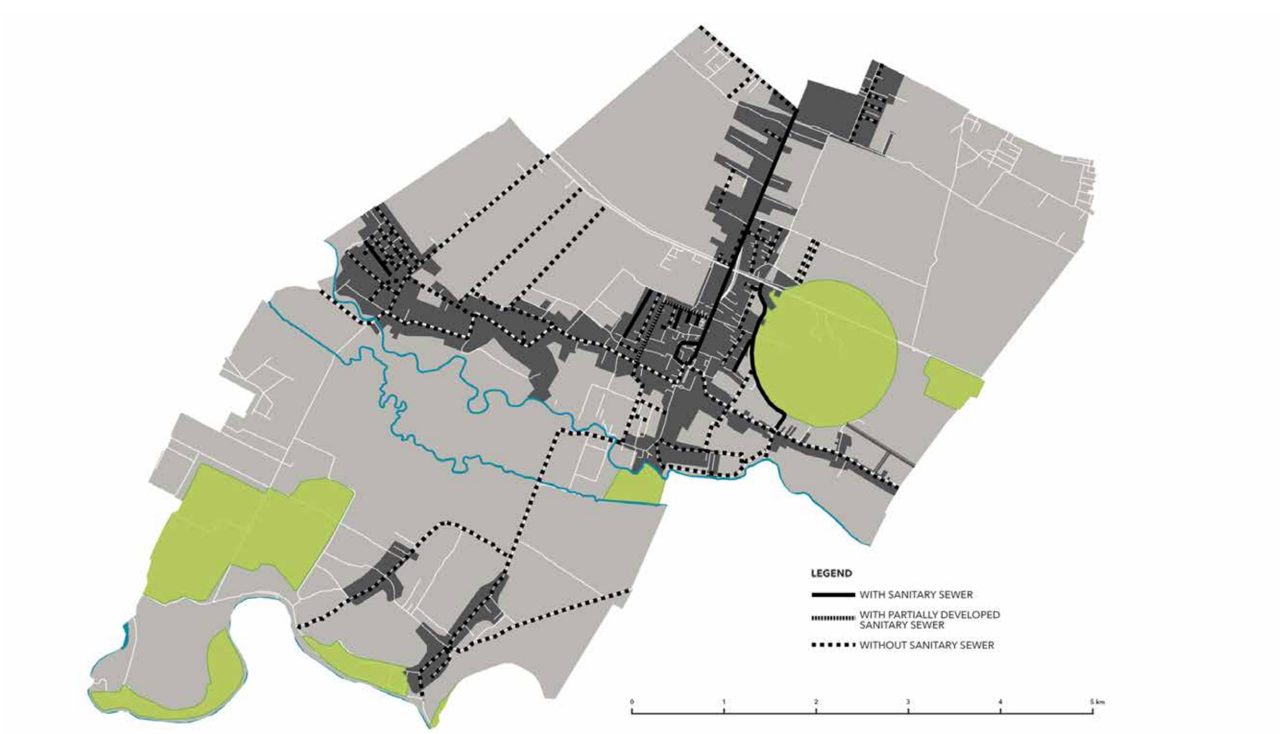
Source: The World Bank, based on the Sustainable Urban Mobility Plan for Măgurele.



Unfortunately, the same observation applies to the sanitary sewer as well (Figure 36). In contrast to the water supply system, the sanitary sewer is far less developed, essentially covering the civic center alone. Given its present-day coverage, it is not difficult to infer that it probably already operates above capacity, with little room for accommodating additional beneficiaries. It is therefore quite likely that the design of a new sanitary sewer will entail a major overhaul effort to recalibrate the current system.

Figure 36. Sanitary Sewer in Măgurele

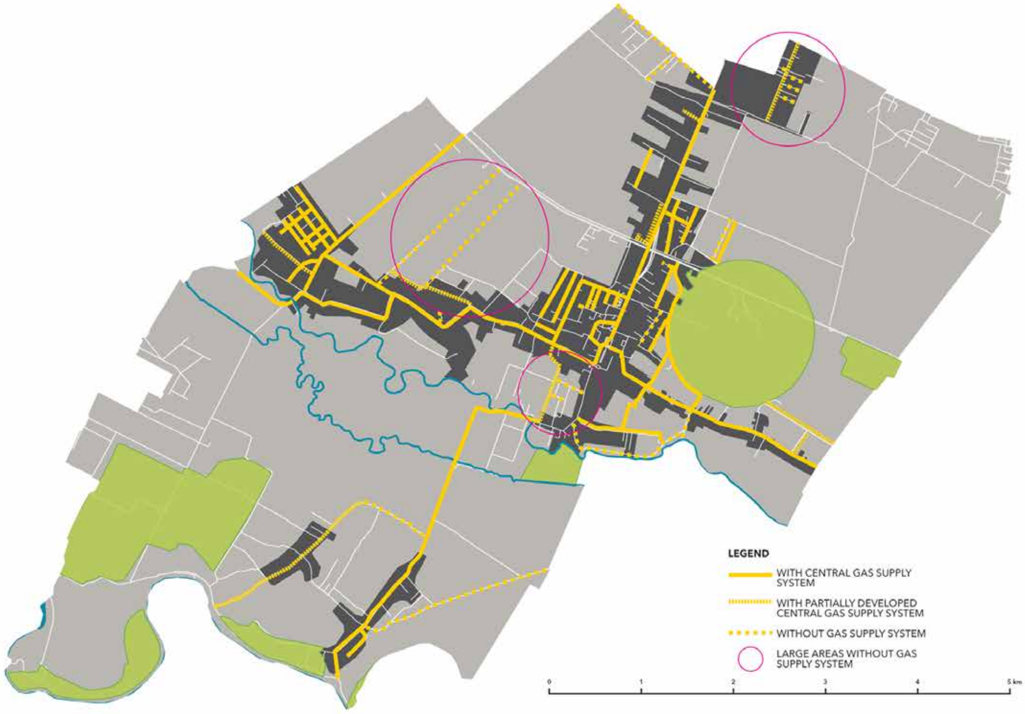
Source: The World Bank, based on the Sustainable Urban Mobility Plan for Măgurele.



The central gas supply system in Măgurele seems to be better equipped to meet current and future needs (Figure 37). The northern and central parts of the municipality seem to be well served, with some new developments foreseen for the villages of Dumitrana and Pruni. Again, the area dedicated to the future science park appears isolated from the rest of the system.

Figure 37. Central Gas Supply System in Măgurele

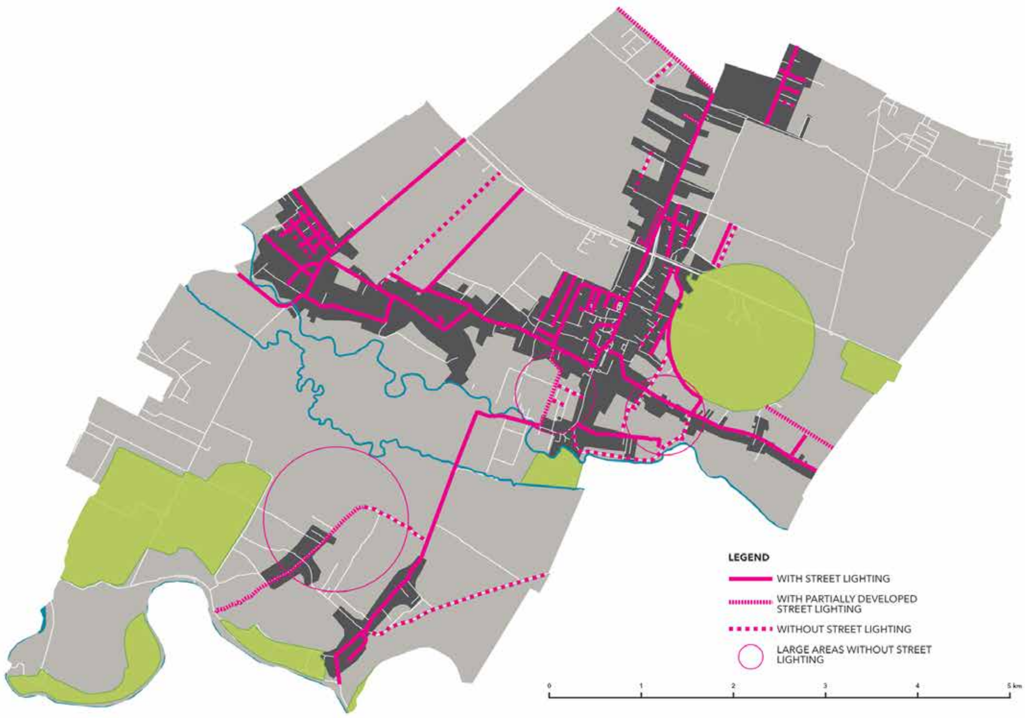
Source: The World Bank, based on the Sustainable Urban Mobility Plan for Măgurele.



Street lighting is by far the most developed infrastructure within the municipality (Figure 38). This is an important aspect, as it directly affects road safety. Yet again, the system is unevenly developed, with the southern villages suffering from a relative lack of provision.

Figure 38. Street Lighting in Măgurele

Source: The World Bank, based on the Sustainable Urban Mobility Plan for Măgurele.



In summary, it is clear that, at least until now, public service provision has proven reactive by adapting to new housing developments as they gradually emerged. However, a far more proactive approach will be needed for accommodating strategic real-estate projects that might stem from the ELI-NP program. These, in turn, are likely to strive for high concentrations of people and amenities, which require easy access to critical infrastructure.

However, by overlapping the different types of infrastructure, the area around the future science park emerges as comparatively deficient in a variety of aspects. This is a barrier against the plans to build the science park on the current location of the military fort.

3.1.4 Catalysts and Inhibitors from a Territorial Perspective

When viewed from a territorial perspective, the Laser Valley project area benefits from the following list of potential catalysts:

- At the national level, the region benefits from a privileged location in terms of commercial flows and international trade. However, most of these advantages pertain more to commercial and industrial policies than they do to current urban planning practices, as they require large-scale infrastructural projects to reach fruition. The most prominent case in point in this respect is the completion of the multimodal corridor connecting Bucharest to the port of Constanța by resuming works on the Bucharest-Danube Canal and the Bucharest-Giurgiu higher-speed railway. However, there is a host of smaller-scale works aimed at increasing the overall accessibility of the region, which affect the Laser Valley project area more directly. Some of them are of critical importance for the project: completing the railway link between the main railway station and the Henri Coandă International Airport, initiating a cadenced rail transport service operating on the Bucharest Ring Railway, completing the overhaul of the southern sector of the Bucharest Ring Road (DXCBS), and preparing for the Bucharest Ring Motorway (A0).
- At the regional level, the analyses have revealed that Bucharest serves as the main origin of commuter flows toward Măgurele. On one hand, this fact implies that Măgurele can gain access to an important source of a qualified workforce. On the other hand, it means that direct connections between Bucharest and Măgurele deserve special attention from a planning perspective. Even though current commuting patterns seem to overcome most of the existing deficiencies within the public transportation system and some of the missing connections, they incur comparatively higher costs in terms of commuting times and transport fares.
- Furthermore, the municipality of Măgurele benefits from an extraordinarily high concentration of R&D personnel compared to the rest of the region. The high qualifications prevalent within the workforce might, in principle, entail higher demands on the quality of the built environment, thereby opening new avenues for more innovative real-estate projects of a higher standard. These projects might eventually engender a new housing and workplace culture, geared toward improving work-life balance.
- Firm location patterns exhibited by the R&D industry have revealed the highest concentrations of dedicated companies and institutions within the Bucharest-Ilfov region. Such agglomerations should, in principle, engender a vibrant business environment, but, unfortunately, a host of inhibitors related to legislation, funding, and business culture might prevent this from happening. Legislative and sectoral interventions might be needed to address these issues in case this hypothesis indeed proves to be correct.
- At the local level, both the municipality of Măgurele and its adjacent municipalities have land reserves, which might, in principle, accommodate future real-estate investments for ELI-NP and the science park. However, these investments are subject to a rather long list of existing inhibitors related to land and property structure as well as critical infrastructure and public service provision, which are listed within the following paragraphs. Nonetheless, many of these inhibitors might eventually be overcome by a strong degree of administrative commitment.

- Some of the most promising land reserves available outside the municipality of Măgurele are three comparatively large pieces of land located within the Fifth Sector in Bucharest. The first is situated adjacent to Antiaeriană Street, encompassing some 300 ha, of which the Fifth Sector owns 66%. The second straddles the boundary between the Fifth Sector and the municipality of Măgurele, south of the Ferentari neighborhood, totaling some 330 ha, of which the Fifth Sector owns 33%. The third comprises the Odăile-Răzoare sector of the former railway connection between the Progresul Railway Station and Cotroceni Railway Station, including the former ROCAR industrial platform. This latter land reserve amounts to about 20 to 30 ha and is fully owned by the Fifth Sector. Therefore, the Fifth Sector harbors about 400 ha for coherent real-estate investments, which might benefit from the Laser Valley project, while at the same time giving it a strong impetus.

Unfortunately, there is also a rather long list of corresponding inhibitors, which might severely affect the future development path of the Laser Valley project:

- At the national level, the development potential of the entire region is severely inhibited by the serious lags in large-scale transport infrastructure provision. The multimodal corridor between Bucharest and Constanța is only partially operational due to the absent navigable connection to the Danube and the missing railway link to Giurgiu. Furthermore, the overhaul of Bucharest Ring Road, especially in its southern sector, is well behind schedule. The same observation applies to the cadenced rail traffic on Bucharest Ring Railway between the main railway station and Progresul Station. In addition, the railway connection to Henri Coandă International Airport is severed by the missing 3-km-long link between the village of Odăile and the airport. As for Bucharest Ring Motorway, it still awaits the planning stage.
- At the regional level, we see the current connections within the commuting shed plagued by infrastructural limitations and poor public transportation provision, with only three lines of metropolitan bus transport currently operational (i.e., lines 427, 453, and 455). In addition, there are some missing overpasses, which might greatly improve traffic flow to and from Bucharest. Against this background, commuters either use their private cars or rely on minibuses. Such a high degree of reliance on the private car gives rise to a host of negative externalities, with the most visible being the daily traffic jams occurring on Bucharest-Măgurele Highway.
- Apart from exhibiting high degrees of concentrations within the R&D industry in and around Bucharest, firm location patterns have also revealed the relative isolation of the research platforms active within the municipality of Măgurele. Furthermore, we suspect that the interactions between the R&D companies and institutions and the rest of the business environment are weak at best, probably due to unbridgeable distances within the innovation chain as well as a relatively low interest in product and process innovation on behalf of local firms.
- When concentrating on the local level, it is worth mentioning that land reserves within the municipality of Măgurele are uncertain. Currently, the exact amount of land available for direct development is unclear. Furthermore, almost all land within the municipality is highly fragmented, thereby requiring preliminary planning intervention and cadastral operations. It is quite probable that a comprehensive land readjustment effort will need to be designed, which might imply land pooling and re-allotments. This might be a sensitive issue, given the few successful re-allotment examples and the possible speculative land acquisitions across the municipality.
- Public service provision within the municipality of Măgurele is currently uneven, with most efforts bestowed upon the immediate vicinity of the civic center. Even so, it is likely that some of the existing critical infrastructure, especially the sanitary sewer, requires major overhaul interventions. Furthermore, if the future science park will eventually be housed within the former military fort, then its surrounding areas will have to be well served with critical infrastructure. Otherwise, the municipality might incur increasing costs when designing the critical infrastructure network. A possible solution to this problem will be discussed later in this report.

A careful examination of this list uncovers a significant development opportunity for the Laser Valley project area, irrespective of the territorial scale considered. Unfortunately, much of this potential currently lies dormant with some large-scale road, rail, and navigable connections still missing. However, many such inconveniences seem to be largely overcome by commuters. Hence, it is quite probable that any improvement in the current accessibility levels will most likely increase the overall commuter shed.

Regrettably, the situation at the local level does not come across as fully prepared to welcome higher concentrations of researchers, specialists, technicians, students, and firms. On one hand, the land within Măgurele and its adjacent municipalities is highly fragmented. This level of fragmentation implies a sustained administrative effort in performing land readjustment operations. On the other hand, many areas within these municipalities, especially in Măgurele, remain unserved by critical infrastructure and thus are comparatively deficient in public service provision. Given the international research and entrepreneurial community that might wish to settle in Măgurele and its environs, providing the new residents with efficient public services and ecosystem services is pivotal in establishing a marketable international reflection of the Laser Valley project area.

It is against this background that alternative land reserves should be considered. The case of the land reserves within the Fifth Sector in Bucharest features prominently among the most likely solutions to the land fragmentation problem. In addition, they benefit from a comparatively higher degree of accessibility and are better endowed with public utilities. However, the matter of dedicating them to the Laser Valley project currently remains open to debate. Furthermore, the precise role they might eventually play for the project needs further study.

3.2 Normative Dimension

This section focuses on the normative dimension of the Laser Valley project, viewed from a spatial and urban planning perspective. It concentrates on planning instruments aimed at increasing the accessibility of the Laser Valley project area and at providing a coherent set of zoning regulations at the local level. The section concludes with an additional list of catalysts and inhibitors, this time drawn from a normative perspective, which complements the set described above.

3.2.1 National Planning Documents

Two relevant national spatial planning documents that govern the development of the Laser Valley project area are discussed below. The first one is the National Spatial Plan and its first section, dedicated to the transport networks, while the second one is the General Master Plan for Transport. For the purposes of this report, we have primarily concentrated on the provisions contained within the General Master Plan for Transport, as they have the additional benefit of a phasing and funding exercise. Furthermore, in drafting the master plan, its authors were compelled to consider the provisions contained within the National Spatial Plan.

Thus, the primary focus of the General Master Plan for Transport is to increase accessibility at the national level and, to a lesser extent, at the international level. Against this background, Bucharest emerges as the main beneficiary of the plan. Such a privileged situation directly affects the Laser Valley project area in terms of both provisions and phasing strategy. An overview of all relevant projects is provided in the following two illustrations as well as in Annex 9 to this report (Figures 39 and 40).

Figure 39. Provisions within the General Master Plan for Transport

Source: The World Bank, based on the General Master Plan for Transport.

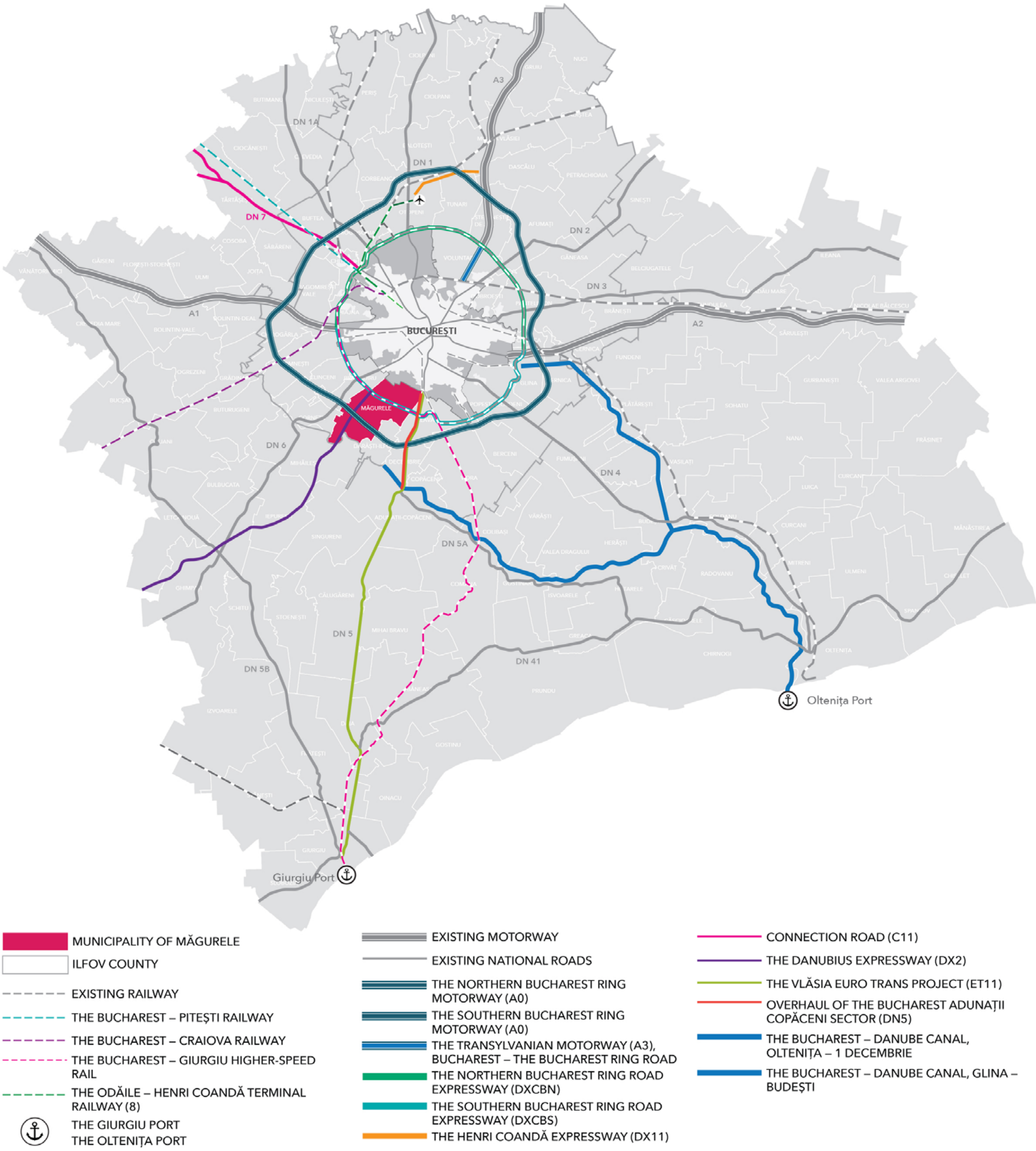
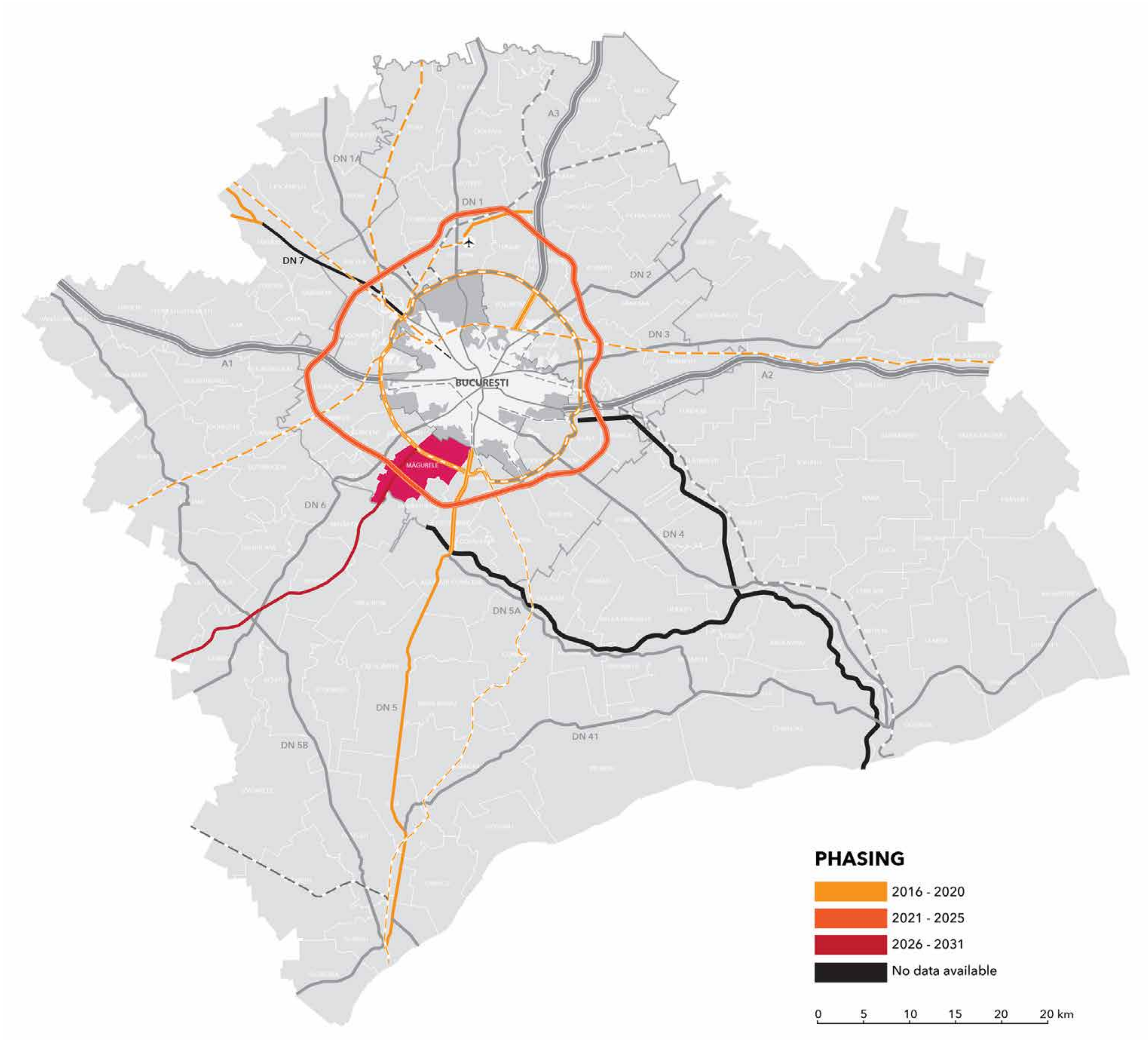


Figure 40. Phasing within the General Master Plan for Transport

Source: The World Bank, based on the General Master Plan for Transport.



Road Connections

The plan relies heavily on the completion of the following three road projects: Bucharest Ring Road, Bucharest Ring Motorway, and Henri Coandă Express (Figure 39). Ring Motorway aims to integrate the three motorway connections linking Bucharest to the port of Constanța, to Pitești, and to Ploiești, with the latter two acting as springboards to Transylvania and then to Central Europe. Henri Coandă Expressway, which aims to connect Henri Coandă International Airport in Otopeni to Transylvanian Motorway, follows the same rationale of large-scale integration. Consequently, all three projects are regarded as a high priority. Unfortunately, their phasing has already proven difficult to achieve, with all projects registering significant delays.

Apart from these major road connections, another set of regional connections is phased for 2021–2025. Hence, Bucharest Ring Road provides an additional layer of integration by linking various expressways and EuroTrans projects, such as the Danubius Express, which connects Bucharest to Alexandria and Craiova, or the Vlăsia EuroTrans project, which connects Bucharest to Giurgiu and Bulgaria. If all these projects reach completion, then the entire Laser Valley project area will gain significant accessibility.

Rail Connections

The same rationale applies to the major railway lines, which are destined to achieve a higher operational speed capacity, with the exception of the higher-speed railway connection between Bucharest and Giurgiu. Since the collapse of the bridge over the Argeș River in 2015, all international rail traffic has been directed to Videle. Hence, even though the General Master Plan for Transport lists it as a top priority for the 2016–2020 period, the tendering procedure for the feasibility study was only launched in 2015. It is therefore questionable whether this connection will resume operations any time soon.

Navigable Connections

The General Master Plan for Transport remains surprisingly silent on inland waterways. Hence, the Bucharest-Danube Canal, with both the Glina-Budești and 1 Decembrie-Oltenița branches, receives no funding provisions and does not enter the phasing exercise.

The spatial development vision for the Laser Valley project hinges on the following considerations. First, the connections between Bucharest and the Danube need special attention and a dedicated research effort, as they essentially form a gateway to the trade flows on the Rhine-Danube Corridor. Second, if the Bucharest-Giurgiu connections achieve maturity, then the Laser Valley project needs to capitalize upon this enhanced accessibility, which might consolidate the local and regional business environment. Third, Măgurele should capitalize on its privileged position neighboring Bucharest Ring Road, Bucharest Ring Motorway, Bucharest Ring Railway, and Danubius Expressway, which will provide a rapid road connection to Craiova, Central Europe, and the Western Balkans.

3.2.2 Regional Planning Documents

When viewed from a regional perspective, the intricate connection between the Laser Valley project area and Bucharest becomes visible. The following illustration displays the provisions contained within the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region, with an overview of all the relevant projects provided within Annex 2 to this report (Figure 41). This plan is pivotal in assessing the local and sub-regional accessibility of the Laser Valley project.

Most of provisions contained in this plan aim at improving the radial connections between Măgurele and Bucharest. Unfortunately, most proposals are stretched far into the future. Hence, the two metro lines connecting Progresul Railway Station to the main railway station and Henri Coandă International Airport are not phased in the immediate future.

This disadvantage might partially be offset by the introduction of five suburban bus routes, which serve a two-fold aim: first, to provide an efficient radial connection between Bucharest and the municipalities of Bragadiru, Măgurele, Dărăști-Ilfov, Vidra, and Berceni and, second, to complement them with a concentric connection between Bragadiru and Jilava. This arrangement might prove effective in supporting the proper functioning of the local and sub-regional commuter shed.

In addition, the municipality of Măgurele will benefit from a bus rapid transit route, connecting its civic center to the main railway station in Bucharest. If deemed feasible, this option might prove beneficial, especially in relation to the southern sector of Bucharest Ring Railway, where a cadenced rail service is set to commence operations later this year. In the more distant future, this integration might further benefit from the completion of Odăile-Henri Coandă International Airport Railway, thereby securing easy access to and from the airport.

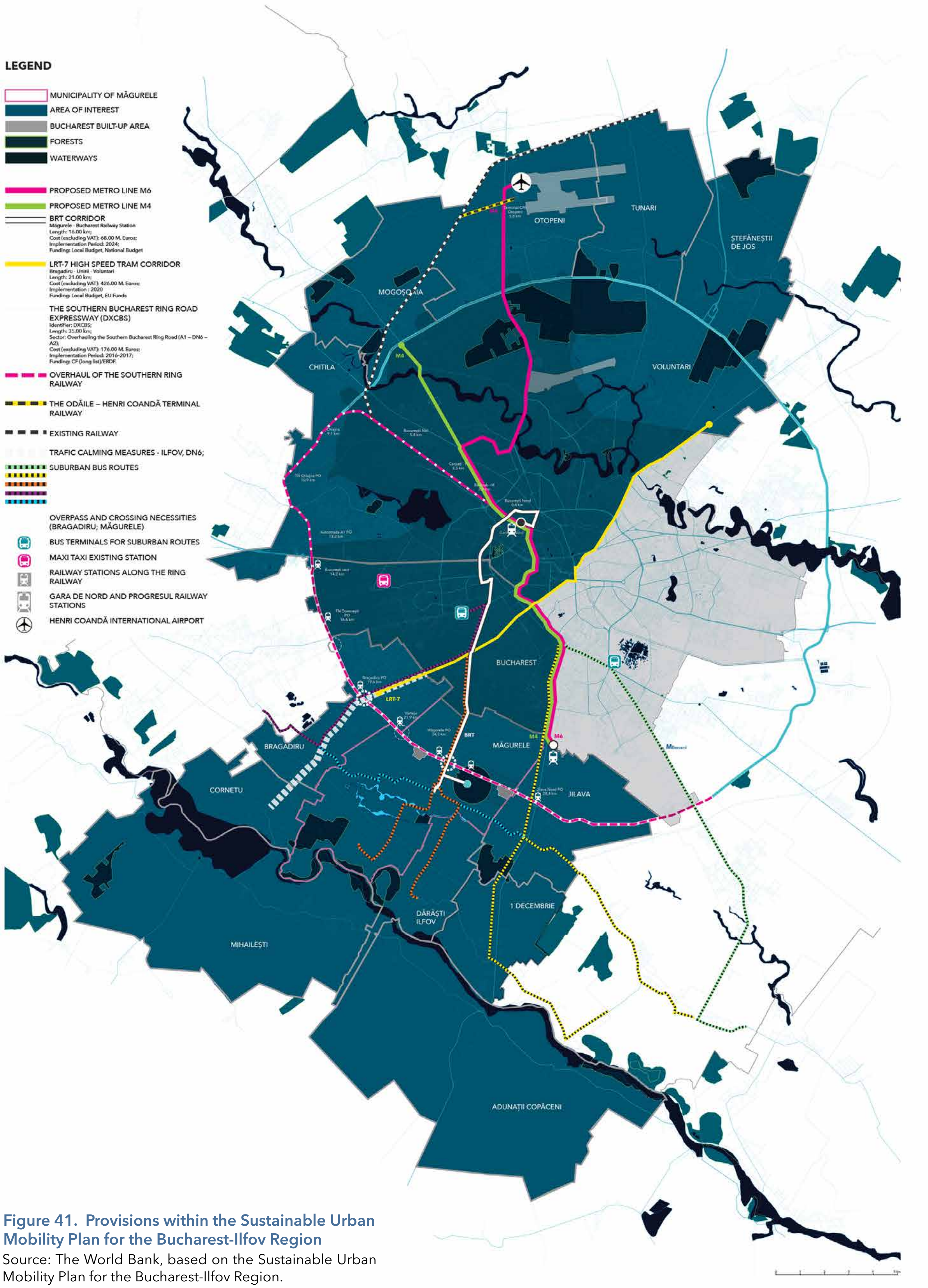


Figure 41. Provisions within the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region

Source: The World Bank, based on the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region.

3.2.3 Local Planning Documents

At the local scale, the future development path of the Laser Valley project area depends on the zoning regulations and building ordinances comprised within the general urban plans that govern each municipality. A preliminary observation is that the general urban plans for the municipalities appearing in the following illustrations have reached different development stages at the time of writing this report (Figures 42 and 43). Thus, the New Dynamic Master Plan for Bucharest is still in its inception phase, currently focusing upon its first series of background studies. In contrast, the general urban plan for Măgurele has been completed but still awaits official endorsement. Other municipalities, such as Jilava and Bragadiru, have already implemented a new generation of operational general urban plans. Further complicating matters is the fact that the new spatial plan for the county of Ilfov, which is aimed at infusing coherence across spatial development paths, has only recently moved past its tendering stage.

Against this background, the following illustration is separated into two distinct sections to render planning processes affecting this area explicit (Figure 42). The upper section displays parts of the 2025 Development Vision of the New Dynamic Master Plan for Bucharest, while the lower section exhibits the zoning regulations for the town of Măgurele and its adjacent municipalities, as envisioned by their respective general urban plans.

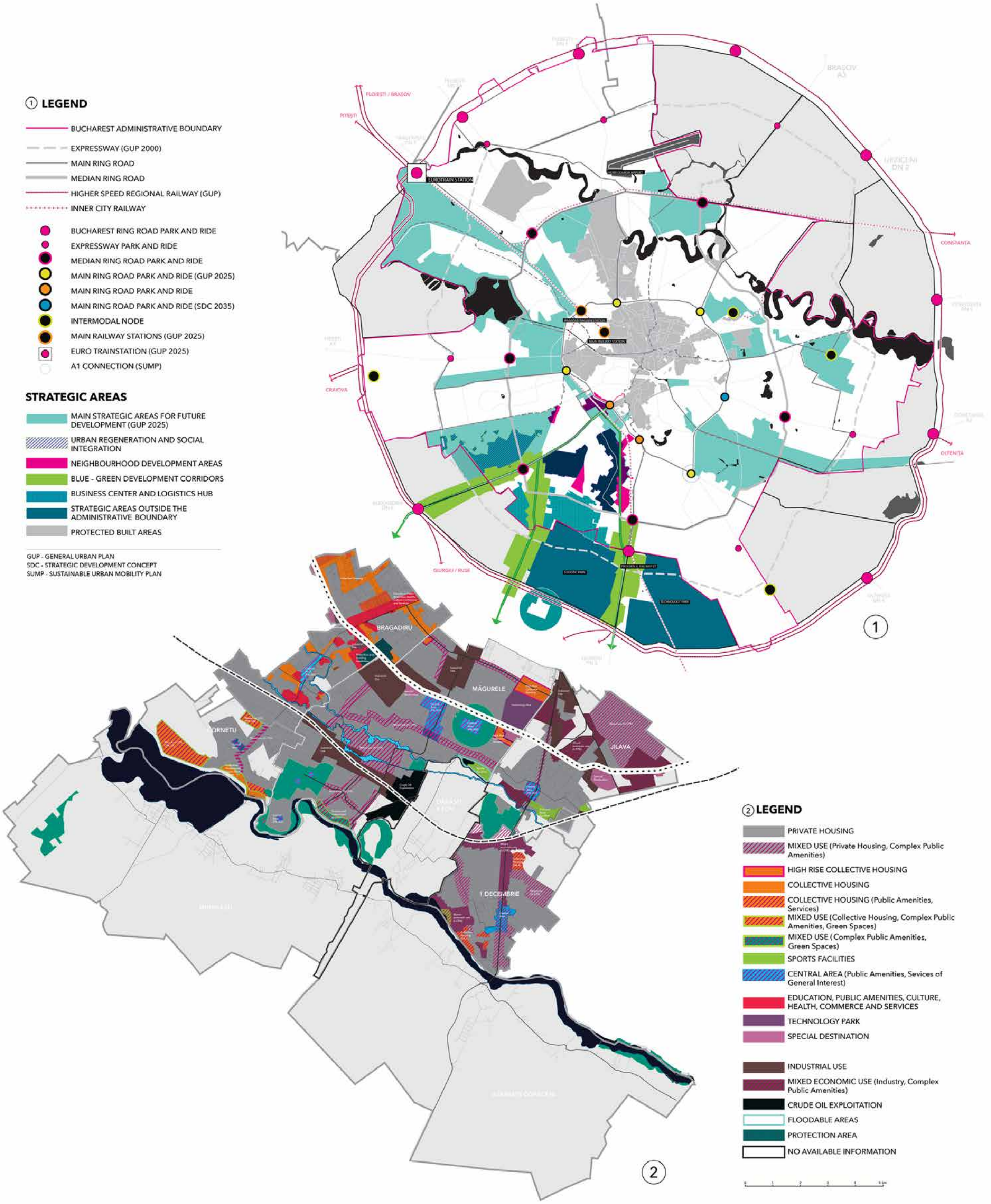


Figure 42. Various General Urban Plans Affecting the Micro-Territorial Scale of the Laser Valley Project area

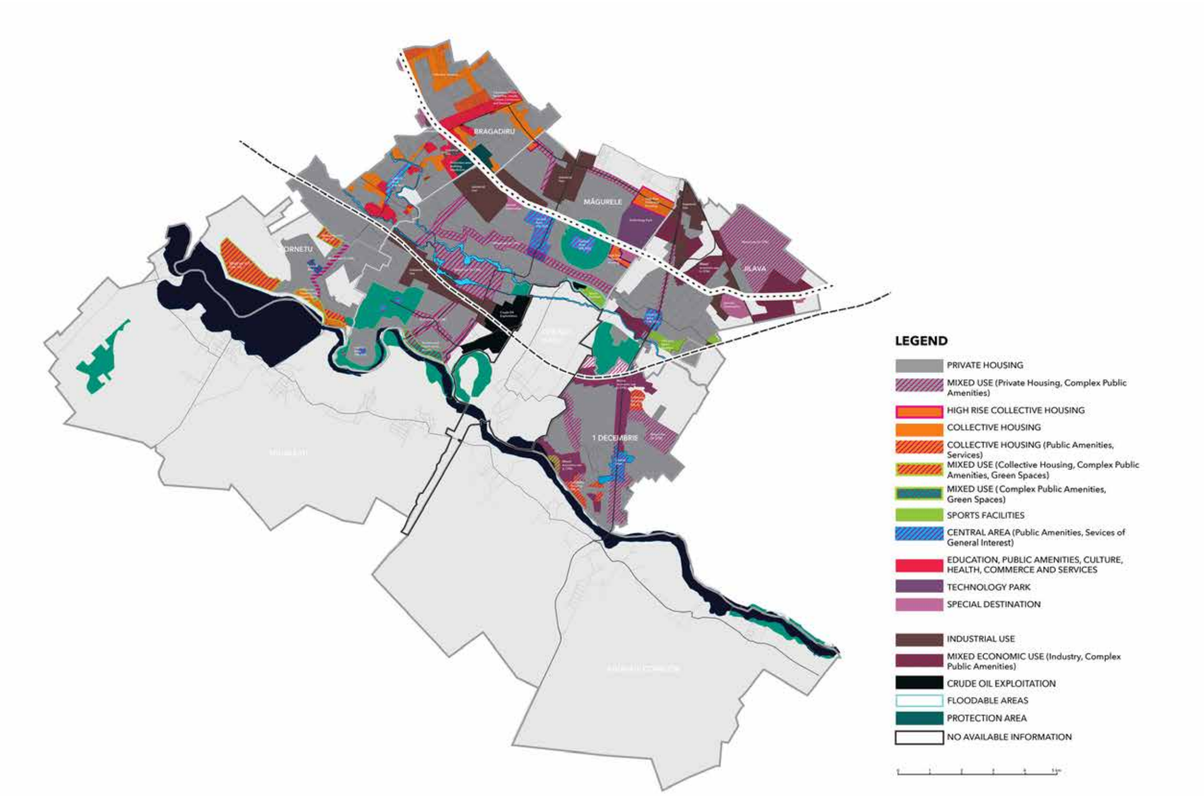
Source: The World Bank, based on the various general urban plans available.

Such differences in timing often produce barriers to functional integration between municipalities. One such barrier becomes clear at the interface between Bucharest and Măgurele. Hence, where the New Dynamic Master Plan for Bucharest foresees the development of large blue-green corridors of a regional importance, the general urban plan of Măgurele concentrates on housing, mixed use, and industrial areas without considering future expansion areas dedicated to these corridors. It becomes extremely difficult to negotiate between these two conflicting sets of planning priorities and associated regulations. However, this is not the only planning conflict, as similar conditions apply to the interface between Bucharest and Bragadiru and to the interface between Bucharest and Jilava.

Furthermore, the comparison between the general urban plans reveals a massive increase in built-up areas, which is mainly dedicated to the provision of new housing and mixed-use areas. This prodigious growth is especially pertinent in Măgurele and Bragadiru, where it points toward a rising real-estate pressure that might also be accompanied by a wave of speculative land acquisitions (Figure 43).

Figure 43. General Urban Plans for Măgurele and Its Adjacent Municipalities

Source: The World Bank, based on the General Master Plan for Transport.



When focusing upon the municipality of Măgurele itself, the main zoning areas become legible (Figure 44). To complement the illustration, Table 5 lists the main zoning areas within the municipality of Măgurele, as foreseen by its general urban plan for 2014. Combined, the illustration and its associated table serve a two-fold purpose. They render the massive growth in residential areas explicit, while highlighting the relative neglect of green areas.

Figure 44. Main Zoning Areas within the Municipality of Măgurele

Source: The general urban plan for Măgurele (2014).

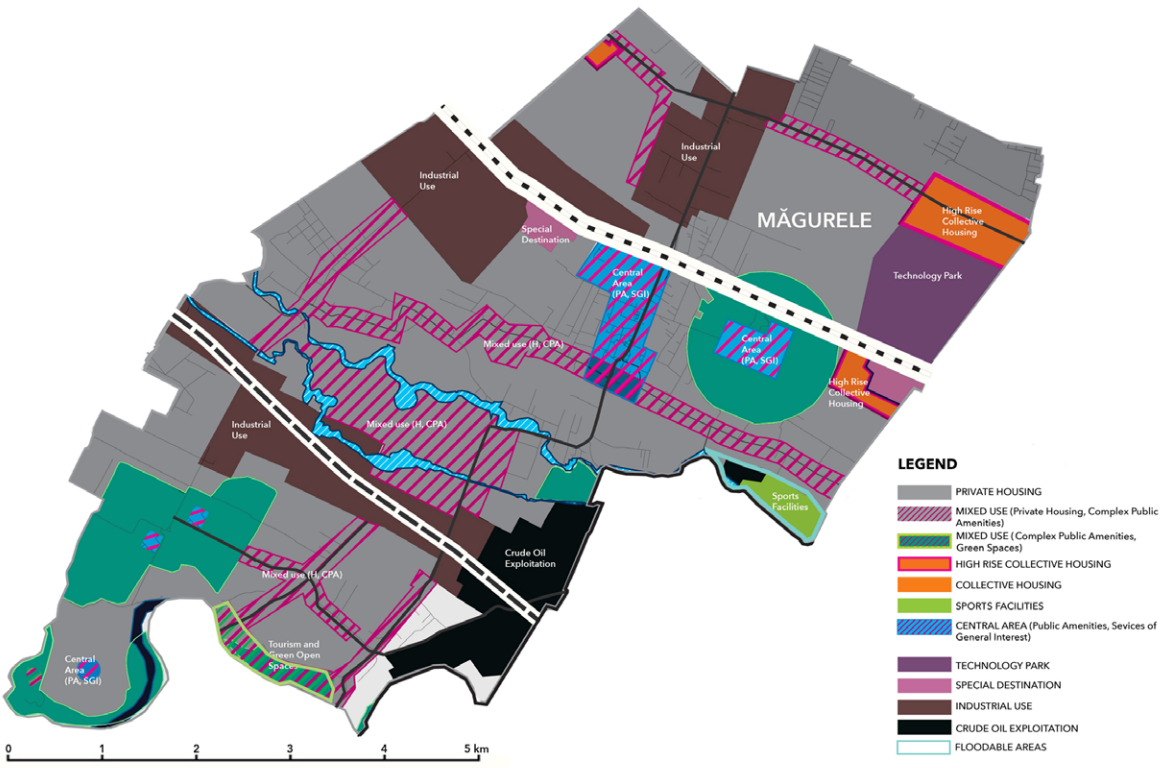


Table 5. Main Zoning Areas within the Municipality of Măgurele

Source: The general urban plan for Măgurele (2014).

	Property	Surface (ha)	Surface (%)
1	**Total Built-Up Area**	**4,017.00**	**100%**
2	**Residential and mixed use (private housing and complex public amenities: ca. 525 ha)**	**2,500.00**	**62.29%**
3	Mixed use (complex public amenities, green spaces)	**2.80**	**0.07%**
4	Industrial and exploitation use	1,000.00	24.89%
5	Public institutions and public services	100.00	2.48%
6	Green areas and sports facilities	125.70	3.10%
7	Transportation	180.00	4.48%
8	Town management facilities	**18.40**	**0.45%**
9	Special destination	66.10	1.64%
10	Inland waterways	**24.00**	**0.6%**

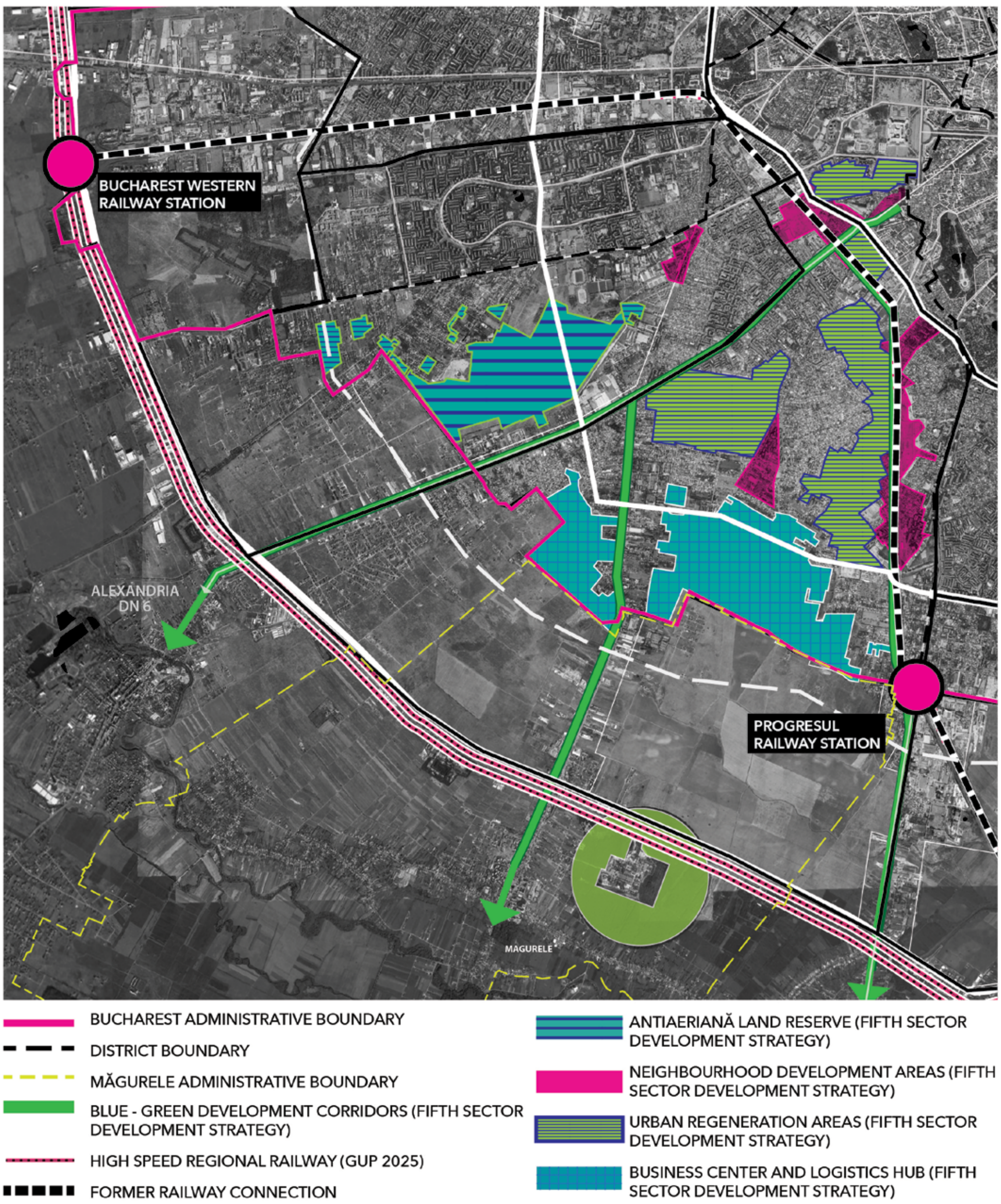
However, large real-estate investments imply spiking concentrations in the population, which require a varied portfolio of amenities, both public and private, and a diversified network of public spaces. In addition, increases in real-estate pressure compel municipalities to develop highly efficient critical infrastructure provision strategies and programs. Furthermore, ecosystem services require special attention, as they directly affect the quality of work and housing. Such strains exerted on public service and amenity provision might considerably affect available development options, thereby transforming the choice of strategic investments into a top priority.

Against this background, the three land reserves mentioned earlier (Sections 2.3.2 and 2.4), which are located within the Fifth Sector in Bucharest, benefit from a privileged role within planning documents. Thus, the Vision of the New Dynamic Master Plan for Bucharest offers the prospect of three blue-green corridors, which envelop all three land reserves, thereby connecting them to a future network of regional parks aimed at expanding ecosystem service provision as well as increasing housing quality. Furthermore, the New Dynamic Master Plan for Bucharest designates Antiaeriană land reserve as a strategic intervention area amenable to an urban regeneration program, while envisioning the southern fringe of the Ferentari neighborhood as a business center and logistics hub. The former ROCAR industrial platform is designated as a neighborhood development area (i.e., it is destined to become a center for the communities living in the neighborhoods of Ferentari, Giurgiului, and Progresul). In addition, the former industrial platform and its environs are subject to an urban regeneration program, which covers large areas of the Ferentari neighborhood (Figure 42).

These provisions have also been integrated into the current incipient strategy for the Fifth Sector, the aims of which add more detail to this vision. It becomes essential to ascertain the role the Laser Valley project will play within this strategy (Figure 45).

Figure 45. Development Strategy for the Fifth Sector in Bucharest

Source: The World Bank, based on the development strategy for the Fifth Sector, the Vision of the New Dynamic Master Plan for Bucharest, and Google Earth satellite imagery.



3.2.4 Catalysts and Inhibitors from a Normative Perspective

Thus, the normative dimension yields the following catalysts:

- At the national level, the Laser Valley project area benefits greatly from the attention that the General Master Plan for Transport bestows upon increasing the national and international accessibility of Bucharest and its direct hinterland. Against this background, the project area will eventually benefit from the overhaul of Bucharest Ring Road and the completion of Ring Motorway as well as from the overhaul of Bucharest Ring Railway. Furthermore, the municipality of Măgurele will also profit from the Danubius Expressway project, which ensures a speedy connection to Alexandria and Craiova. However, this potential increase in accessibility must be qualified by the question of investment phasing and administrative commitment needed for these large-scale infrastructural projects.
- The question of connecting the Laser Valley project area to the Danube has recently gained in importance at both the central and local administrative levels. The potential benefits seem increasingly important from a variety of standpoints, but their planning support is currently lacking. This situation will have to be remedied in a timely manner, as many advantages derived from the trade on the Danube are currently not capitalized upon.
- At the regional level, the accessibility of the municipality of Măgurele is set to increase in what are essentially two stages. The first stage comprises the introduction of the metropolitan bus lines and the bus rapid transit line, which would complement the existing suburban bus lines. In addition, a concentric bus line will link the municipality of Măgurele to Bragadiru and Jilava. The initiation of the cadenced rail service on Bucharest Ring Railway between the main railway station and Progresul Railway Station, would also belong to this first stage. A second, more ambitious stage would subsequently follow, in which these metropolitan bus lines would be complemented by two additional metro lines (i.e., M4 and M6), which would connect Progresul Railway Station with the main railway station and with Henri Coandă International Airport. Combined with the railway connection between the main railway station and the airport, these projects would ensure a considerable increase in the current levels of accessibility.
- At the local level, the Laser Valley project area benefits significantly from the Vision of the New Dynamic Master Plan for Bucharest, which actively seeks solutions to a host of regional challenges. Among the most prominent features of this vision are the special attention bestowed upon strategic intervention areas located outside Bucharest's administrative boundaries and the three blue-green corridors that cross the municipalities of Măgurele, Jilava, and Bragadiru. Such careful consideration benefits the entire Laser Valley project area, as it ensures supportive regulations by the time the New Dynamic Master Plan enters its regulation phase.
- In parallel, existing land reserves located within the Fifth Sector in Bucharest should be considered, as they feature prominently both within the New Dynamic Master Plan and the development strategy of the Fifth Sector, which is currently being drafted. The New Dynamic Master Plan envisions ample urban regeneration programs covering many of these land reserves. Furthermore, it designates them either as strategic intervention areas or as new focal points for their surrounding neighborhoods. Within such a context, it becomes necessary to ascertain the exact role the Laser Valley project might play for the development of these land reserves.

INHIBITORS

Nonetheless, the normative dimension also harbors the following list of inhibitors:

- At the national level, the General Master Plan for Transport already faces some significant delays. Thus, the overhaul of the Southern Bucharest Ring Road, including the necessary overpasses, is set to be completed sometime around the year 2020. However, construction is currently halted. In addition, the exact date for construction of Odăile-Henri Coandă railway sector is still unknown, thereby confining air passengers to use the 783 bus lines or to take a taxi. Coupled with the poor and unpredictable connections between Bucharest and Măgurele, these lags directly affect the Laser Valley project area. Furthermore, development opportunities related to the future Ring Motorway and Danubius Expressway remain uncertain, as both projects seem likely to register some delays. The same applies to the railway connection between Bucharest and Giurgiu.
- At the regional level, the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region seems to offer temporary relief in terms of accessibility by introducing a series of metropolitan bus lines. However, an integrated system of public transportation will only emerge once the overhaul of Bucharest Ring Railway and Ring Road is completed and the two metro lines, M4 and M6, commence operation. Until then, most solutions are bound to remain fragmentary.
- At the local level, there is incongruity between zoning regulations and the actual state of public service provision. Such disparities might compel the municipality to adopt a reactive approach toward future real-estate developments instead of adhering to a more proactive approach in preparing for them. The difference between the reactive and proactive approach amounts to inefficiencies in public service provision as well as a higher cost in serving disparate areas with critical infrastructure. Furthermore, the mismatch between the zoning regulations of adjacent municipalities greatly impedes functional integration across a wider area. The most prominent case in point in this respect are the blue-green corridors foreseen by the New Dynamic Master Plan for Bucharest, which receive no consideration within the General Master Plans of Bucharest's adjacent municipalities.
- In addition, considering the high level of land and property fragmentation pervading the municipality of Măgurele, there is a stringent need for land readjustment projects focused upon strategic intervention areas. Apart from the financial and administrative commitment necessary for such endeavors, a series of dedicated zonal urban plans (Planuri Urbanistice Zonale/PUZ) are also required. Initiated by the municipality, they serve the purpose of producing viable solutions to the problem of re-allotments. However, it is also important to note that they run the danger of speculative land acquisition.

The normative dimension further expands upon the previous set of catalysts and inhibitors that resulted from the spatial dimension. Hence, if capitalizing on existing catalysts generally implies committing to the implementation of the provisions contained within the General Master Plan for Transport and the Sustainable Urban Mobility Plan, addressing the inhibitors requires a more focused approach in combining various spatial and urban planning instruments. Essentially, such an approach implies framing zoning regulations against a larger planning framework, which is geared toward their subsequent harmonization. At the same time, this combination of planning instruments would set the stage for coherent real-estate investments and efficient public service provision. A planning concept is needed for the Laser Valley project.

3.3 Financial Dimension

Any vision for the development of the Măgurele Laser Valley area must be realistically anchored. Ultimately, people can significantly contribute to the success of the area. Quality infrastructure can help attract people and firms there, but its development depends on available funds. While the needs of the area are limitless, the resources available are unfortunately limited. In what follows, we shall discuss some of the most important actors involved in the development of the Măgurele Laser Valley area and the resources they could mobilize to make the vision for the area a reality.

Arguably, EU funds are the most reliable source of funding for R&D infrastructure in Romania, and many researchers and innovative companies rely on these funds for critical infrastructure investments. The Operational Programme (OP) "Innovation and Competitiveness" 2014–2020 is the major source of EU financing that potential beneficiaries can turn to for R&D investments.

Other important players are the sub-national public authorities, which could finance critical public infrastructure projects required to make the area more attractive to investors, firms, and researchers. The major investments planned in the area have already been discussed earlier in the report. In what follows, we will look at the budgetary capacity of several sub-national authorities, with a focus on the value of capital expenditures that these authorities could finance between 2014 and 2023.

The World Bank has devised a simple tool for the Ministry of Regional Development and Public Administration to estimate the amount that sub-national administrations could spend on capital investments between 2014 and 2023. The tool started from the premise that most capital expenditures will also require operations and maintenance costs once they are finalized, and it is therefore prudent to not over-allocate funds for capital investments. To estimate a safe margin for capital investments, the following steps were followed:

1. Budget executions were collected for the years 2009–2013, and averages were calculated for this period.
2. For each sub-national authority, the non-earmarked budget was separated from the earmarked budget (i.e., the budget that is pre-allocated for distinct expenditures).
3. The non-earmarked budget of every sub-national administration was then projected for the 2014–2023 implementation period, assuming modest inflation and modest economic growth.
4. Then, 30% was extracted from the estimated non-earmarked budget for 2014–2020, which is a rough threshold (the equivalent of how much sub-national authorities in Romania have spent on average on capital investments between 2009 and 2013).
5. The resulting sum is the operational budget of the respective sub-national administration for the 2014–2023 implementation period.

Table 6 below indicates the estimated operational budget for the sub-national authorities most relevant for the Laser Valley project.

Table 6. Operational Budgets for the 2014–2023 Implementation Period

Source: The World Bank.

	Municipality	Estimated Operational Budget (Euros)
1	Bucharest City Hall	€ 2,949,204,688
2	Sector 5 City Hall	€ 276,936,593
3	Ilfov County Council	€ 131,467,153
4	Măgurele City Hall	€ 17,142,206
5	Bragadiru City Hall	€ 20,502,676
6	Jilava City Hall	€ 15,881,594
7	1 Decembrie City Hall	€ 7,939,996
8	Dărăști Ilfov City Hall	€ 3,029,880
9	Mihăilești City Hall	€ 5,644,041
10	Cornetu City Hall	€ 6,410,684
11	Adunații Copăceni City Hall	€ 7,937,680

What becomes immediately evident is that the sub-national administrations, which can undertake investments on the territory where ELI is located (Ilfov County and Măgurele City Hall), have relatively limited resources for capital investments at their disposal. Bucharest City Hall has a large investment budget and a wide palette of needs. It can nonetheless strategically help the Măgurele area by improving its connection to Bucharest and by making it more accessible to people.

In addition to public funds, private investments could be attracted to the area, but it is difficult to predict how easily such investments could be attracted.

In summary, we can state the following:

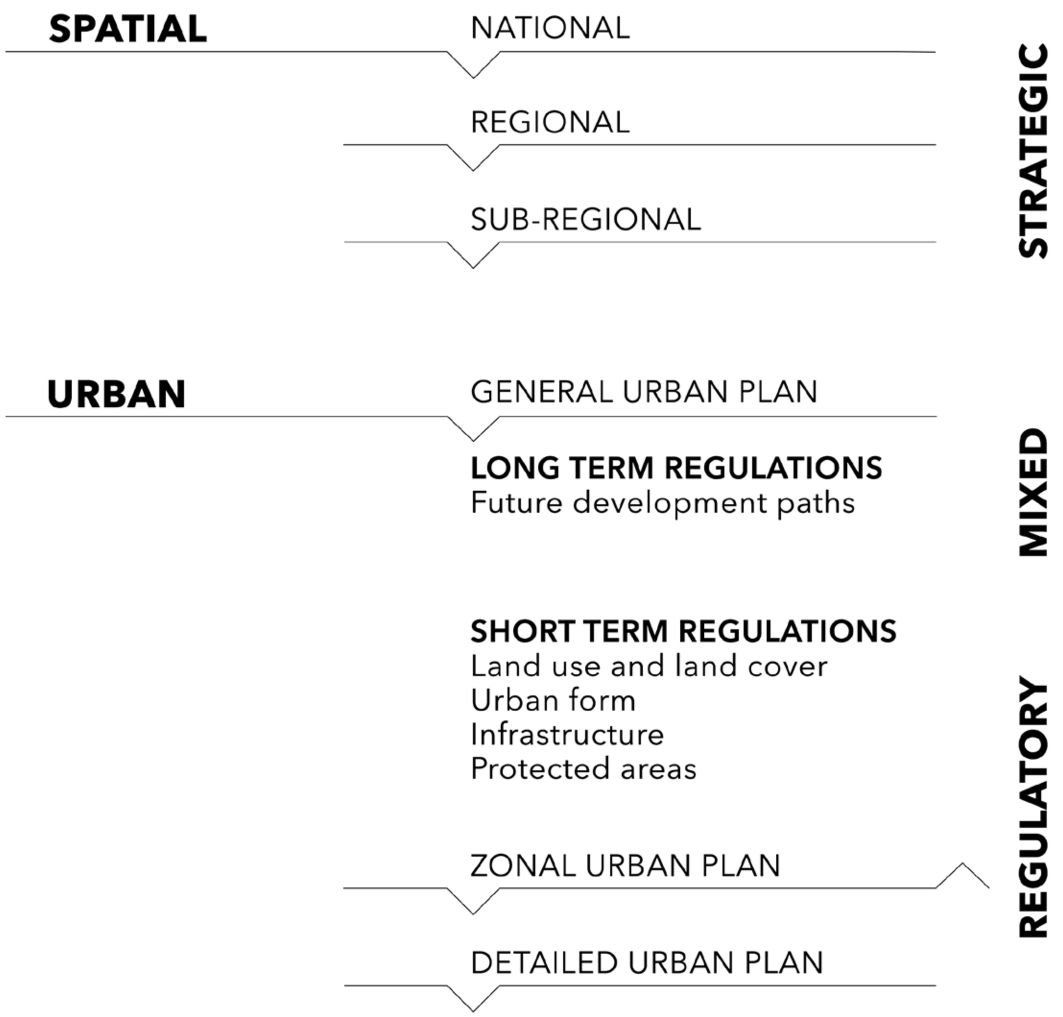
1. The largest sums of money for investments in infrastructure and R&D projects in the Măgurele Laser Valley area will likely come from the state budget through the Ministry of Research and Innovation—at least around EUR 460 million through 2023;
2. The most secure and reliable source of funds will be EU funds, with around EUR 189 million available for the entire Bucharest-Ilfov region for the 2014–2023 implementation period. How much of this sum will be absorbed by beneficiaries in Măgurele depends on how actively and efficiently they apply for these EU funds;
3. Sub-national authorities (particularly Măgurele City Hall and Ilfov County) can undertake targeted territorial investments, but they have limited resources at their disposal.

3.4 Planning Dimension

Designing a feasible planning concept for the Laser Valley project is a daunting task. On one hand, the spatial dimension implies a wide array of different priorities and visions, acting at different territorial scales. On the other hand, the planning perspective unveils a plethora of planning documents that concomitantly affect the future development paths within the region. The design exercise therefore translates into constructing a planning concept grounded in the current Romanian planning practices, while accommodating this wealth of different visions and priorities.

Against this background, a short overview of the Romanian spatial and urban planning instruments might prove instructive. Thus, the following illustration depicts the two tiers of this system (i.e., the strategic tier and the regulatory tier; Figure 46).

Figure 46. Romanian Spatial and Urban Planning Instruments
Source: The World Bank.



Within this system, spatial plans are concerned with providing strategic development guidelines for a wide array of territorial scales. These guidelines are subsequently assimilated within the lower tier of the system, governed by the general urban plans, which transforms them into zoning and building ordinances. Hence, the formal integration between strategic development guidelines and zoning ordinances comes across as seamless, albeit with some careful attention involved when dealing with the zonal urban plans and their inherent potential for engendering a tradition of derogatory urban planning practices.

Nevertheless, a planning concept for the Laser Valley project is indeed feasible by combining the strategic and regulatory parts of the system into a straightforward solution (Figure 47).

The current planning situation resembles a fragmented patchwork of often-conflicting zoning regulations, with each municipality striving to provide local solutions to the challenges it faces (Section 3.3). Harmonizing these regulations is a tedious process, implying direct negotiations between adjacent municipalities and, very often, additional negotiations between municipalities and the county council. Given the lack of integration that becomes apparent when comparing the existing general urban plans, one can infer that there was little, if any, interjurisdictional cooperation in matters related to urban planning.

Hence, there is another option, which capitalizes upon such an interjurisdictional cooperation but provides it with the framework of a dedicated planning documentation of a higher order. We therefore propose the initiation of an interjurisdictional spatial plan *(Plan de Amenajare a Teritoriului Zonal Interjudețean/PATZ–IJ)*, which will essentially act both as an agreed strategic development framework and as a blueprint for managing the functional urban area underpinning the Laser Valley project.

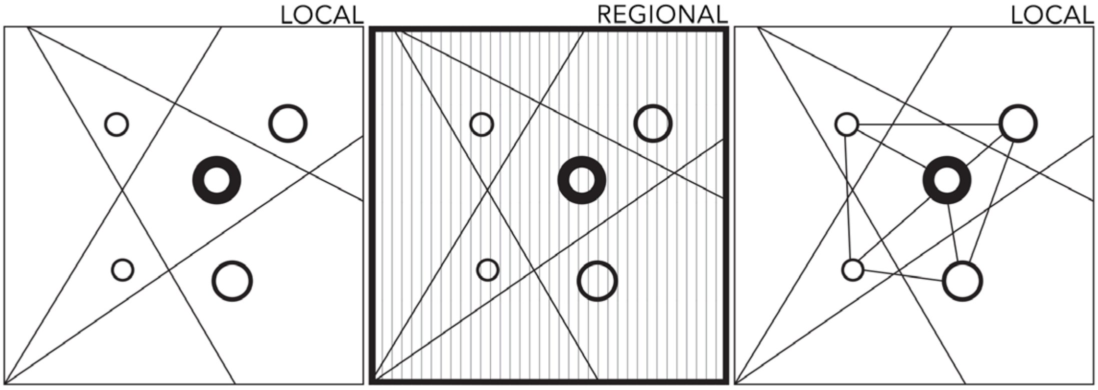
This plan will offer provisions for defining strategic intervention areas, while proposing general solutions to connectivity issues, providing support for the critical infrastructure design at the regional and sub-regional scale, and assessing the potential for ecosystem service provisions, among others. Its provisions would become mandatory for the subsequent revision and harmonization of the general urban plans of the affected municipalities.

Such an approach harbors the additional benefit of reducing the financial burden exerted upon the affected municipalities, as the initiation of an interjurisdictional spatial plan lies well within the purview of the Ministry for Regional Development, Public Administration and European Funds *(Ministerul Dezvoltării Regionale, Administrației Publice și Fondurilor Europene*), which can additionally fund subsequent revisions of the general urban plans.

Furthermore, this interjurisdictional spatial plan acts as a suitable framework for designing an urban regeneration program aimed at tackling the urban challenges related to public service provision, critical infrastructure, and the quality of the built environment. In addition, the land readjustment problem, along with its dedicated planning instruments, would finally receive proper attention. If deemed successful, this urban regeneration program would lend much needed visibility to the spatial dimension of the Laser Valley project, thereby contributing to its international appeal.

The planning concept deserves attention from both planning professionals and public authorities, as it would provide a flagship initiative among current Romanian urban and spatial planning practices.

Figure 47. Planning Concept for the Laser Valley Project Area
Source: The World Bank.



	CURRENT SITUATION	FUA DESIGN	ALLOCATION OF RESPONSIBILITIES
NORMATIVE DIMENSION	a series of disjointed General Urban Plans (PUG) with conflicting provisions and regulations	an Inter-Jurisdictional Spatial Plan (PATZ-IJ), which provides strategic development guidelines	a series of revised and coordinated General Urban Plans (PUG), which transform the strategic development guidelines into coherent building and zoning ordinances
FINANACIAL MECHANISM	initiated and funded by each municipality	initiated and funded by the Ministry for Regional Development, Public Administration and European Funds (MDRAPFE)	revision supported by the Ministry for Regional Development, Public Administration and European Funds (MDRAPFE)
TERRITORIAL IMPLICATIONS	local solutions to existing needs	a strategic development framework: strategic intervention areas; connectivity; critical infrastructure; ecosystem services	a coherent system for implementing and monitoring the agreed strategic development framework

3.5 Conclusions

The previous sections have offered useful information, which can now be distilled into a concise summary. The insight gained starts from the local dimension and consequently progresses toward increasing territorial scales. Hence, this report has produced the following findings, which can be divided into four main categories:

A. Spatial and Urban Planning Prerequisites

- Ensuring a coherent and consistent planning environment for the future development of the area requires the combination of at least two existing planning instruments. Hence, the Laser Valley planning concept encourages the initiation of an interjurisdictional spatial plan (PATZ–IJ) by the Ministry for Regional Development, Public Administration and European Funds. This plan would act as an agreed development framework, which would consequently inform the revisions of the general urban plans within the Laser Valley project area. Funding for the interjurisdictional spatial plan and the subsequent revisions of the general urban plans would be supported by the same ministry.
- Furthermore, this interjurisdictional spatial plan (PATZ–IJ) would also serve as an agreed framework for an urban regeneration program dedicated to increasing the domestic and international appeal of the municipality of Măgurele and its environs. This program would provide solutions aimed at addressing the land fragmentation issue, enhancing public service provision, increasing the quality of the built environment, and encouraging the provision of ecosystem services.

B. Land Structure and Necessary Planning Operations

- The ELI-NP program benefits from an investment of around EUR 500 million, which is bound to produce a series of real-estate development opportunities in or around the municipality of Măgurele. Against this background, the town of Măgurele and its adjacent municipalities are in possession of some land reserves that might potentially accommodate these future investments. Unfortunately, we were unable to determine the exact amount, location, and legal status of these available land reserves.
- Furthermore, by considering the structure of allotments, it becomes apparent that most land reserves require designing a future system of land pooling. This system will probably imply some form of land readjustment, most likely in the form of re-allotments, for which a considerable municipal commitment is needed as well as the employment of a series of dedicated zonal urban plans (Planuri Urbanistice Zonale/PUZ). These dedicated planning instruments would form the backbone of the urban regeneration program described above.
- Another issue requiring careful consideration is the question of critical infrastructure and public utility provision. Thus, large areas outside the civic center of Măgurele remain unserved in terms of water supply, sanitary sewers, and central gas supply. One of the most prominent areas affected by insufficient provision is the area around the former military fort, which is expected to house the future science park.

C. Accessibility

- The municipality of Măgurele harbors the most prominent concentration of R&D personnel within the entire country. However, this concentration is largely dependent upon a consistent commuter shed, with Bucharest acting as the main origin of commuter flows. Such a large commuter shed implies a stark difference between the housing and amenity portfolios that Bucharest and Măgurele offer. This is an issue that needs to be addressed soon.
- Once the ELI-NP program becomes operational, the number of R&D personnel along with the associated communities of specialists and technicians will presumably increase. Considering the international dimension of these future communities that will be working, studying, and living in or around Măgurele, it is highly likely that demands related to the quality of housing, the diversity of amenities, and the quality of public and green open spaces will increase dramatically.
- Insufficient levels of public transportation provision currently impair the accessibility of Măgurele. Easy and direct connections to Bucharest's city center and Henri Coandă International Airport are currently lacking. The difficulty of reaching Măgurele and its environs will easily become increasingly pertinent once foreign researchers and their families start to arrive.
- In addition, the question of poor accessibility extends to a series of missing overpasses, which would greatly alleviate the current traffic congestion but are more expensive than solving public transportation problems.

D. Large-Scale Infrastructure Projects

- Viewed from a macro-territorial perspective, the Laser Valley project area commands a vast transport infrastructure, which connects it to foreign markets. However, there are a few missing links within this network that directly affect the project area. As mentioned earlier, stagnation within both the overhaul of the Southern Bucharest Ring Road including the necessary overpasses as well as delays in introducing a cadenced rail service between the main railway station and Progresul Station directly affect the degree of accessibility in Măgurele. The same observation applies to the missing railway link between Progresul Railway Station and Giurgiu.
- Furthermore, Bucharest Ring Motorway and Danubius Expressway have been postponed for the time being, with little information available concerning when they will enter the planning stage. Until then, Ring Road takes over the traffic resulting from transit and commuter flows.
- From the industrial and commercial perspectives, Bucharest's relation to the Danube is currently in need of a thorough reassessment, which implies a more proactive approach in improving navigability on the Danube as well as devising a contemporary international role for the Bucharest-Danube Canal in relation to European and Asian markets.

Chapter 4

Lessons from International Experience: Spillovers from Large Science Investments

This section reviews international cases of large anchor science investments and the local effects. The objective of this review is to identify the opportunities and challenges that the LVI is likely to encounter and to suggest the needs for policy reform and investments that will enable spillovers from ELI-NP. The review employs a case study approach for two primary reasons. First, scholars have yet to investigate the knowledge-based economic effects of large-scale basic science facilities or to determine the policy and programmatic approaches to maximize their effects. The review therefore focuses on the specific elements for improving knowledge exchange, including institutional factors, demand-side factors, organizational intermediaries, and innovation ecosystem conditions. The findings from the case studies are then compared to the framework conditions in Romania and around ELI-NP with the intention to identify opportunities to apply lessons learned to this specific context. Based on this analysis, the lessons learned from the cases are summarized, and recommendations are made for addressing opportunities with ELI-NP and its innovation ecosystem. The section succinctly presents the economic theory of knowledge, the conceptual framework and methodology used for the review, the case study analysis, and the recommendations.

4. Lessons from International Experience: Spillovers from Large Science Investments

4.1 Economic Theory of Knowledge

The review of the economic theory of knowledge is important in the context of the ELI-NP science infrastructure facility, as the creation and spillover production of new knowledge, typically through R&D, is a critical input for economic dynamism and productivity growth (Solow 1956; Romer 1990). Further, the production and accumulation of scientific knowledge raises the productivity of labor, thereby increasing the value of education and training embodied in the human capital of individuals (Becker 1964).

Knowledge is created by incumbent firms and research organizations, such as research laboratories (Utterback 1994) but often goes unexploited. In turn, knowledge spills over to knowledge-based ventures that, even though they may undertake limited R&D, are particularly adept at utilizing new knowledge created by other sources (Almeida and Kogut 1999; Audretsch et al. 2004, 2005).

Two types of knowledge exist: (1) **codified knowledge**, which can be embodied in publications and (2) **tacit knowledge**, often referred to as "know-how," which is more difficult to codify and is typically embodied in individuals, organizations, and processes (Audretsch and Feldman 1996). While codified knowledge is easily transmitted, tacit knowledge tends to spill over within geographically bounded regions, promoting clustering among firms in similar industries (Audretsch and Feldman 1996; Jaffe et al. 1993; Jaffe 1989).

However, according to recent research, knowledge does not automatically spillover (Ács et al. 2009; Braunjerhelm et al. 2010) **nor does it always lead to useful applications** (Audretsch et al. 2015). Knowledge is instead subject to institutional, geographic, and cost constraints (Almeida and Kogut 1999; Jaffe et al. 1993; Jaffe 1989) known collectively as the "knowledge filter" (Ács et al. 2004). Audretsch et al. (2015) posited that spillover is also affected by the properties of knowledge itself. First, the economic value of knowledge is relatively uncertain, especially compared to the more certain nature of information; R&D can serve different aims ranging from basic discovery to close-to-market applications favored by the industry (Stokes 1997). Second, knowledge is characterized by asymmetry across economic agents. The same knowledge may be assigned different values or may have different expected values by different economic agents. Third, while the transaction cost for sharing information across economic agents is trivial, the tacit nature of knowledge often requires face-to-face communication, thus increasing transaction costs. In short, R&D investments do not necessarily lead to economic development outcomes.

Recent research has shown that knowledge spills over through individual researchers, entrepreneurs, and other boundary-spanning individuals (so-called agents of knowledge) who help transmit tacit knowledge to firms (Ács et al. 2009). Further, represented by firms that have the capability to create applications and commercialize new technologies, knowledge demand factors are often overlooked in linear views of innovation, whereby knowledge investments are expected to generate economic benefits (e.g., Bradley et al. 2013).

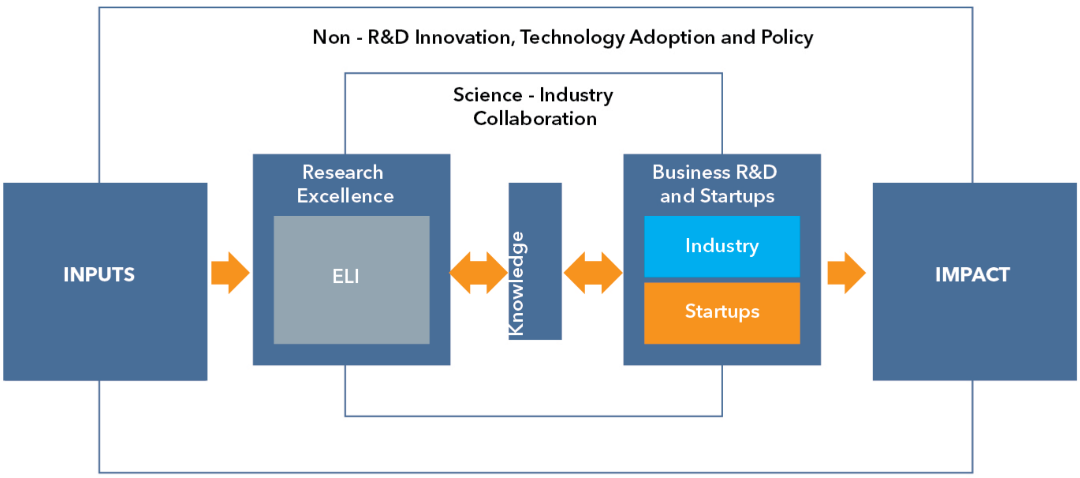
In other words, **the potential economic value of basic science depends on the degree to which it leads to useful applications, especially those relevant to existing or future industries.** The type of research undertaken by a firm or research organization influences its applicability. Traditionally, R&D has been dichotomized into basic research, the sole purpose of which is learning and discovery, and applied research, which is intended to solve a specific social or economic problem (Stokes 1997). While exceptions exist, the government funds most basic research efforts, such as ELI-NP, just as the industry funds most applied research. However, studies show that publicly funded basic research is the foundation of future innovations and industries and is thus critical for long-term economic growth and productivity (Scherer 1999).

Of course, **the uncertain nature of the new knowledge described above makes it nearly impossible to understand ex ante what applications will emerge from basic R&D** (Audretsch et al. 2015). However, Stokes (1997) posited that the two principle categories of research, basic and applied, are not mutually exclusive. Policymakers can emphasize conducting "use-inspired research" that combines elements of both and can undertake policy interventions that help mitigate knowledge asymmetries and the existence of myriad knowledge filters. Intervention may come in the form of public-private research partnerships, proof-of-concept centers, public venture capital funds, and entrepreneurship assistance programs, among other policies and programs. Furthermore, institutional and additional framework conditions may exist that improve the likelihood of knowledge exchange, application, and commercialization. It is important to understand these elements to prevent ELI and Măgurele from becoming a disconnected enclave of scientists.

4.2 Conceptual Framework

As illustrated in Figure 48, ELI-NP receives resources in the form of financial, human, and physical capital that lead to the production of new knowledge (backward linkages). Traditional technology transfer models assume that these knowledge flows are unidirectional and result in technology applications and prototypes that can be transferred to the industry vis-à-vis licensing or further commercialized by affiliated spinoff companies. However, recent research has shown that patenting, licensing, and spinoffs are but one pathway for the dissemination of new knowledge, and many alternatives exist for knowledge exchange (Bradley et al. 2013). Asymmetries are reduced when knowledge flows are bidirectional.

Figure 48. Factors Mediating Spillovers from ELI to Realize Intended Impact
Source: The World Bank.



Correa (2014) outlined an effectiveness assessment framework to assess the extent to which policy outputs result in expected outcomes. Derivative outcomes include (i) research excellence, (ii) business R&D and firm startups, (iii) science-industry collaboration, and (iv) non-R&D innovation, technology adoption, and policy. We add a fifth consideration, spatial aspects, to the framework given its relevance to the development of ELI-NP. Each desired outcome corresponds to the elements illustrated in Figure 48.

To understand how the five elements above generate economic and social impact, it is important to recognize the specific mechanisms for knowledge exchange. Following the human capital views mentioned above, education, training, and researcher mobility are perhaps the most important. Through their discoveries, researchers create new knowledge and codify these findings in publications. They also share these works during conferences and workshops. Research often leads to technology applications that may, depending on their level of maturity, be licensed to the industry or be the basis for a new spinoff company. Researchers also generate tacit knowledge (i.e., learning by doing) that requires face-to-face communication, such as consulting and industry personnel exchanges for transmission. Joint research with industrial partners (e.g., joint research centers and shared facilities) may increase the likelihood that researchers will generate use-inspired applications.

In addition to specific knowledge-exchange mechanisms, the effects of the elements above also depend on the extent to which they are governed *collectively*. For example, Clarysse et al. (2014) found that research institutions and their attendant policies and programs (which the authors referred to as knowledge ecosystems) are typically disconnected from the industrial capabilities and resources (i.e., business ecosystems) needed to apply and commercialize new knowledge. Thus, economic impact is a function of disparate, yet collectively supportive organizations (Whittington et al. 2009).

To maximize the potential economic impact of ELI-NP, including its ability to help improve urban and infrastructure conditions, this research investigates large-scale basic science facilities and their attendant strategies for maximizing the exchange, application, and commercialization of new knowledge. Special emphasis will be placed on the five elements mentioned above and on their interconnectivity. The research aims to provide lessons to ELI-NP, as it develops its own institutional policies and mechanisms, as well as to regional, Romanian, and EU policymakers.

4.3 Methodology

The research employs a case study approach (Eisenhardt 1989; Yin 2009) for two primary reasons. First, scholars have yet to investigate the knowledge-based economic impact of large-scale basic science facilities as well as policy and programmatic approaches to maximize their effects (Siegel 2014). The report therefore focuses on the specific elements for improving knowledge exchange, including institutional factors, demand-side factors, organizational intermediaries, and innovation ecosystem conditions.

The research methodology includes the following:

- **Literature Review and Desk Research:** The research includes a review of the scholarly and policy literature related to challenges and enablers corresponding to the exchange, application, and commercialization of new knowledge with large-scale basic science facilities, such as ELI-NP. Desk research was also conducted to investigate facets of basic science laboratories and their suitability for the project.
- **Case Study Research and Analysis:** The research employs case study selection criteria that emphasize relevant comparisons according to the scientific focus, scope, and scale, and geography. Especially important is the applicability of the cases to the ELI-NP context and strategies and to the Măgurele region.
- **Qualitative Interviews and Field Research:** The researchers collected information through qualitative interviews with academic experts on the evaluation of scientific institutions and projects and with practitioners to gain feedback on the methodological approach and the selected case studies. The team interviewed key personnel from the selected cases following the defined cases outline (see below). Finally, the team interviewed research and innovation stakeholders in

Romania to better identify contextual conditions and the relevance of lessons derived from the case studies.

The findings from the case studies were then compared to existing strategies and framework conditions for ELI-NP, and the ongoing national policy and programmatic efforts by the Romanian government with the intention to identify opportunities to apply lessons learned to this specific context. Based on this analysis, the lessons learned from the cases are summarized, and recommendations are made for addressing opportunities with ELI-NP and its innovation ecosystem.

4.4 Case Selection

The ELI-NP has a unique set of characteristics that limits the set of comparator cases that could be of valuable relevance. These characteristics are that it is a sophisticated fundamental science research facility of pan-European interest in a less developed regional innovation ecosystem. Relevant and comparable case studies require similarities with key characteristics of the ELI-NP, as listed below:

1. **Mega research infrastructure** or "big science" that involves many scientists as part of a large-scale research framework rather than smaller teams or resources. Moreover, ELI was selected by ESFRI and will be operated by ELI-ERIC whose main task is to establish and operate the full scope of the infrastructure.
2. **Basic research** that advances knowledge of the fundamental studies of phenomena and observable facts without any application or use in view. Primarily, ELI-NP research will focus on the fundamental study of laser-matter interaction and laser-based nuclear physics with potential applications in other fields.
3. **Laser or nuclear physics** with laser facilities that offer high energy, intensity, or speed (petawatt-class lasers) or research infrastructures that focus on nuclear physics. Additionally, ELI-NP will house lasers several times more powerful than the strongest laser in existence today along with a laser-based gamma source. Furthermore, ELI-NP has applications in nuclear physics.
4. **Distributed research infrastructure facility** located at multiple national or institutional nodes but part of a network, in comparison to a facility that is geographically located at a single site. Moreover, ELI-NP is one of multiple ELI pillars, with two other locations in Hungary and the Czech Republic.
5. **International open access or interest** in the research infrastructure involving coordination and collaboration with a multinational scientific community. Single-site and distributed research infrastructure facilities typically garner international interest and are governed through international partners, while national facilities of global interest attract international interest but are governed through national bodies. Further, ELI-NP is an open-access international user facility of pan-European dimensions.
6. **Less developed innovation ecosystem** where the framework conditions for generating spillovers and economic growth are sub-optimal and characterized by low R&D investments (public and private); weak research governance, collaboration, and commercialization activities; and a lack of risk financing.

This study identified a primary list of seven cases with characteristics relevant to ELI-NP. This primary list is based on an extensive review of basic research infrastructures, including those with powerful laser facilities and a focus on nuclear physics (Annex 10.1). While it is impossible to find perfect comparators for ELI-NP, the selected case studies offer an opportunity to draw lessons from global practices, as they (i) match at least three of the defined characteristics of ELI-NP, (ii) present a diverse geographical representation (continent and country levels of development), and (iii) include a mix of under-construction, new, and established research infrastructure facilities:

- Laser Megajoule (LMJ) and PETawatt Aquitaine Laser (PETAL), Bordeaux area, France;
- Very Large Telescope (VLT), Paranal Observatory, Chile;
- Advanced Photonics Research Institute (APRI), Gwangju, South Korea;

- European Organization for Nuclear Research (CERN), Geneva area, Switzerland;
- Lawrence Livermore National Laboratory (LLNL), the San Francisco Bay Area, California, USA;
- ELI Beamlines, Prague, Czech Republic (under development); and
- ELI-ALPS, Szeged, Hungary (under development).

Table 7. Selected Case Studies

Case	Mega - RI	Basic Research	Laser or Nuclear Physics Facility	Distributed RI	Inter. Governance	Less Developed Innovation Ecosystem	Cluster
APRI		●	●		●		●
CERN	●	●	●		●		
LLNL	●	●	●				●
ELI Beamlines*	●	●	●	●	●	●	●
ELI-ALPS*	●	●	●	●	●	●	●

** Under development*

Due to time and budget constraints, this study focuses on the seven cases identified above. However, additional case studies listed below and in Annex 10 could further explore the different dimensions of economic development associated with research infrastructures and could draw relevant lessons for ELI-NP.

- European Synchrotron Radiation Facility, Grenoble, France;
- European Molecular Biology Laboratory, multi-site, Europe (France, Germany, Italy, and the UK);
- Sandia National Laboratories, Albuquerque, New Mexico, USA;
- University of Osaka, Institute of Laser Engineering, Osaka, Japan;
- Square Kilometer Array, multi-site, South Africa and Australia;
- Oak Ridge National Laboratory, Tennessee, USA;
- Thomas Jefferson National Accelerator Facility, Virginia, USA.

4.5 Case Study Analysis and Recommendations

Summary Recommendations

- Recognize that the short-term economic impact of basic and security-related science is limited.
- Focus on facility use arrangements, researcher exchanges, and educational outreach programs to support the development of human capital.
- Align organizational programs and policies with regional efforts to spur industrial development.
- Align laboratory location and impact strategies with national policies and programs.
- Consider spatial elements when designing policies and programs to maximize lab effects.

The seven selected case studies were analyzed in detail in terms of their context, governance, research excellence, science-industry collaboration, business innovation, startups, economic geography, and enabling factors (Annex 10 includes the individual cases). The following sub-sections present an analysis of these cases and pertinent recommendations for ELI-NP.

Table 8. Snapshot of Case Studies

Name	Country	Year Established
LMJ and PETAL	France	2014
VLT	Chile	1999
APRI	South Korea	2001
CERN	Switzerland	1954
LLNL	USA	1952
ELI Beamlines*	Czech Republic	2017
ELI-ALPS*	Hungary	2017

4.5.1 Impact of Basic Science

Recommendation: ELI-NP and Romanian policymakers need to acknowledge that the short-term effects of basic and national security-related science are limited.

Illustrated in Table 9 below, the primary focus of the four cases is the advancement of fundamental science, what Stokes (1997) calls science for science's sake, while the scientific mission of the two other cases, LMJ-PETAL and LLNL, is to maintain the performance and safety of their respective national nuclear-weapons stockpile. The purpose of the Paranal Observatory, for example, is to observe and document astronomical phenomena. Astronomy is considered among the most basic of sciences, typically with few short-term applications. One of the largest, most respected physics laboratories in the world, CERN similarly focuses on fundamental scientific topics in nuclear physics. By design, LMJ-PETAL and LLNL limit the spillover of sensitive, application-oriented information pertaining to their core missions. However, both facilities conduct basic science in support of their missions and have established mechanisms (discussed below) to promote outside scientific collaboration.

Table 9. Scientific Mission and Related Economic Impact of Selected Research Organizations

Organization	Scientific Mission	Economic Impact
LMJ-PETAL	Maintain the performance and safety of the French nuclear stockpile and conduct related laser research.	Limited spillover from core research areas; provides access to dual-use facilities in support of civilian research; Route des Lasers has developed into an industrial cluster based on harnessing upstream linkages during the construction of LMJ-PETAL.
Paranal Observatory	Advance fundamental science in astronomy through the observation of related phenomena.	Limited spillover from the core research areas.
GIST-APRI	Provide engineering services, training, and translational research for optics and photonics companies in cooperation with basic science organizations within the Gwangju region.	Region has evolved into an emergent optics and photonics cluster, but industrial development challenges remain.
CERN	Advance fundamental science related to nuclear physics; understand constituents of matter by colliding fundamental particles close to the speed of light.	Limited technology-related spillover benefits from the core research areas.

Organization	Scientific Mission	Economic Impact
LLNL	Maintain the performance and safety of the US nuclear stockpile; conduct complementary basic research; conduct civilian research related to alternative energy and the environment.	Limited spillover from core research areas; industry partnerships in civilian research areas; and utilizing dual-use facilities, such as the labs supercomputer.
ELI Beamlines	Advance fundamental science in physics and material science by offering a source of radiation and particle sources.	In development.
ELI-ALPS	Advance fundamental science in nuclear physics by offering a broad range of ultra-short laser light sources to investigate the behavior of electrons.	In development.

In other words, **while the (publicly-available) research contributions of the cases advance society's scientific and security interests, their short-term economic contributions are relatively limited. Thus, policymakers must understand that large-scale science investments do not necessarily lead to economic impact.** Of course, this fact does not diminish the scientific or national security-related value of basic science investments. The maintenance of a country's nuclear-weapons stockpile, for example, serves a critical public safety and national defense mission. Similarly, astronomical or physics research contributes to understanding the fundamental scientific building blocks of the universe.

It is important to note that policymakers must manage their expectations regarding the short-term economic impact of these facilities. Generating economic spillovers from basic research activities may be time dependent. For example, CERN and LLNL were established years ago (in 1954 and 1952, respectively), while LMJ-PETAL was established in 2014. Thus, it would be misleading to compare the effects of these institutes on the local economy. Time not only allows laboratories to develop internal programs that fit the unique nature of their research but also enables the co-development of other supportive institutions and, in some cases, an industrial cluster. Moreover, as discussed below, policymakers can focus on efforts that, when spillovers do occur, maximize the social and economic impact of research facilities.

4.5.2 Human Capital Development

Recommendation: Focus on facility use agreements, researcher exchange programs, and education outreach programs to maximize human capital development.

Specific actions include the following:

- Establishment of an ELI-NP fund, similar to that established by the European Southern Observatory (ESO) Paranal in Chile, to support the development of scientific capabilities in Romanian universities and related conferences, training, and outreach programs.
- Establishment of robust international collaboration mechanisms, including well-articulated facility use agreements, researcher exchange programs, and postdoc research programs.
- Allocation of 15% to 20% of research capacity for Romanian researchers. For example, ELI-NP could implement an increasing use rate that complements the development of Romanian research capabilities, starting at ~15% and increasing to 20% after five years.
- Establishment of a technical/vocational training institution to provide a skilled workforce for the laboratory and to provide technical talent for area companies.

Beyond their core knowledge generation mission, human capital development is perhaps the most important mission of scientific facilities. Most scientific endeavors include mechanisms for educating and training the next generation of scientists from postdocs to primary education students. The cases, summarized below, illustrate the mechanisms utilized in the cases to fulfill this mission and their influence.

Perhaps the most common feature among the cases is the existence of facility access mechanisms that ensure researchers not only have access to advanced equipment but also help lab researchers stay abreast of state-of-the-art scientific findings and approaches. For example, CERN's culture of openness and its world-class research facilities attract talented researchers from all over the world, especially its 22 nations. Additionally, while national security safeguards at LMJ-PETAL and LLNL present challenges to outside collaboration, both have established dual-use research facilities and protocols for their civilian research use.

International researcher exchange and rotation programs also support the human capital mission of the case laboratories. For example, CERN hosts hundreds of scientists and postdocs and structures staff contracts to encourage mobility. Through Livermore Valley Open Campus (LVOC), LLNL establishes and maintains research-oriented partnerships with university researchers, just as it hosts hundreds of postdocs each year, often with the intention of hiring them for research positions at the laboratory.

Discussed in greater detail below, the alignment of institutional goals with regional and national policies increases the human capital effects of laboratories. For example, facility use requirements and funding associated with the establishment of the Paranal Observatory helped develop research capabilities in astronomy at Chilean universities. These actions attracted Chilean students from universities around the world to return as postdocs. Moreover, GIST-APRI's bolstered human capital among companies in the Gwangju region by tailoring its course offerings to applications, commercialization, and operational themes of great value to the industry. Furthermore, LMJ-PETAL is in a region where PYLA, an industry-focused applied skills training organization, similarly focuses on building within regional companies.

Table 10. Scientific Mission and Related Economic Impact of Selected Research Organizations

Organization	Actions	Impact
LMJ-PETAL	LMJ-PETAL provides researchers access to its petawatt laser facilities. Several programs encourage international collaboration, especially LAPhiA, which organizes transdisciplinary research projects among institutions within the Bordeaux region and beyond. Visiting scientists are paired with lab scientists who are co-authors on papers resulting from scientific experiments. The University of Bordeaux offers related professional degrees, and PYLA focuses on building applied skills for industrial employees.	Facility use agreements allow European researchers to utilize specialized facilities. Partnerships with outside scientists keep lab personnel up-to-date with cutting-edge science. Other organizations and intermediaries support human capital development in the region, including skill development among companies.
Paranal Observatory	Generous facility usage allocations for Chilean scientists; financial support to Chilean universities to sponsor faculty and PhD students.	Partnership requirements have led to substantial improvements in Chilean astronomy research capabilities.
GIST-APRI	GIST-APRI offers specialized seminars and classes focused on optics and photonics as well as their application. Classes are targeted to an industrial audience and taught by professors recruited from the industry.	GIST-APRI has played an important role in contributing to the region's human capital, particularly in terms of optics and photonics applications.
CERN	CERN promotes relatively open-access and international scientific collaboration among its members. CERN hosts hundreds of postdocs who can return to their home countries with valuable scientific networks and an understanding of CERN research capabilities. Several programs target Swiss institutions.	CERN enables member countries to pool resources to support world-class research facilities and advance their respective scientific capabilities.

Organization	Actions	Impact
LLNL	LLNL provides a space (LVOC) for scientific and industrial collaboration. Outreach is a critical goal of the lab, which includes teacher-focused programs. Numerous postdocs train at LLNL.	Partnerships with the industry provide an opportunity to apply LLNL capabilities to advance the performance of US companies. Education partnerships provide robust science and engineering education for teachers and students. The postdoc program provides LLNL with a pool of potential employees.
ELI Beamlines	The facility will provide research facilities with access based on merit-based proposals. Facility leaders are also planning to develop regional outreach efforts to build scientific capabilities within local organizations.	In development.
ELI-ALPS	In development.	In development.

Laboratories and organizations in the region can also work together to train technicians to work in these facilities. For example, for LMJ-PETAL, PYLA trains individuals to work in regional companies, and these individuals are well qualified to undertake various jobs within the laboratory. Lawrence Livermore offers generous technical training programs for existing and new employees in several scientific, technical, and trade areas. Similarly, CERN offers what they term a technical training experience, which is meant to provide individuals with hands-on technical and research skills before they undertake advanced study.

Finally, human capital development, especially in science and engineering, begins at an early age; thus, education outreach is a critical, related lab function. For example, LLNL trains teachers on cutting-edge scientific discoveries and, perhaps more importantly, provides creative pedagogical approaches for conveying complex scientific ideas to students and lay audiences. Further, LLNL hosts school groups from all over California, and the lab also sends scientists throughout the country to give school lectures, attend science fairs, and provide demonstrations of lab-related research.

4.5.3 Organizational and Regional Policy Alignment to Spur Entrepreneurship and Commercialization

Recommendation: Align organizational programs and policies with regional efforts to spur industrial development.

Specific actions include the following:

- Focus industrial policy on the growth of an instrumentation industry, among other areas, to take advantage of backward linkages with equipment suppliers, construction companies, and contractors, as in the LMJ-PETAL case.
- Establish a regional institution, such as Route des Lasers and the Centre for Innovation and Technology Transfer (CITT), for ELI Beamlines to design and implement an industrial engagement strategy.
- Based on an industrial engagement strategy, establish intermediaries to support industry-related needs in technical training, research, and technical assistance.
- Introduce institutional changes that encourage researchers/professors to engage in commercialization activities, such as those introduced within GIST.
- Establish an intra-laboratory coordinating entity that supports commercialization-related activities and coordinates laboratory efforts at the regional level. Examples include LLNL's Industrial Partnerships Office (IPO) and the Knowledge Transfer Office/Knowledge Transfer Fund at CERN.

Despite their focus on basic or security-related science, scientific facilities have established several efforts to align their research programs with regional economic and social development efforts. Effective efforts follow a complementary approach whereby multiple program and policy interventions are aligned in support of economic and social development. Annex D includes schemes that represent the different components, actors, and functions of a research infrastructure cluster anchored around a research institution. Such an approach increases the likelihood of knowledge spillover. Table 11 below summarizes industry-focused alignment efforts and the reported effects.

Policymakers can align policies with all aspects of laboratory establishment and operations, such as strengthening backward linkages with firms involved in laboratory establishment and operations. For example, the development of Bordeaux's Route des Lasers can be attributed to efforts to support and encourage regional growth among firms involved in the construction of LMJ-PETAL and the design and manufacturing of advanced lab equipment. Alignment came from a diverse suite of policies from the special designation of the geographic area between Bordeaux and LMJ-PETAL to the establishment of shared entrepreneurship and business-related services.

Laboratories can also create intermediaries to establish and coordinate R&D partnerships with the industry. For example, CERN and LLNL established offices to promote collaboration with firms that could make use of laboratory equipment, IP, and technical consulting to improve their operations and profitability. Furthermore, CERN established its Knowledge Transfer Office to manage the lab's IP policies and technology transfer, to coordinate multidisciplinary activities related to the life sciences, and to coordinate affiliated relationships with other research organizations, the industry, and the government. Similarly, LLNL's IPO manages formal public-private collaboration projects, IP policies, and commercial aspects of LLNL's dual-use research facilities.

To accelerate the commercialization of promising technologies, labs can encourage and support spinoff companies and form development partnerships with the industry. For example, CERN established its Knowledge Transfer Fund to provide resources for lab researchers interested in commercialization. Researchers submit a brief proposal to a committee that evaluates the proposal based on its overall quality, dissemination probability, possible effects, and scientific and technical value. Furthermore, GIST supports commercialization among its researchers by hiring individuals with industry experience, deploying commercialization-related resources, and establishing a supportive internal policy environment for commercialization activities. In addition, LLNL focuses on the dissemination and commercialization of technologies through cooperative R&D agreements (CRADAs) and by solving specific industry problems using its facilities and equipment. Additionally, LLNL works with regional organizations to connect its researchers with local companies in Silicon Valley as well as federal or regional support organizations, such as the Manufacturing Extension Partnership (MEP), which helps small companies develop manufacturing-related capabilities, such as proof-of-concept creation and prototyping, which are important for commercialization.

Finally, and most elaborately, policymakers can design entire research organizations to focus on bridging differences between basic science institutions, including universities and national labs, with the needs of the industry. For example, GIST-APRI was established to serve as an industry-focused research organization that provides valuable courses, business services, and engineering support to help translate knowledge produced in other research organizations to support regional industrial development. With the establishment of APRI and the creation of an industry-related technical curriculum, GIST became a critical component of a regional industrial development strategy to prioritize optics and photonics.

Table 11. Industry-related Programs and Associated Impact

Organization	Actions	Impact
LMJ-PETAL	Policymakers are focused on backward links with LMJ-PETAL, creating initiatives to harness industrial development among firms involved in construction and equipment development associated with LMJ-PETAL. Route des Lasers' initiatives coordinate the development of emerging industrial clusters in the Bordeaux region with ongoing policy and research efforts.	Several industrial clusters have developed in the region, including an emergent instrumentation cluster.
Paranal Observatory	Few regional initiatives have been established to promote influence.	Limited spillover from the core research areas.
GIST-APRI	GIST-APRI offers services and research tailored to the needs of the local industry, including startups. Service offerings are coordinated with other intermediaries in the region.	GIST-APRI is a key contributor to developing Gwangju into an optics and photonics cluster in cooperation with several supporting intermediaries and organizations.
CERN	CERN established its Knowledge Transfer Office with several constituent industry outreach programs, including industry-focused technology consulting services. When appropriate, CERN uses a unique IP policy that provides royalty-free licenses to companies that agree to further develop technologies stemming from research in the lab. Several regional incubators are established in partner countries.	Numerous technologies are freely transferred based on the capability of the firm to develop the technology. Services and facilities focus on transferring CERN technologies to member states.
LLNL	LLNL's IPO manages formal public-private collaboration projects, IP policies, and commercial aspects of LLNL's dual-use research facilities. Moreover, LVOC provides shared facilities to promote research and commercially oriented partnerships.	Public-private partnerships continue to grow, especially in areas that utilize LLNL's specialized facilities, such as the lab's supercomputer and civilian-oriented research areas (e.g., alternative energy).
ELI Beamlines	In development: There are plans for the Center for Innovation and Technology Transfer (CITT) to develop an industrial engagement approach; CITT offers industrial research and technology transfer services for the region. The STAR Cluster initiative will focus on developing an industrial cluster and will offer services in support of this mission.	In development.
ELI-ALPS	In development; policymakers plan to build the ELIPOLIS science park to support knowledge transfer between scientific research organizations and companies.	In development.

4.5.4 Macro-view: Alignment with National Policies and Programs

Recommendation: Align laboratory location and impact strategies with national policies and programs.

Specific actions include the following:

- Coordinate and align ELI-NP and regional efforts, economic and national smart specialization priority sectors demonstrated by GIST-APRI, and Korea's national focus on optics and optoelectronics.
- Similarly, coordinate and align ELI-NP research capabilities with national R&D objectives.
- Establish national legal and policy frameworks to authorize and enable lab-industry partnerships. Implement upgrading policies that complement commercialization-focused knowledge dissemination.

The economic and social impact of large-scale scientific facilities is also dependent on the alignment of national programs and policies with organizational and regional level efforts. Scholars have long recognized the importance of central government policies and programs in a so-called national innovation system. Summarized below, the cases similarly illustrate that national governments play an important role in the establishment, operations, evolution, and influence of basic and national security-oriented scientific research facilities.

National policy may affect large science initiatives before location decisions are made and facilities are built. For example, ESO's decision to locate its flagship observatory in Paranal was due in part to the Chilean policy to grant large observatories diplomatic status and provide generous tax exemptions. Thus, imported construction materials and equipment relating to the construction of facilities, such as the Paranal Observatory, are exempt from customs duties and fees. The Paranal Observatory is also exempt from a substantial national value-added tax (VAT).

Location decisions can also be made based on the desire to catalyze existing national and regional assets. For example, the decision of the Korean government to locate GIST-APRI in Gwangju was based on the previous failure of the region's science park and on the lesson that regional growth needed to be driven by the desire to encourage and support industrial development, rather than solely based on the funding and conduct of basic science. The decision of the French government to site LMJ-PETAL was to complement existing national security-related research facilities in the area and the presence of related civilian research capabilities at the University of Bordeaux.

Once large-scale science facilities are established, national policy frameworks may be required to enable and encourage public-private partnerships. For example, legislation in the early 1980s created a legal mechanism (CRADAs) for federal laboratories to work with companies to transfer non-security-related technologies to industry. Further, greater government emphasis on technology commercialization and industry partnerships has led to collaborative agreements among national laboratories in the US to create shared public-private R&D platforms, such as LVOC.

Institutional policy can similarly focus on leveraging national needs and programs to improve their economic and social impact. For example, Route des Lasers has relied heavily on ALPhANOV, a French program to support SMEs and to encourage and support entrepreneurship in the Bordeaux region. Similarly, CERN has worked with the governments of its 22 members to site nine regional incubators, the purpose of which is to serve as a regional hub for the dissemination of CERN technologies, provide technical assistance to interested companies, and build constituencies for CERN among its members.

Policymakers can complement commercialization-focused policies by implementing industrial upgrading policies and programs. Industrial upgrading policies focus on the development of process and product engineering in addition to other manufacturing capabilities (quality standards) among firms. In the context of Romania and similar transition economies, upgrading may offer a more promising path to economic development through creating future firm demand for local R&D and engineering services compared to the widely adopted R&D-focused policies (Rodosevic 2017). Further, in many cases, entrepreneurial development and technology commercialization are dependent on the existence of manufacturing capabilities within a region. For example, a startup established based on technologies developed at LLNL will likely need to develop proofs-of-concept and prototypes. If successful, it will need to establish production capabilities. Programs such as the MEP program offer specific services designed to enable small firms to establish, improve, and scale manufacturing operations.

Table 12. Alignment of Programs with Regional and National Priorities and Associated Impact

Organization	Actions	Impact
LMJ-PETAL	LMJ was built in Bordeaux due to existing national security-related facilities (CEA) and the presence of universities with research capabilities in physics and lasers. Organizations funded by the French government (ALPhANOV) provide support for SMEs in the region and receive a generous research tax credit to support their mission.	Coordination between regional and national development efforts accelerated industrial cluster development within the region.
Paranal Observatory	Chile offers several benefits for organizations aiming to build observatories, including diplomatic status, a VAT exemption, and the exemption of telescope construction from customs duties.	Among other organizations, ESO selected Chile (in this case, Paranal) as the location for its observatory.
GIST-APRI	GIST-APRI was among several organizations established as part of a long-term ecosystem strategy and co-evolved with these organizations, along with existing universities and public laboratories in support of industrial development.	Over time, the region developed research capacity support from the myriad institutions focused on industrial development, including GIST-APRI.
CERN	CERN has coordinated its efforts with a regional technology transfer/incubation strategy, locating incubators in member countries.	A regional strategy has allowed CERN to better disseminate its technologies while aiding companies in adopting these technologies.
LLNL	Legislation in the early 1980s created legal mechanisms (CRADAs) that allowed federal laboratories, such as LLNL, to conduct joint research commercialization projects with industry and other organizations. Federal funding of dual-use equipment and civilian research through LLNL provided ways for labs to work with outside stakeholders.	In addition to its lab-centric initiatives, LLNL increasingly partners with other national labs, such as Sandia National Laboratory, to improve knowledge spillovers to the industry and other organizations.
ELI Beamlines	Draws upon existing physics capabilities in the region. The director of the Czech Institute for Physics is the project director. The Czech Government has given several research awards to the facility.	In development.
ELI-ALPS	Draws upon existing laser capabilities in the region and country and has a high degree of involvement from the regional Hungarian development authority.	In development.

4.5.5 Economic Geography and Spatial Considerations

Recommendation: Consider spatial elements when designing policies and programs to maximize lab influence.

Along with the applicability of scientific discoveries and the presence of industries, geography plays a critical role in the spillover of new knowledge. As discussed in the first section, tacit knowledge is transferred through face-to-face communication. Thus, proximity is generally an important mediating factor for technology transfer, for example. As previously discussed, scientific discipline and the nature of knowledge (tacit vs. codified) are also important mediating factors. All three are needed for successful knowledge generation and transfer.

The social and economic impact of large science facilities are mediated by their proximity to basic infrastructure and the connectivity of the region to relevant industry networks. For example, LLNL's Silicon Valley location makes it well positioned to take advantage of the region's entrepreneurship resources, including human, technical, and financial capital. Further, the San Francisco Bay Area is home to several world-class research universities, including Stanford, the University of California Berkeley, and the University of California San Francisco. In contrast, the Paranal Observatory is in a remote desert in northern Chile, far removed from the nearest metropolitan region and lacks basic infrastructure, such as potable water. Further, GIST-APRI co-evolved with the region, contributing to the development of a nascent industry in optics and photonics.

Space, in the form of land and facilities, is also a critical component of influence. At times, it is at odds with the need for industry- and research-oriented networks. For example, the population density and high cost of the Bay Area limits LLNL's access to space that might be required for expansion or new initiatives, while the Paranal Observatory is surrounded by vast expanses of land. Though LMJ-PETAL's location (nearly 30 km from Bordeaux) was initially perceived as relatively removed, policymakers took advantage of the areas between Bordeaux to establish the Route des Lasers. Thus, companies can be well positioned between the dual-use laser facilities of LMJ-PETAL and the civilian research capabilities of the University of Bordeaux. Further, companies in the Route des Lasers can take advantage of Bordeaux's transportation infrastructure and quality-of-life offerings. Similarly, CERN's location near Geneva offers scientists a high quality of life.

Time (i.e., the long-term and short-term processes involving national and local authorities) guides the development of infrastructures for a research and innovation cluster. For example, the development of the photonics cluster in Gwangju, a metropolitan city in a less developed region, was driven by central government initiatives to achieve 'balanced' economic development across South Korea. The development of the cluster was part of a multi-decade, multi-phase process with continuously evolving efforts from national and local governments to promote research, industry, and regional development. Concerted efforts, such as tax incentives and low rents, incentivized a critical mass of firms to relocate to Gwangju and develop the cluster. New research institutes like GIST contributed to building highly skilled human capacity. In parallel, central government investments provided the resources necessary to build different urban infrastructures and improve accessibility of the city and broader development of the cluster. A detailed discussion on the economic geography and other enabling factors for development for the photonics cluster in Gwangju is presented in Annex 10.9.

Table 13. Location and Spatial Dimensions and Associated Impact

Organization	Actions	Impact
LMJ-PETAL	While LMJ-PETAL is located 20 km from Bordeaux, the nearest metropolitan area, the nearby Route des Lasers provides space for industrial facilities and support services and excellent infrastructure and high quality of life.	Route des Lasers offers a development space between LMJ-PETAL and Bordeaux. Several industries are emergent with networks developing among firms and research organizations.
Paranal Observatory	Far removed location in the Atacama Desert in northern Chile with minimal infrastructure to support development.	In development.
GIST-APRI	Located in northern Korea, GIST-APRI was established in Gwangju as an important component of industrial development focused on optics and photonics. The area possesses good infrastructure and opportunities for expansion.	
CERN	CERN is located near Geneva and little emphasis has been placed on regional development.	The Gwangju region has successfully co-evolved with GIST-APRI; however, its location away from larger population centers has made industrial recruitment more difficult.
LLNL	LLNL is in Silicon Valley, providing excellent access to scientific and entrepreneurial talent and networks but has limited expansion opportunities due to restricted space and high cost.	While CERN is located near Geneva, other lab characteristics limit its geographic effects.
ELI Beamlines	It is in the Prague metropolitan region with good transportation access and is part of the STAR industrial development cluster.	Though space is a constraint, LLNL's location provides excellent opportunities to partner with the industry and take advantage of entrepreneurial opportunities within the region.
ELI-ALPS	Located near Szeged, with a science park planned, it has good possibilities for expansion.	In development.

4.6 Conclusions

The main conclusions from the case studies can be grouped around three types of influence: knowledge, commercial, and spatial.

4.6.1 Knowledge Impacts

The first insight from the international experience is that knowledge does not automatically "spill over" in the case of large research infrastructure investments. Knowledge is subject to institutional, geographic, and cost constraints, known collectively as the 'knowledge filter.' In addition, the tacit nature of knowledge often requires face-to-face communication to be transmitted; otherwise, it remains embodied in specific individuals, organizations, and processes.

In the examined cases, core research did lead to knowledge spillovers if specific mechanisms were put in place to encourage knowledge transmission. Specific initiatives include:

- *Facility access mechanisms.* These initiatives provide conditional access by local scientists to the research facilities. For example, in Chile, these policies have helped develop research capabilities in astronomy at Chilean universities and have attracted Chilean students from universities around the world to return as postdocs. To maximize knowledge transmission during access, local scientists can be paired with international scientists and become co-authors on papers resulting from experiments (as has been the case in LMJ-PETAL).
- *Local educational outreach.* Teachers can be trained on cutting-edge scientific discoveries, and school groups can be hosted on visits. Even highly sensitive research institutions, such as LLNL, have found a way to do this. The long-term effects can help build motivation for a next generation of researchers and engineers.

4.6.2 Commercial Impacts

In the examined cases, large-scale science investments did not necessarily lead to economic impact in the form of spinoffs and technologies that could be commercialized in the local area. This was the case even where the core research functions were highly successful in their own right. Sometimes the research findings are repatriated elsewhere by visiting researchers. In other cases, the commercial applications of fundamental research were simply of limited scope. In Chile, for example, the Paranal Observatory has generated only limited local spillovers from its core research. Like-wise, CERN has been able to transfer CERN technologies to member states widely but has not caused much commercial application locally in Geneva.

This risk seems relatively likely in Romania, given that the R&D ecosystem is relatively underdeveloped. Private-sector firms in Central and Eastern Europe, including Romania, are not well-suited to take advantage of research-driven innovation (Radosevic 2017). Romania is a modest innovator, and its innovation performance has declined over time by about 14% relative to that of the EU in 2010.[53] Romanian firms underperform EU peers in (i) product and process innovation; (ii) expenditures on in-house innovation, RDI, and venture capital; (iii) intellectual assets, such as patent, trademark, and design applications; and (iv) collaborations with other private or public research organizations. A more likely path to upgrading of the local private sector is provided through adopting technologies that have already been developed and commercialized elsewhere ('adoption of foreign technology').

53 European Innovation Scoreboard 2017–2018

However, there may be a short-term scope for economic spillovers around Măgurele and Bucharest through linkages with supplier firms. For example, Route des Lasers in France has developed into an industrial cluster based on harnessing upstream linkages during the construction of LMJ-PETAL. This includes the design and manufacture of advanced lab equipment and instruments. Since Romania's research and innovation performance is highly concentrated in the Bucharest-Ilfov region, there a scope for such spillover to occur given the proximity to the Măgurele area. Both public research organizations and firms in Bucharest are much more competitive than elsewhere in Romania. Bucharest is Romania's largest university center and has the most modern research infrastructure. It captures the largest share of national RDI funds (54%–57% between 2007 and 2014). It employs 53% of Romania's RDI personnel[54] and 37% of the country's high-tech personnel.[55] Similarly, firms in Bucharest are more successful than firms in other regions of Romania at accessing EU funds for RDI. For example, almost half of the firms that were successful in getting funding for innovating their products and processes[56] were from the Bucharest-Ilfov region, while the remaining firms were scattered across the remaining seven regions.

Linkage programs are widely used and can be adjusted to the most likely opportunities. In LMJ-PETAL, programs included the establishment of shared entrepreneurship and business-related services. Programs designed to support such linkages could be also developed for the Laser Valley area.

4.6.3 Spatial Impacts

In most of the examined cases, the research sites were in or within commuting distance of a metropolitan area: Bordeaux, Geneva, Gwangju, Silicon Valley, Prague, and Szeged. These cities are of a relatively large size and include social amenities, accommodations, catering, and associated requirements.

Increased demand for social amenities, housing, and infrastructure can usually be absorbed within a neighboring city. An expanded number of 'permanent' and short-term visiting researchers will require a certain level of infrastructural development and social amenities.

That said, the availability of land for new development can be an advantage. For example: LMJ-PETAL's location approximately 30 km from Bordeaux has allowed several subsidiary activities to be established along the 'Route des Lasers' between the site and Bordeaux. In contrast, this has not been possible around LLNL (in Silicon Valley), where land is limited and of excessive cost.

Overall, these international cases demonstrate the opportunities available from large science projects and demonstrate that those opportunities are not inevitable. Specific actions were required in each of the three areas (knowledge, commercial, and spatial) to achieve positive spillovers from mega science projects.

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54 Romania National Institute of Statistics, 2015.

55 https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/bucharest-ilfov

56 http://www.poc.research.gov.ro/uploads/rezultate-competitii/2016/rezultate-finale-sectiunea-c-ii-anexa2-la- decizia-9433_24-11-2016.pdf

Chapter 5

Laser Valley Development Pathways: Gaps and Needs

This chapter suggests possible development paths around ELI-NP based on selected intended outcomes and highlights the enabling conditions for each scenario to succeed. The chapter formulates insight from preceding analysis of the R&D and spatial framework conditions in which ELI-NP operates (Chapters 2 and 3) and from the lessons learned from similar international large science infrastructure (Chapter 4). Framework conditions have been also completed with the findings of the survey that assessed the perception of researchers and firms regarding the possible effects of ELI-NP (Annex 11: Survey on R&D Framework Environment).

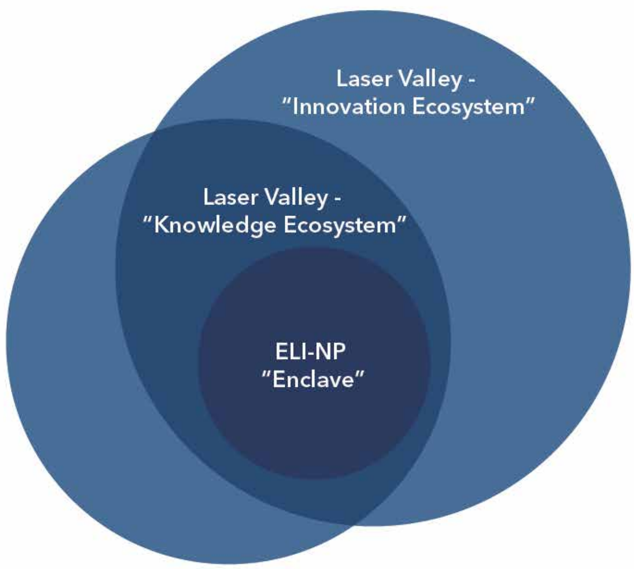
5. Laser Valley Development Pathways: Gaps and Needs

5.1 Potential Scenarios

Three scenarios are developed to suggest possible development paths for Laser Valley, based on their intended outcomes. Although these scenarios differ in terms of outcomes, they have ELI-NP in common as an anchor science infrastructure/platform. These scenarios overlap to a certain extent and evolve and emerge next to each other (Figure 49). The final development path depends on the existence of the enabling conditions, the players, and their dynamic interactions.

- **Scenario A:** ELI-NP as an "enclave." This is the basic scenario. The ELI-NP science infrastructure functions as a self-sufficient system with minimum interaction with local organizations (research organizations or firms). The science infrastructure is utilized mainly by fly-in/fly-out visiting scientists selected based on the scientific merits of their project proposals with little to no collaboration with researchers from other local research organizations. Spillovers are focused on service provision to the foreign and local scientists that will have R&D collaboration and experiments at ELI-NP. Such spillovers are mainly spatial spillovers (housing, accommodations, and transport).
- **Scenario B:** Laser Valley as a "knowledge ecosystem." The outcome of this scenario is the creation of new knowledge through joint research work and collaboration within the geographic boundaries of the Măgurele/Bucharest area among the different local research organizations and firms and with ELI-NP having a catalytic role. This scenario assumes knowledge spillovers to the local research community and universities and spatial spillovers derived from service provision to local and foreign scientists.
- **Scenario C:** Laser Valley as an "innovation ecosystem." The outcome of this scenario is the integration of the new knowledge created by and around ELI-NP and its exploitation for value creation through commercialization and linkages. In this scenario, commercial spillovers (spinoffs and backward linkages) are added to the knowledge spillovers under Scenario B. Scientific research successfully leads to commercial spinoffs, either channeled through existing companies or through startups located in or around Măgurele. Backward linkages are fostered for suppliers to ELI-NP and associated initiatives (maintenance, services, and suppliers). Spatial spillovers are expected.

Figure 49. Three potential development pathways for Laser Valley



A

5.2 Scenario A: ELI-NP Enclave

5.2.1 Scenario Hypothesis

This scenario envisages the basic operation of ELI-NP, disconnected from other local research organizations and businesses. The ELI-NP science infrastructure would be utilized by fly-in/fly-out visiting scientists and top ELI-NP/IFIN-HH researchers with little to no spillovers to nearby research institutes and local researchers. Key requirements are focused on service provision to visiting researchers (especially housing, transport, and catering), and on ensuring the human and financial resources to maintain operations at ELI-NP.

5.2.2 Premises and Challenges

The following enabling conditions that are relevant for this scenario are examined below:

- financing requirements,
- human resources requirements,
- institutional and regulatory requirements, and
- spatial requirements.

The anticipated spillovers would be mainly knowledge (however beneficiaries will be Romanian and foreign scientists that will use the ELI-NP infrastructure to conduct their research experiments) and some limited local economic development impact due to better transportation and other accommodation facilities.

Financial Requirements: The main financial requirement is to ensure the operational cost for ELI-NP. The annual operating costs for ELI-NP are estimated to about EUR 29 million. Romania expressed its commitment to support at least 30% of these costs and to increase this share in case the contributions from other participant countries and grants do not cover the remaining 70%. This amount is significant and needs to be specifically earmarked in multiannual budget plans. In addition, efforts should be made to convince countries/research organizations that plan to use the ELI-NP infrastructure for research experiments to contribute to the ELI-NP operational budget. The cuts in the research public funding and the lower-than-planned budget execution (discussed in Chapter 2) add risks to this scenario.

Human Resources requirements: The core ELI-NP team is formed of repatriated Romanian scientists with PhDs earned abroad and international scientists and has a strong research orientation. Additional human capital needs appear relatively modest in number but are important in terms of the level of qualification, experience, and talent. It is anticipated that about 225 researchers and 70 technicians are needed to operate the equipment. This compares with over 1,000 researchers and more than 500 technicians who currently work in the research institutes in Măgurele.[57] However, the challenge would be to attract and maintain such top researchers given the current constraints, such as recognition of foreign diplomas or the rigid employment criteria for public administration. In addition, ELI-NP/IFIN-HH, possibly with the Faculty of Physics and the local administration, need to consider organizing/establishing technical schools to qualify technicians in physics.

Institutional and regulatory requirements: Regulatory requirements for certifying or approving visiting researchers may need to be reviewed (or exempted) for the case of ELI-NP. During preparation of this report, the team was informed that international scientists coming to work in Romania must comply with the same requirements as Romanians when being recruited to a position.[58] This includes producing diplomas dating all the way back to high school, which seems curious when dealing with an internationally accredited scientist.

57 These figures are estimates and are inferred from data on the number of specialists and technician commuters in Măgurele. If the precision of these numbers can be improved, they should be.

This topic should be discussed to understand the regulatory barriers that may impinge on the successful functioning of ELI-NP, including access by international scientists and researchers. In addition, the IP regulations for IFIN-HH and the requirements for carrier development need to be reviewed to provide incentives to researchers to increase the quality of their research outputs.

Spatial development requirements: From the spatial angle, the requirement under this scenario envisages developing a set of accommodation and transportation options for visiting researchers and the expanded local workforce that will be working with them. These options need to be configured according to the likely profile of the visitors (such as length of stay and single or with families) using the existing commuting profile as a guide.

The high proportion of commuters suggests that housing needs and social amenities may not all be required to be in Măgurele itself to attract and house researchers. That is especially the case if visiting researchers are looking for social amenities of a large city (Bucharest) as opposed to a small settlement (Măgurele). According to the previous analysis, it appears that a substantial proportion of workers in Măgurele will continue to commute from Bucharest and surrounding areas. We anticipate that higher skilled and higher wage workers are more likely to commute since they can afford housing in more central areas of Bucharest with better social amenities (quality of housing, schools, access to urban amenities, and so on). The proportion of short-term visiting researchers versus long-term visiting researchers should be estimated upfront. The length of the visit will have implications for the type of accommodations to be provided (e.g., hotels and scholarly hostels for short technical visits versus housing for researchers and their families).

Conversely, transportation needs may come to the fore. An increase in the number of commuters will further increase the burden on roads, especially in the absence of other public transport options. The current accessibility levels are likely to remain unchanged with the sole exception of the new metropolitan bus lines foreseen by the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region. The commencement of the cadenced rail services on Bucharest Ring Railway between the main railway station and Progresul Railway Station might trigger a perceptible improvement in accessibility.

Supporting amenities, including lodging, conference venues, and food service operators can be housed by the municipality of Măgurele, albeit with a sustained refurbishment effort. Such amenities will be mostly distributed throughout the civic center of Măgurele and housed within existing buildings. Public utility provision should be extended throughout the civic center and the research platform. Retrofitting might prove necessary as the critical infrastructure is largely obsolete.

Lastly, the scenario requires some planning prerequisites, as it does not imply major operations, such as land adjustment or large-scale real-estate investments. The necessary planning operations are solely dedicated to public utility provisions.

5.2.3 Intermediate Goals and Lines of Actions

Overall, the preconditions for this scenario require some support but appear to be achievable. Some recommendations for attention by decision makers would include the following:

- *Ensuring the necessary funding for maintaining ELI-NP in operation;*
- *Ensuring that regulatory requirements are in tune with the needs of ELI-NP to efficiently and accessibly bring international scientists to Măgurele and to maximize the number and quality of the research outputs;*
- *Developing a set of accommodation and transportation options for visiting researchers and the expanded local workforce that will be working with them. These options would be configured according to the likely profile of the visitors (such as length of stay; single or with families) using the existing commuting profile as a guide;*
- *Undertaking planning activities for public utility provision.*

B

5.3 Scenario B: Laser Valley as a "Knowledge Ecosystem"

5.3.1 Scenario Hypothesis

This scenario envisages Laser Valley – Măgurele evolving into a "knowledge ecosystem" based on research excellence and increased productivity. The knowledge ecosystem is understood here as a dynamic and self-organized system that fosters new knowledge and innovation through improved networks of collaboration and interactions between different actors within the geographic boundaries of the Măgurele/Bucharest area (such as research organizations, universities, and firms), and ELI-NP as international research anchor with a strong catalytic role.

5.3.2 Premises and Challenges

There are some good premises for this scenario to happen; however, important challenges need to be addressed:

Long tradition in atomic and subatomic physics research: Despite Romania's modest overall research and innovation performance, Măgurele was specifically selected to locate ELI-NP research infrastructure given its "long tradition as a pole of excellence in Physics, the only site in Romania and in all South-East Europe with such a concentration of research, educational and technological facilities in all major fields of Physics and related domain."[59] Indeed, the research activity in Măgurele started in 1949 when the Physics Institute of the Academy was established. The first nuclear research reactor imported from the former Soviet Union was commissioned in 1957 in Institute for Atomic Physics (IFA) Măgurele. In the same year, Romania became a founding member of the International Agency for Atomic Energy in Vienna. After several reorganizations of the research sector done after 1990, Măgurele now hosts a cluster of six public research institutes,[60] two private research and engineering firms,[61] and the Physics Faculty of the University of Bucharest. About 2,000 people work in these research institutes, of which about 1,500 are researchers. Măgurele generates about 30% of the research outputs in Romania, while IFIN-HH alone generates 10%.

High density of human resources in science and technology and researchers: The Ilfov/Bucharest region concentrates the highest share of human resources in science and technology in Romania of about 49% of the total active population,[62] above the EU average of 46%. Researchers represent 0.85% of total employment in Ilfov/Bucharest region, six to eight times higher than in the rest of the regions in Romania, but two-three times lower than in the most advanced regions in Europe. In this regard, Ilfov/Bucharest compares well with the Aquitaine region where the Laser Megajoule (LMJ), the large laser-based inertial confinement fusion (ICF) research infrastructure is built (near Bordeaux).

Researchers are open to scientific collaboration: The survey highlighted that there are strong premises for scientific collaboration and knowledge creation in the Măgurele area. Incumbent researchers in Măgurele and in ELI-NP-related institutes located elsewhere in Romania have relatively high expectations regarding the spillover effect from ELI-NP: 91% of respondents anticipate a positive or highly positive effect of ELI-NP on Romanian fundamental research, 87% anticipate a positive or highly positive effect on the capacity of Romanian scientific communities, and 81% anticipate a positive or highly positive effect on Romanian applied research. Researchers in fields related to ELI-NP do have a strong intention to develop research projects related to ELI-NP. In addition, 41% (or 91) of the respondents declared that they have the intention to conduct research experiments using the ELI-NP infrastructure. Moreover, 36 respondents declared that have already applied to ELI-RO calls for preparatory proposals through the Institute of Atomic Physics, and only six of them already collaborated with the ELI-NP team (Table 14).

59 ELI White Book, p. 494.
60 IFIN-HH, INPLR, NIMP, IGSS, INFP, and INOE.
61 Optoelectronica 2001, Accent Pro 2000.
62 Eurostat, 2017, Human resources in science and technology as a share of the active population in the age group of 15-74.

Table 14. Perceptions Among Researchers about the Likely Effects of ELI-NP

What is your perception of ELI-NP's impact in the following areas? (B3)	Highly Positive Impact	Positive Impact	No or Negative Impact	Total
Enhancing scientific cooperation between Romanian and international research organizations	46	47	7	100
Advancing Romanian fundamental research	43	49	9	100
The economic development of the Magurele Town and the surrounding region	41	47	12	100
Science discovery and progress in general	35	57	8	100
Attracting additional research funding from European and international sources	35	57	8	100
Improving the capacity of Romanian scientific communities in associated scientific fields	26	61	13	100
Advancing Romanian applied research	23	58	19	100
Enhancing scientific cooperation among research/ academic organizations in Romania	20	60	20	100
Improving science - industry collaboration and technological transfer	16	46	39	100
Building technological capacity of local firms in relevant fields through accessibility of sophisticated experimentation instruments	14	49	37	100

Steps have been made to strengthen the governance and coherence of the R&D policies in the atomic and subatomic fields. Since 2008,[63] the IFA has been empowered to provide an appropriate framework for the development of the Romanian physics research in these fields, evaluate the scientific potential, elaborate a coherent strategy, and facilitate national and international cooperation. The IFA was delegated by the Ministry of Research and Innovation to act as a management and financing agent for the implementation of the PNCD Subprogram 5.1 that supports nuclear physics and higher laser research projects, particularly related to ELI-NP (Box 2). Selected using international evaluators, the projects are expected to prepare future research and applications that would use the ELI-NP infrastructure, based on the ELI-NP White Book[64] and ELI-NP Technical Design Reports.[65] The IFA also ensures the participation of the Romanian researchers in European and international projects, such as Euratom, CERN, ITER[66], etc.

However, the challenges affecting the National R&D and Innovation (discussed in Chapter 2) equally affect the research excellence and science-industry collaboration in the Măgurele area. The survey (Annex 10) highlights that some of challenges stem from the national framework conditions and are consistent with the findings from Chapters 2 and 4. Others stem from the local framework conditions that are relevant for the Măgurele area and for the physics research community in Romania:

- R&D regulations are noted as a specific challenge, more so than for infrastructure, management, or human capital. Government procurement policies are mentioned as a particular problem (90% of respondents said they are inadequate or need improvements) as well as regulations on spinoffs (77%), IP (63%), and licensing (61%). The rates of dissatisfaction are higher among respondents that were involved in such projects compared to colleagues that were not, indicating this dissatisfaction seems to grow among those that are more knowledgeable of their provisions. One-quarter of respondents do not know what proportion of royalties are passed on to individual researchers in the organizations in which they work, which indicates a lack of knowledge and incentives for researchers to pursue such projects. Awareness of spinoff practices is low (17%).
- Researchers note that they face challenges in attracting and maintaining top talent in research projects. Among researchers directly involved in ELI-NP, fully 74% of respondents express that they face problems either in attracting or retaining talent in research projects. The reasons for this opinion seem to include the unpredictability of funding (this is the most common answer), low

63 Government Decision 1608/2008.
64 http://www.eli-np.ro/documents/ELI-NP-WhiteBook.pdf
65 http://www.rrp.infim.ro/2016_68_S.html
66 ITER ("The Way" in Latin): First fusion devised to produce net energy for which 35 nations collaborated to develop the world's largest totamak, a magnetic fusion device that has been designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy based on the same principle that powers our Sun and stars.

financial or other professional incentives, legislative obstacles (e.g., non-recognition of foreign qualifications in Romania), and a few other factors. Many respondents consider migrating abroad from Romania, especially those that are dissatisfied with the work environment, infrastructure, and quality of management. Even more concerning, there is a significant correlation between those researchers that consider migrating abroad and those that are involved in research with commercial potential. This result suggests there is a marked risk of the most relevant researchers for spillovers from ELI-NP to leave the country. That said, researchers in the Măgurele area appear to be significantly more satisfied than those in other locations.

The Măgurele area does not offer proper venues for conferences, meetings, technology transfer, or platforms for prototyping, production development, and engineering. Such facilities would need to accommodate and foster the growth of tenant firms and could potentially affiliate with the research organizations and universities based on proximity, ownership, and/or governance. This is so that knowledge can be shared, innovation promoted, and research outcomes progressed to viable commercial products. The construction of a science park is planned[67] by the Ilfov County authorities; however, its potential location poses challenges, such as the need to ensure the land property transfer between the Ministry of Defense and the Ilfov County Council.

The living and working environment in Măgurele needs improvements. The survey highlighted the improvements that would make Măgurele a more attractive area for researchers. This question was open ended (i.e., not multiple choice) and thus encouraged a choice free of constraint. The results suggest that institutional constraints are as important as transport infrastructure (Table 15).

Table 15. Researchers' Opinions to Improve Măgurele as a Location for Research

Primary Needs	Count	Secondary Needs	Count
Institutional	28	Quality of Life	18
Transport Infrastructure	27	Public Transport	12
Basic Infrastructure	16	Basic Infrastructure	6
Public Transport	14	Housing	4
Quality of Life	7	Institutional	4
R&D Infrastructure	4	Transport Infrastructure	4
Housing	2	R&D Infrastructure	3
TOTAL	98	TOTAL	51

5.3.3 Intermediate Goals and Lines of Actions

Overall, Scenario B might have a good potential for knowledge spillovers given its existing position as a strong pole of research in Romania. However, it is held back by several national factors, as discussed above. Against this background, without being exhaustive, several intermediate goals and lines of actions are examined below in addition to those discussed under Scenario A.

Improving the research base and the conditions for research excellence and collaboration:

- Strengthened scientific governance and framework for the development of the Romanian physics research, particularly in the atomic and subatomic fields where the research competency is concentrated. The Ministry of Science and Innovation needs to increase its financial support to IFA to be able to properly exercise its mandated role.
- Strengthened collaboration between the local and international scientists: Implementation of initiatives and programs that increase the interactivity between international and local researchers through collaborative research activities and increasing access by local scientists to the research facilities. Such initiatives could take different forms from programs that fund collaborative projects to other non-financial activities that could be considered by IFA, such as knowledge handovers, peer-to-peer seminars, subject matter expert meetings, communities of practice, knowledge management and exploitation groups, collaborative networks (shared drives), repositories of knowledge generated by scientific and innovative projects (past or current), etc.

67 The feasibility study was commission by the Ilfov County Council.

- Effective policies and instruments to retain and repatriate human capital: Policies need to include a reward structure that focuses on merits rather than age should they envisage the return of scientists. In addition, they need to be designed to create a critical mass of returnees with a similar profile. Policies that aim to foster the development of networks with the diaspora and that improve mobility are critical for promoting linkages between migration and development. Lastly, policies that prevent 'brain drain,' such as those that provide incentives to research organizations and firms to hire young researchers with a doctoral degree.
- Ensure open access to research infrastructures: The public research institutes in Măgurele along with the Ministry of Science and Innovation need to review the policies and regulations that prevent the access of researchers from other public institutes. This is not only because such assets are not used up to their full potential but there is also the threat that they may be decommissioned earlier due to unpredictable funding to keep them in operation.

Improved accessibility, amenities, and public utility provision in the Măgurele area. The following intermediate objectives and lines of actions are envisaged (see Table 15):

- Improved levels of accessibility to/from Măgurele: The levels of accessibility remain relatively the same as in Scenario A, with the exception of the science park, which slowly could become a new commuting destination. The need for an easy, safe, and interesting pedestrian and cycling connection between the civic center of Măgurele and the newly proposed science park becomes apparent. A richer research-based interaction implicitly increases the international exposure of Măgurele. It is therefore highly likely that foreign researchers as well as students will seek a more diverse offer of leisure activities. Against this background, the idea of the blue-green corridors along the Argeș, Ciorogârla, and Sabar Rivers will gain traction.
- Amenities reach a more consistent level of demand: In comparison to the previous scenario, amenities need to respond to increased levels of demand, as the scientific environment becomes more active. The catering and hospitality industry are likely to capitalize upon this emerging local market through a few anchor investments. In addition, the University of Bucharest and the Bucharest Polytechnic may capitalize upon this emerging local market and expand their presence in the Măgurele area. New housing projects could gain momentum, albeit making use of the existing land and property structures. The need for a land readjustment program becomes increasingly evident as contrasts in building densities become less tolerable.
- Public utility provision: The public utility provision program would need to focus first on servicing the science park and then to gradually expand toward the civic center. However, the southern part of the municipality might be left behind.
- Planning prerequisites: Planning prerequisites become more stringent within this scenario. Land readjustment is necessary to consider the new housing requirements. In addition, as new real-estate investments multiply, an integrated urban regeneration program becomes necessary. Its primary goals are to ensure a more efficient public utility provision; to increase the quality of the built environment, including the network of public spaces and green open areas; to increase the quality of housing; and to set the framework for ecosystem service provision along the Argeș, Ciorogârla, and Sabar Rivers.

Conclusions: Overall, Scenario B has good prospects given Măgurele's current position as a strong pole of research in Romania. However, it is held back by several national and regional factors, as discussed above. Several intermediate goals need to be achieved to increase its likelihood. The following intermediate outcomes and lines of action are suggested, in addition to those discussed under Scenario A:

Improving the research base and the conditions for research excellence and collaboration

- Improve scientific, funding, and M&E governance for the research in the physics domain;
- Promote collaboration between local and international scientists;
- Attract the diaspora in research collaboration;
- Enable open access to the research infrastructure

Improve the accessibility, amenities, and public utility provision

5.4 Scenario C: Laser Valley – an "Innovation Ecosystem"

5.4.1 Scenario Hypothesis

The expected outcome of this scenario is the integration of the new knowledge and technologies created by and around ELI-NP and by their exploitation for value creation through commercialization and linkages. In this scenario, commercial spillovers (spinoffs and backward linkages) are added to the knowledge spillovers under Scenarios A and B. Scientific research successfully leads to commercial spinoffs, either channeled through existing companies or through startups located in or around Măgurele. Backward linkages are fostered for suppliers to ELI-NP and associated initiatives (maintenance, services, and suppliers). Spatial spillovers are expected. This scenario evolves and emerges to a certain extent from the previous one; however, it brings new entrepreneurship and spatial development dimensions.

5.4.2 Premises and Challenges

The premises and challenges discussed under Scenario B remain relevant. Additional ones, such as technology transfer and commercialization, backward linkages, business environment, and spatial development were also covered by Chapters 2 and 3. They are briefly summarized below:

The potential for spin offs from the existing research organizations in Măgurele is rather low in the short term. Researchers in Măgurele seem to be relatively pessimistic regarding the commercialization prospects of their research. Very few could identify specific commercially viable applications. In contrast, the researchers working in ELI-NP believe that the experiments that could be implemented in ELI-NP have the potential to lead to commercial applications in the medium and long term. These include nuclear medicine (radio nuclide and hadron therapy), telecommunications (materials in high intensity radiation fields), engineering (non-destructive testing), security (scanners based on nuclear resonance fluorescence of sensitive nuclear materials, industrial tomography, and nuclear forensics), cultural heritage preservation (historical dating and treatment of surfaces for restoring artifacts), spatial applications, and space travel (through creating similar conditions as in a space environment; Annex 4). However, they are less optimistic about commercial spillovers than about core research collaboration. The responses of the survey participants cited in Annex 11 indicate that 93% of respondents anticipate a positive or highly positive effect of ELI-NP on scientific cooperation, but only 62% anticipate a positive or highly positive effect on science-industry collaboration and technological transfer. Indeed, 39% of respondents anticipated zero or a negative effect. Only 64 of the respondents anticipated a positive or highly positive effect of ELI-NP on the technological capacity of local firms through accessibility of sophisticated experimentation instruments.

The low level of expectations about the potential commercial applications of their research stem from the researchers' belief that firms are not interested and that the risks and costs are prohibitive. These beliefs were stronger among researchers who had collaborated with companies in the last four years, compared to researchers who had not.

Table 16. Perceptions of Difficulties in Research-Firm Commercial Collaborations

In your opinion, which are the difficulties in collaboration with small and medium size companies? (A21)	Cooperated with a company in the last four years (A19)		Total
	no	yes	
Absence of interest from industry	46	70	58
Finance and costs	46	70	55
Absence of interaction between RDIs and firms	46	48	42
Unclear questions from companies	5	14	11
The deadlines	3	14	10
Matching the technical level requested to fulfil the work	3	10	8
Other	4	7	6

There is no clear consensus among researchers to explain the lack of spinoffs. The survey identified several reasons that constitute impediments against spinoffs. Table 17 presents a range of issues highlighted by the interviewed researchers. This result can suggest that, indeed, there are very many constraints that researchers need to face or that researchers never explored regarding the spinoff avenue. Irrespective of the interpretation of the survey results, it appears that the findings from Section 2 are also relevant for the local context in Măgurele. Thus, it appears that researchers conducting applied research face an adverse incentive environment that does not recognize commercialization and spinoff achievements when promotion decisions are made (Table 20).

Table 17. Researchers' Perceptions of Barriers to Spinoffs

What is the main barrier your institution is facing regarding spin-offs?	%
Poor management and entrepreneurship culture	16
Regulations, laws	13
Costs, financing	9
Poor interest of researchers and managers	8
Poor information	6
Lack of experience	5
Bureaucracy	5
Poor innovation capabilities	5
Market demand	4
Poor targeted research	2
Lack of policies or strategies	2
Other	9
Do not know	16
Total %	100
N	128

Table 18. Technology Transfer Achievements Are Not Clearly Recognized in Promotion Decisions

Institution and Activity	Are achievements from technology transfer (such as patenting, licensing) and volume of contract research with industry criteria for promotion in your institution? (A24)			Total
	yes	no	no answer	
Directly involved in ELI-NP	65	27	8	100
Close to ELI-NP	61	30	10	100
Universities	41	54	5	100
Other far from ELI	38	57	5	100
Fundamental Research	61	26	13	100
Fundamental and Applied Research	61	28	10	100
Research and Experimental Development	59	41	0	100
Applied Research	51	44	5	100
Applied Research and Experimental Development	47	43	10	100
Other	58	33	8	100
Total	57	36	8	100

The local business economy in Măgurele area is rather basic. Chapter 3 summarizes some of the salient indicators of the structure of the local economy in Măgurele compared to the rest of Ilfov County and to Bucharest. The average per capita income is markedly lower, the firm density is lower, and the local economy is mainly composed of non-tradable goods and services (including restaurants, household services, and related activities).

The demand for maintenance services and technological products and systems will increase once ELI-NP becomes operational. These include state-of-the-art electronics, detectors for which new designs and construction are needed, computer equipment and software, precise mechanics, optical equipment, vacuum systems, cryogenic systems, shielding systems, gas handling and gas purification systems, pure and liquid gas supplies (Annex 4). The components, spare parts, and specialized maintenance services are likely to be supplied by the international firms that produced the equipment installed in ELI-NP, at least in the short and medium term. Only local non-tradable services (e.g., basic cleaning, catering, and accommodations) will be supplied locally, where it is too expensive or impractical to bring international suppliers. The challenge ahead is to maximize the proportion of supplies that are provided by Romanian firms. So far, the only local contracts for specialized technical services or supplies were with Microelectronica and Accent Pro 2000. However, there is a potential for more.

The opportunities around ELI-NP may attract companies to relocate in the region or new companies to be established. However, the land and property issues discussed in Chapter 3 would affect such decisions, at least in the short term. First, the land is already being built upon in a relatively unplanned way. Land speculation and development is already taking place around the ELI-NP site. Residential villas are constructed relatively close to the scientific institutions. This land could subsequently be utilized for research centers, commercial developments, offices, industrial locations, and other uses related to an innovation ecosystem. However, it will become increasingly complicated to do so if it has already been developed for residential use. Second, the remaining land available is uncertain and fragmented. The largest plots in Măgurele range from approximately 20 ha to 103 ha but are almost all in wooded areas belonging to the Bucharest Forest District. The main exception to this rule is an area of 84 ha, belonging to the municipality of Dărăști–Ilfov. A second class of plots ranges from about 1 ha to 15 ha. Most of these plots are private property, though some are listed as land reserves. The last class of lot sizes comprises plots smaller than 1 ha (and these represent the greatest proportion of plots). Third, the land cadaster and urban plans for Măgurele present conflicting information about the availability of land within the public domain, with the land cadaster restricting it to two plots of 8 ha and 0.5 ha, while the urban plan suggests more extensive land reserves are available. Chapter 3 discusses other issues constraining the spatial spillovers under this scenario, such as accessibility, amenities, public utility provision, and planning prerequisites.

A larger geographical radius around Măgurele offers better business framework conditions for entrepreneurship. The Bucharest/Ilfov region concentrates the highest number and the most dynamic firms in Romania, while the employment in high-tech sectors amounts to 9.6% of total employment, which is much higher than in any other region. In addition, the nearest large plot of land available for development may be outside the immediate Măgurele area, in the Fifth Sector in Bucharest. Three large reserves totaling 650 ha are available there, of which 400 ha are already owned by the municipality of the Fifth Sector. These three are located at Antiaeriană Street (300 ha); the border between the Fifth Sector and Măgurele (330 ha); and the former industrial railway connecting Progresul Station to the ROCAR industrial platform and Bucharest Ring Railway (20–30 ha).

5.4.3 Intermediate Goals and Lines of Actions

Overall, Scenario C is increasingly demanding in terms of the expected outcome, which requires more complex interventions and governance arrangements. The scenario has more prominent regional development and perspectives than Scenario B. Most of the premises that could enable this scenario are present at a lower extent or not present at all. Against this background, without being exhaustive, several intermediate goals and lines of actions are examined below in addition to those discussed under Scenario B.

Improving the science-industry collaboration and technology transfer:

- Develop an engagement policy to take advantage of backward linkages with equipment suppliers, construction companies, and contractors (as in the LMJ-PETAL case).
- Establish an organization to design and implement an industrial engagement strategy with (as in the case Route of Lasers and the Center for Innovation and technology Transfer).
- Based on an industrial engagement strategy, establish intermediaries to support industry-related needs in technical training, research, and technical assistance.
- Introduce incentives and institutional changes that encourage researchers/professors to engage in commercialization activities.
- Establish a coordinating entity (possibly IFA) that supports commercialization-related activities for all research organizations in Măgurele and coordinates laboratory efforts at the regional level. Examples include LLNL's IPO and the Knowledge Transfer Office/Knowledge Transfer Fund at CERN.

Enabling start up creation and technology adoption:

- Develop and implement support programs to start up companies that locate in Măgurele/ Scientific Park.

Improved land availability, accessibility, amenities, and public utility provision: The following intermediate objectives and lines of actions are envisaged.

Increased availability of land for firm locations:

- Stimulating land owners to assemble more efficient plots of land to allow coherent rea-estate investments could be done, for example, through pooling and re-allotments for which a considerable municipal commitment would be needed. Land pooling would usually take place through a process along the following lines:
    (i) First, interested owners employ a chartered land surveyor to prepare the conjoining procedure/land merger ('operatiune de alipire'), which is then finalized in front of a notary public. This conjoining procedure also clearly states what percentage of the newly formed parcel belongs to whom, after the required area for public utility provision and accessibility requirements has been subtracted from the total area.

(ii) Second, the owners agree to submit the newly formed lot to a dismantling procedure ('operatiune de dezmembrare'), which results in a dismantling deed that explicitly states the area and the shape owned by each owner. Like the land merger operation, the dismantling operation is also done by the chartered land surveyor.

(iii) Third, the dismantling deed serves as the cadastral foundation for the partition deed ('act de partaj'), in front of a notary public.

Increased accessibility:

- Implementing the actions planned by the General Master Plan for Transport, such as (i) changing to cadenced services on the higher-speed regional and national railway connections; (ii) completion of the railway connection between the main railway station, Ring Railway, and Henri Coandă International Airport; (iii) completion of the overhauled Bucharest Ring Road, Ring Motorway, Danubius Expressway, and Vlăsia EuroTrans Project.
- Completing the actions foreseen by the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region to achieve the full regional integration of public transportation, such as the completion of the M4 and M6 metro lines, along with their associated park and ride facilities.
- Prospecting the benefits that might arise from the geographic proximity with the Danube river and the Bucharest-Giurgiu channel.
- Improved amenities, public utilities, and urban planning:
- The incipient scientific and business connections of the previous scenario now become fully functional, thereby linking the ELI-NP program to the University of Bucharest and to Bucharest Polytechnic. Hence, amenity provision is shared between the municipality of Măgurele, municipality of Bucharest, and municipality of the Fifth Sector, respectively. Such a network approach is likely to elicit a more adaptable response to the changing needs of the scientific and business community.
- Increasing the provision and quality of public utilities by including the areas outside the civic center of Măgurele, which currently are underserved in terms of water supply, sewage infrastructure, gas supply, etc. One of the most affected area that needs such interventions is the area around the former military fort, which is the expected location of the future science park.
- Developing an interjurisdictional spatial plan (Plan de Amenajare a Teritoriului Zonal Interjudețean/ PATZ—IJ), which will essentially act both as an agreed strategic development framework and as a blueprint for managing the functional urban area underpinning the Laser Valley project. Its provisions would become mandatory for a subsequent revision and harmonization of the General Urban Plans of the affected municipalities.

5.5 Governance

The complexity and ambition level of the outcomes envisaged for the Laser Valley ecosystem development scenarios dictate the most appropriate governance arrangements that need to be put in place. The ecosystem is seen here as a group of organizations (public and private) and individuals that interact to simultaneously create and capture value by combining their resources. The Laser Valley ecosystem cannot be seen in the limits of its geographic boundaries, as changes in the national system have an effect on the Măgurele area or Ilfov/Bucharest region, but also the changes inside the local ecosystem influence the emergence of changes in the national system.

Each development path suggested above has different stakeholders that need to coexist, collaborate, and coevolve to achieve the shared outcomes. They include research organizations, firms, local authorities, central government and line ministers, associations, and citizens. Their role increases in complexity as the ecosystems evolve, and the need for coordination becomes absolutely critical:

- Scenario A requires basic and ad-hoc interventions, which do not necessarily require complex and long-term governance arrangements. Simple interactions and voluntary agreements would be enough to enable the implementation of the proposals made under this scenario.
- Scenario B requires a number of more ambitious medium-term interventions, which would benefit from the presence of a formal governance arrangement. The IFA should strengthen its strategic and coordination role for research excellence, particularly in the atom and sub-atom physics field of research. For the spatial interventions, the most commonly used, and best-known governance arrangement for interventions across administrative boundaries, is the inter-communal development association (IDA). Such associations are now used to manage regional water and wastewater provision, regional waste collection, the implementation of EU funds at the regional level, and the management of metropolitan areas. In the case of Măgurele, Scenario B would require the collaboration and coordination of the following territorial administrative units: Măgurele City Hall, Ilfov County Council, Bucharest City Hall, and Sector 5 City Hall. A potential Măgurele IDA would be in charge of preparing a Masterplan and Cross-jurisdictional Zonal Urban Plan for the extended intervention area. The Măgurele IDA would also play a coordination role for cross-jurisdictional interventions.
- Scenario C requires consistent policies and large and long-term investments, which will be difficult to implement without a major and reliable source of financing. The large majority of large infrastructure investments in recent years in Romania have been undertaken with the help of EU funds. In the case of Măgurele, an integrated territorial instrument[68] (ITI) would be most appropriate, as it provides a platform that enables multiple and complex interventions. An ITI would also be useful, as it addresses some of the scenario needs, such as the following:
    - (i) It is prepared for a clearly defined area.
    - (ii) It requires an integrated development strategy for that area with a clear list of needed investments.
    - (iii) It has dedicated funds, both from EU programs and from other sources (state budget, county budget, local budget, private financing, etc.).
    - (iv) It follows a clear implementation time line.
    - (v) It includes clear monitoring framework with clear performance indicators.

68 An integrated territorial investment is a new tool introduced in the Common Provision Regulation (CPR) for use during the European Structural and Investment Funds (ESIF) programming period (2014–2020). Its aim is to make it easier to run territorial strategies that need funding from different sources.

Chapter 6

Conclusions

Policy makers in Romania have high expectations for future returns from ELI-NP as the location of ELI-NP in Măgurele opens large opportunities for the development of the RDI sector in Romania and for the development of the local economy. Indeed, ELI-NP can trigger economic benefits from knowledge spillovers, can lead to commercial applications of research (through selling, licensing, or contracting technology services, intellectual assets, and related knowledge into spinoff creations and R&D collaboration) and can have a multiplier effect from linkages with knowledge-intensive sectors (based on the supply of goods and services to the research facility and associated activities.

However, the EUR 300 million investment in ELI-NP does not have an automatic return. The best-case future return prospects are inherently uncertain, critically dependent on the decisions and actions that policy makers will be willing to make for them in the future. Policymakers need to manage their expectations in the short term, as basic research may take time to generate spillovers. They need to acknowledge that, without a coherent and consistent policy and investment agenda and without a high-level political commitment, the realization of the expected returns from ELI-NP could fade away.

The report attempts to lay out the framework conditions that could maximize the returns and suggests three different development pathways that overlap to a certain extent and evolve and emerge from each other: (i) Scenario A: ELI-NP as an "enclave" is the basic scenario. As one of the ELI's pillars, ELI-NP operates with minimum interaction with local organizations (research organizations or firms). The science infrastructure is utilized mainly by fly-in/fly-out visiting scientists selected based on the scientific merits of their project proposals with little to no collaboration with researchers from other local research organizations. Spillovers are focused on service provision to the foreign and local scientists that will have R&D collaboration and experiments in ELI-NP; (ii) Scenario B: Laser Valley as a "knowledge ecosystem." The expected outcome of this scenario is the creation of new knowledge through joint research work and collaboration within the geographic boundaries of the Măgurele/Bucharest area among the different local research organizations and firms with ELI-NP having a catalytic role. This scenario assumes knowledge spillovers to the local research community and universities and spatial spillovers derived from service provision to local and foreign scientists; (iii) Scenario C: Laser Valley as an "innovation ecosystem." The outcome of this scenario is the integration of the new knowledge created by and around ELI-NP and its exploitation for value creation through commercialization and linkages. In this scenario, commercial spillovers (spinoffs and backward linkages) are added to the knowledge spillovers under Scenario B. Scientific research successfully leads to commercial spinoffs, either channeled through existing companies or through startups located in or around Măgurele. Backward linkages are fostered for suppliers to ELI-NP and associated initiatives (maintenance, services, and suppliers). Spatial spillovers are expected. Table 19 provides a summary of the framework conditions for the three scenarios.

The final development path depends also the stakeholders and their dynamic interactions. The complexity and ambition level on the returns dictate the most appropriate governance arrangements that need to be put in place. Each development path suggested above has different stakeholders that need to coexist, collaborate, and coevolve to achieve the shared outcomes. Their role increases in complexity as the ecosystems evolve and the need for coordination becomes critical.

6. Conclusions

Table 19. Scenario Framework Conditions

KEY ENABLING FACTORS	SCENARIO A: ELI-NP "ENCLAVE"	SCENARIO B: KNOWLEDGE ECOSYSTEM	SCENARIO C: INNOVATION ECOSYSTEM
RESEARCH EXCELLENCE (QUALITY AND FUNDING	Funding available for maintaining operation of ELI-NP	Clear vision and good quality decisions on funding and M&E.	Funding/incentives (to researchers) for collaborative research
REGULATORY REQUIREMENTS (INCLUDING BUSINESS ENVIRONMENT, REGULATIONS)	Accessibility for international visiting scientists (certification, etc.).		Business environment to facilitate startup, financing, and operations.
HUMAN CAPITAL NEEDS (NUMBERS OF DIRECT EMPLOYEES; REQUIRED SKILLSETS–INCLUDING ENTREPRENEURIAL SKILLS)	Researchers and technicians to staff ELI-NP; Smooth process for recognition of foreign diplomas.	High-quality pool of Romanian researchers for joint initiatives with international researchers; Collaborative programs with universities.	Skilled workforce (e.g., mechanical engineering, software development) as resource for investors and/or spinoffs.
INNOVATION INTERMEDIARIES (E.G., IP, TECHNOLOGY TRANSFER OFFICES (TTO), AND FINANCIAL INSTRUMENTS)		Transparent conditional access to research facilities.	TTO, including guidance on IP; Risk financing for applied R&D; Shared facilities (e.g., Fab lab, Center of Excellence) for collaborative research with private sector.
SUPPORTING INDUSTRIES/ BACKWARD LINKAGES (SERVICES, INTERMEDIATE GOODS, ETC.) AND INDIRECT EMPLOYMENT	List of needs (not quantified) and potential suppliers already identified.		Dissemination of procurement opportunities; Assistance to firms in attaining eligibility level and submitting high-quality procurement bids.
SPATIAL AND REAL-ESTATE IMPLICATIONS (COMMUTING PATTERNS AND COMMERCIAL TRANSPORT NEEDS)	Connections to Bucharest city and to airport for visiting researchers.		Larger land requirements in Măgurele and/or adjacent municipalities; Larger commuting and commercial transport provision for increased usage.

Chapter 7

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7. References

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Annexes

Annex 1. List of Research Organizations in Măgurele

1. National Institute for Physics and Nuclear Engineering "Horia Hulubei" (IFIN-HH):

This is the largest R&D organization in Romania both in terms of research infrastructure and research personnel and generates 10% of the national scientific output. The institute addresses a wide spectrum of R&D, in both fundamental and applied sciences, including nuclear physics, astrophysics, particle physics, atomic physics, life and environmental physics, theoretical physics, nuclear techniques, and advanced communication systems. In addition, IFIN-HH has 688 employees, which include 307 R&D personnel, 235 PhDs, and 21 PhD advisors. It is the leading the implementation of the ELI-NP project in Romania.

2. National Institute for R&D for Physics of Lasers, Plasma and Radiation (INFLPR):

The institute employs 447 researchers and administrative staff to conduct frontier research ranging from basic photonic materials and high-power lasers, nanomaterials and nanotechnologies, quantum dots and information technologies, plasma physics and X-ray microtomography, industrial photonics, biophotonics, and plasma coatings. The Institute of Space Science branch conducts research on astrophysics, space engineering, and gravitation. Recently, INFLPR commissioned the installation of 1 PW laser facility in the Center for Advanced laser Technologies (CETAL). Institute for Spatial Sciences (IGSS), a subsidiary of INFLPR employs about 84 researchers of which 38 are PhDs. The main areas of research cover mathematical physics, high energy and astrophysics, microgravity, space dynamics and nano-satellites, astroparticle physics, cosmology, etc.

3. National Institute for Material Physics (NIMP)

conducts research in the field of solid-state physics and materials, such as multifunctional materials and structure, magnetism and superconductivity, optical processes in nanostructured materials, atomic structures and defects in advanced materials, etc., with a balanced focus on basic and applied research.

4. National Institute for Earth Physics (INFP)

is the leading institution for earth science and seismology in Romania. It has established a network of 130 seismic stations that collect information in real time and has two operational centers and multiple seismic observation points. It has about 50 research personnel.

5. National Institute for Optoelectronics (INOE):

The institute develops fundamental and applicative research in optoelectronics, analytical chemistry, and mechanical engineering. With about 160 researchers, the institute has also two subsidiaries: the Institute of Analytical instrumentation and the Hydraulics and Pneumatics Research Institute in Cluj-Napoca.

6. The Faculty of Physics, University of Bucharest,

has a highly trained teaching staff composed of 89 active teachers, 13 honorary professors, and seven consulting professors. The activities of teaching and scientific research are organized within the three departments: (i) Electricity & Magnetism, Solid-State Physics, Biophysics (formed by merging the former chairs of Electricity & Biophysics with Solid-State Physics); (ii) Theoretical Physics & Mathematics, Optics, Lasers, and Plasma; and (iii) Structure of Matter, Physics of the Earth, Atmospheric Physics, and Astrophysics (formed by merging the former chairs of Nuclear Physics with Mechanics, Molecular Physics, Polymer Physics, and Physics of the Earth). The number of students decreased significantly in the last ten years from 800 to less than 300 each year. The faculty provides academic studies for bachelor's, master's, and doctoral degrees with a total duration of 8 years.

7. The MĂGURELE HIGH-TECH Innovative Cluster

represents an association of more than 55 organizations including 14 public research institutes, 33 SMEs, Măgurele public administration, etc.).

Annex 2. List of Exploitable Technologies and Services Offered by ELI NP

Available beamlines:

- Laser, ultra-short pulse high power: two beams, < 25 fs, 2.5 J/pulse (100 TW), 10 Hz repetition rate in short-long focal configurations or collimated;
- Laser, ultra-short pulse high power: two beams, < 25 fs, 2.5 J/pulse (1 PW), 10 Hz repetition rate in short-long focal configurations or collimated;
- Laser, ultra-short pulse high power: two beams, < 25 fs, 2.5 J/pulse (10 PW), l/min repetition rate in short-long focal configurations or collimated;
- Gamma-ray beams: two beams with tunable photon energy ranges (0.2–19.5 MeV) and (0.2–3 MeV), relative bandwidth 0.3%, intensity 10 4 ph/s/e/v;
- Polarized positrons beamline.

Other equipment and infrastructure:

- Vacuum interaction chambers: 30, 25, and 10 m3 for 10 PW laser experiments; 5 m3 for 1 PW experiments, and 3 m2 for 100 TW experiments (all aluminum);
- Computer center for data acquisition and online and off-line processing with up to 400 CPU cores available;
- Detector arrays for: gamma, neutron (moderated and prompt), charged particles (SSD array and TPC);
- Laboratories for target preparation/fabrication and optics available onsite.

Experimental capabilities:

- 2x High-power lasers (10 PW) – solid target interaction (E1 experimental area);
- 2x High-power lasers (10 PW) – gas target interaction (E6 experimental area);
- 2x 1 PW laser – gas/solid target interaction (E5);
- 2x 100TW laser – gas/solid target interaction (E4);
- 2x High-power lasers (10 PW) – target – gamma beam interaction (E7);
- Experiments with low-energy gamma beam (< 3 MeV, E2);
- Experiments with high-energy gamma beam (0.2-19.5 MeV, E7 & E8);
- Experiments with polarized positron beam.

Annex 3. ELI-NP Applied Research Fields

The ELI-NP areas of applied research could include the following:

- Industrial tomography with high-power gamma beam for use in active interrogation of material structure and industrial ICT:
    - Scanning of complex objects with 2D and 3D imaging;
    - Automatic positioning systems (with biaxial translation and precision rotation);
    - Development of software products for scanning;
    - Beam collimation and radioprotection;
    - Development of radiation resistant detectors.
- Active interrogation of materials through non-invasive and non-destructive techniques: nuclear resonance fluorescence:
    - Measurement of concentration of some chemical elements in a specific structure. Fabrics, explosives, polymers, and miscellaneous materials can be detected and measured.
- Use of the high-power gamma beam for nuclear forensics:
    - Identification of U and Pu isotopes; investigation of uranium enrichment in nuclear plants;
    - Cargo scanning for nuclear and explosive materials;
    - Ionized radiation treatments for cultural heritage preservation (patrimoniu.nipne.ro).
- Sterilization of disposable medical instruments;
- Use of R&D research infrastructure for:
    - Historical dating and analyzing artifacts for auctioning houses or banks;
    - Historical dating and analysis for companies that restore artifacts;
    - Determining the level of pollution of a given environment;
    - Development of materials for industry, treatment of medical surfaces, testing of electronic components to radiation fields through ion implantation.
- Application of high-power laser in medicine and biology:
    - Innovative medical equipment based on high-power lasers for real-time imaging and treatment of cancer with protons of heavy ions;
    - Testing of effectiveness of new materials for protection against radiations;
    - Development and testing of pharmaceutical substances to counteract the negative effect of radiations on health of human being;
    - Application of radioisotopes in nuclear medicine through high resolution imaging, low radiation exposure, and treatment of diseases through highly specific targeting (for tumors for example);
    - Spatial applications for space travel with human crew and development of permanent settlements outside earth, applications for geo-satellites and the Institute of Space Science through the creating of similar conditions as in the space environment.

Annex 4. List of Research Infrastructures in the Măgurele Area

No.	Research Infrastructure	Host Organization	No. of Research Services	No. of Tech Services	Domains
1	IFIN GRID - Grid Computing System for Research in Physics and Related Areas	IFIN-HH	1	0	Distributed Computing Facilities
2	Molecular Biology and Single Molecule Biophysics LAB in DFVM	IFIN-HH	1	0	
3	MicroBequerel Laboratory	IFIN-HH	4	0	Underground Laboratories; Nuclear Research Facilities; Astroparticle and Neutrino Detectors and Observatories
4	ROSPHERE	IFIN-HH	2	0	Nuclear Research Facilities
5	CEXMECDIF	IFIN-HH	0	0	High-Energy Physics Facilities; Nuclear Research Facilities; Distributed Computing Facilities
6	TRITIULAB	IFIN-HH	7	0	Nuclear Research Facilities; Materials Synthesis or Testing Facilities; Aerospace and Aerodynamics Research Facilities
7	Tandem Accelerators Complex	IFIN-HH	5	0	Nuclear Research Facilities; Materials Synthesis or Testing Facilities; Research facilities for cultural heritage
8	Radiopharmaceuticals Research Centre	IFIN-HH	3	0	Nuclear Research Facilities; Translational Research Centers; Biomedical Imaging Facilities
9	Radioactive Waste Treatment Plant	IFIN-HH	4	0	Nuclear Research Facilities; Materials Synthesis or Testing Facilities
10	National Repository for Low and Intermediate Level Wastes Baita - Bihor	IFIN-HH	2	0	Nuclear Research Facilities; Materials Synthesis or Testing Facilities; Underground Laboratories
11	LCRSE - Local Centre for Radiological Surveillance of the Environment)	IFIN-HH	3	0	Environmental Health Research Facilities; Atmospheric Measurement Facilities
12	IRASM - Radiation Processing Center of the Horia Hulubei National Institute of Physics and Nuclear Engineering	IFIN-HH	8	0	Nuclear Research Facilities; Pilot Plants for Process Testing; Analytical Facilities
13	BIOEVAL - Laboratory for biocompatibility evaluation of medical materials and devices	IFIN-HH	2	0	Cell Culture Facilities; Animal Facilities
14	Romanian GPS Network	National Institute for Earth Physics (NIEP)	1	0	Earth Observation Satellites; In Situ Earth Observatories
15	Seismo-acoustic network	NIEP	1	0	Acoustic Monitoring Stations; Atmospheric Measurement Facilities; In Situ Earth Observatories
16	National Data Center	NIEP	3	0	Earth, Ocean, Marine, Freshwater, and Atmosphere Data Centers; Research Aircraft. Solid Earth Observatories, including Seismological Monitoring Stations; Acoustic Monitoring Stations
17	Romanian National Seismic Network	NIEP	6	0	Research Aircraft; Solid Earth Observatories, including Seismological Monitoring Stations; In Situ Earth Observatories; Earth, Ocean, Marine, Freshwater, and Atmosphere Data Centers
18	Centre of Competence for Space Technologies - Computer Assisted and Information Feedback Training for Human Spaceflight Support (STARWALKER)	Institute of Space Science (ISS)	3	0	
19	Romanian Nanosatellite Competence Center (ROST-CC)	ISS	14		Aerospace and Aerodynamics Research Facilities; Earth Observation Satellites; Micro and Nanotechnology Facilities
20	CETAL	INFLPR	6	0	High-Energy Physics Facilities; Micro and Nanotechnology Facilities; Extreme Conditions Facilities

No.	Research Infrastructure	Host Organization	No. of Research Services	No. of Tech Services	Domains
21	Plasma Physics and Nuclear Fusion Department	INFLPR	7	0	
22	Lasers Department	INFLPR	11	0	Materials Synthesis or Testing Facilities; Environmental Health Research Facilities; Micro and Nanotechnology Facilities
23	Low Temperature Plasma Physics Department	INFLPR	14	0	Micro and Nanotechnology Facilities; Materials Synthesis or Testing Facilities
24	Laboratory of Solid-State Quantum Electronics	INFLPR	11	0	
25	Electron accelerators ALID and ALIN	INFLPR	1	0	High-Energy Physics Facilities; Nuclear Research Facilities
26	LABORATORY FOR TESTS AND MEASUREMENTS	OPTO-ELECTRONICA 2001	2	0	Micro and Nanotechnology Facilities
27	PRODUCTION DEPARTMENT	OPTO-ELECTRONICA 2001	5	0	Electrical and Optical Engineering Facilities; Mechanical Engineering Facilities
28	DEPARTMENT OF DESIGN AND PRODUCTION OF HOLOGRAPHIC SECURITY ELEMENTS	OPTO-ELECTRONICA 2001	8	0	
29	INFRASTRUCTURE FOR CHARACTERIZATION AND DIAGNOSIS BY OPTICAL AND COMPLEMENTARY METHODS - INDICO	National Institute of R&D for Opto-electronics	4	0	Electrical and Optical Engineering Facilities
30	Multi-site Infrastructure Fostering Research and Innovation in Optoelectronics and Analytical Instrumentation - INOVA – OPTIMA	National Institute of R&D for Opto-electronics	13	0	Materials Synthesis or Testing Facilities; Analytical Facilities
31	Optospintronics	National Institute of R&D for Opto-electronics	17	0	
32	Optoelectronic Methods and Techniques for Cultural Heritage Restoration	National Institute of R&D for Opto-electronics	12	0	Research facilities for cultural heritage; Arts & Art History Collections; Web mapping and Geographical Information Systems data facilities
33	Research Centre for Advanced Surface Processing and Analysis by Vacuum Technologies	National Institute of R&D for Opto-electronics	0	0	Materials Synthesis or Testing Facilities; Micro and Nanotechnology Facilities; Analytical Facilities
34	RADO Romanian Atmospheric Observatory	National Institute of R&D for Opto-electronics	2	0	Atmospheric Measurement Facilities; In Situ Earth Observatories
35	Acoustics and Vibrations Research and Experiments Center	COMOTI - National R&D Institute for Gas Turbines	24	0	Acoustic Monitoring Stations; Laboratories for the study of sound; Environmental Management Infrastructures
36	National Network of Complex XPS/ESCA Spectrometers	National Institute of Material Physics	3	0	Analytical Facilities; Materials Synthesis or Testing Facilities
37	CEUREMAVSU-Euro-Regional Centre for Studies of Advanced Materials, Surfaces and Interfaces	National Institute of Material Physics	12	0	Micro and Nanotechnology Facilities; Materials Synthesis or Testing Facilities; Analytical Facilities
38	Research Department for Condensed Matter Physics and Advanced Materials	National Institute of Material Physics	18	0	Micro and Nanotechnology Facilities; Materials Synthesis or Testing Facilities; Analytical Facilities

No.	Research Infrastructure	Host Organization	No. of Research Services	No. of Tech Services	Domains
39	RITecC-Research Innovation and Technology Center for New Materials	National Institute of Material Physics	6	0	Materials Synthesis or Testing Facilities; Micro and Nanotechnology Facilities; Analytical Facilities
40	Research & Development Centre for Materials, Electronic and Optoelectronic Devices	University of Bucharest, Faculty of Physics	0	0	Micro and Nanotechnology Facilities; Materials Synthesis or Testing Facilities
41	Paleomagnetic Laboratory	University of Bucharest, Faculty of Physics	4	0	Earth, Ocean, Marine, Freshwater, and Atmosphere Data Centers; Environmental Management Infrastructures; Analytical Facilities
42	Faculty of Physics: Nanosciences & Alternative Energy Sources Research Center (3Nano-SAE)	University of Bucharest, Faculty of Physics	12	0	Energy Engineering Facilities (non-nuclear); Micro and Nanotechnology Facilities; Materials Synthesis or Testing Facilities
43	Research and Development Department, Măgurele, Ilfov county	Research & Development National Institute for Metals and Radioactive Resources INCDMRR ICPMRR	7	0	Analytical Facilities; Pilot Plants for Process Testing; Environmental Management Infrastructures

Source: ERRIS online database (www.erris.ro)

Annex 5. List of Technologies and Services Potentially Needed for Maintaining the ELI-NP Facility

Some of the potential areas of cooperation with the private sector regarding the supply of systems and maintenance and repairs services were mentioned. These include state-of-the-art electronics, detectors for which new designs and construction are needed, computer equipment and software, precise mechanics, optical equipment, vacuum systems, cryogenic systems, shielding systems, gas-handling and gas-purification systems, and pure and liquid gas supplies:

- Equipment components for the future functioning of the laser and gamma experiments;
- Laser optics;
- Maintenance, repairs, testing of command and control equipment, spare parts;
- Cleaning, validation, and quality control of rooms for experiments;
- Vacuum techniques, cryogenics, and radiofrequency;
- Room environment; control of parameters: temperature, humidity, cleanness;
- Maintenance, repairs, testing of geothermal systems, and heat pumps;
- Techniques of measurement of electro-magnetic fields on frequency criteria;
- Repairs and maintenance of video surveillance equipment for the interior of the building and experimental rooms, access control systems, security systems, and fire extinguishing systems;
- Repairs and maintenance of automatic control and command systems for electric energy, diesel generators, and PRAM;
- Measurements of authorized labs, environmental factors, sewage treatment, and disposal.

In the short term, related to the construction of the instrumentation and the equipment of the experimental areas and the laboratories of ELI-NP:

- Tenders for delivery of equipment and components (e.g., kilometers of cables, tons of lead bricks or casted lead, hundreds of meters of tubes for gas transport, and beam transport lines (vacuum) to list a few);
- Tenders for construction of equipment (e.g., mechanical frames and supports for the spectrometers, reaction chambers and other systems to hold the detectors under special conditions, gas-handling and gas-purification systems, cryostats, etc.).

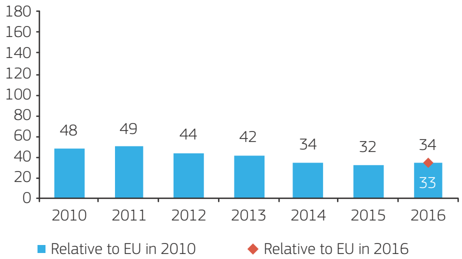
In the longer term, related to the new technical developments at ELI-NP:

- Technology transfer of new products or techniques;
- New techniques for industrial applications (e.g., radiography and 3D tomography, studies of new materials with slow positrons, etc.).

Annex 6. European Innovation Scoreboard 2017

64 European **Innovation** Scoreboard 2017

Romania is a **Modest Innovator**. Over time, performance has declined by 14.1% relative to that of the EU in 2010.



Innovation system

Relative strengths of the innovation system are in Innovation-friendly environment, Sales impacts, and Human resources. Relative weaknesses are in Innovators, Firm investments, and Finance and support.

Structural differences

Notable differences are a larger share of employment in Agriculture & Mining, a lower share of employment in High and Medium high-tech manufacturing, Services and Public administration, a larger share of foreign controlled enterprises, a lower number of Top R&D spending enterprises and a lower average R&D spending of these enterprises, a larger share of enterprise births, lower GDP per capita, a higher growth rate of GDP, a lower and negative growth rate of population, and lower population density.

	RO	EU
Structure of the economy		
Composition of employment, average 2011-15		
- Agriculture & Mining (NACE A-B) (%)	29.3	5.1
- Manufacturing (NACE C) (%)	18.1	15.6
of which High and Medium high-tech (%)	*27.6*	*36.4*
- Utilities and Construction (NACE D-F) (%)	9.5	8.6
- Services (NACE G-N) (%)	38.1	63.6
of which Knowledge-intensive services (%)	*46.9*	*58.0*
- Public administration, etc. (NACE O-U) (%)	5.0	7.1
Business indicators		
Composition of turnover, average 2011-2014		
- Micro enterprises (0-9 employees) (%)	16.5	17.3
- SMEs (10-249 employees) (%)	41.5	38.0
- Large enterprises (250+ employees) (%)	42.0	44.1
Share of foreign controlled enterprises, 2014 (%)	5.31	1.18
Top R&D spending enterprises		
- average number per 10 mln population, 2011-15	0.3	29.9
- average R&D spending, mln Euros, 2011-15	11.0	165.8
Enterprise births (10+ empl.) (%), avg 2012-14	3.4	1.5
Buyer sophistication 1-7 (best), 2013-14	3.0	3.6
Ease of starting a business, Doing Business 2017	74.3	76.5
Socio-demographic indicators		
GDP per capita, PPS, avg 2011-13	13,500	25,400
Change in GDP between 2010 and 2015, (%)	12.8	5.4
Population size, avg 2011-15 (millions)	20.0	505.5
Change in population between 2010 and 2015 (%)	-2.1	1.1
Population aged 15-64, avg 2011-2015 (%)	67.9	66.1
Population density, average 2011-15	87.9	116.4
Degree of urbanisation, average 2011-15 (%)	54.4	74.4

Values in green show performance above 120% of EU, values in red show performance below 80% of EU.

Romania	Performance relative to EU 2010 in		Change 2010-2016
	2010	2016	
SUMMARY INNOVATION INDEX	**47.9**	**33.8**	**-14.1**
Human resources	**42.3**	**49.8**	**7.4**
New doctorate graduates	100.0	96.4	-3.6
Population with tertiary education	17.1	44.1	27.0
Lifelong learning	2.1	0.0	-2.1
Attractive research systems	**23.4**	**30.0**	**6.5**
International scientific co-publications	23.4	47.6	24.2
Most cited publications	31.1	40.1	9.0
Foreign doctorate students	12.3	9.0	-3.4
Innovation-friendly environment	**74.9**	**89.8**	**14.9**
Broadband penetration	122.2	144.4	22.2
Opportunity-driven entrepreneurship	41.5	51.2	9.7
Finance and support	**52.6**	**18.1**	**-34.6**
R&D expenditure in the public sector	27.1	21.8	-5.3
Venture capital expenditures	84.8	13.3	-71.5
Firm investments	**64.4**	**11.9**	**-52.5**
R&D expenditure in the business sector	13.3	15.9	2.6
Non-R&D innovation expenditures	209.4	21.3	-188.1
Enterprises providing ICT training	0.0	0.0	0.0
Innovators	**38.5**	**0.0**	**-38.5**
SMEs product/process innovations	26.4	0.0	-26.4
SMEs marketing/organizational innovations	50.8	0.0	-50.8
SMEs innovating in-house	38.0	0.0	-38.0
Linkages	**52.3**	**29.4**	**-22.9**
Innovative SMEs collaborating with others	10.7	5.8	-4.9
Public-private co-publications	39.3	15.0	-24.3
Private co-funding of public R&D exp.	97.5	61.1	-36.4
Intellectual assets	**15.9**	**24.9**	**9.0**
PCT patent applications	21.1	26.7	5.6
Trademark applications	16.6	31.3	14.8
Design applications	8.5	17.5	9.0
Employment impacts	**21.0**	**37.0**	**16.0**
Employment in knowledge-intensive activities	3.8	19.2	15.4
Employment fast-growing enterprises	33.6	50.0	16.4
Sales impacts	**84.8**	**62.2**	**-22.7**
Medium and high tech product exports	87.1	93.4	6.4
Knowledge-intensive services exports	56.0	54.7	-1.3
Sales of new-to-market/firm innovations	115.9	33.2	-82.7

Dark green: normalised performance above 120% of EU; light green: normalised performance between 90% and 120% of EU; yellow: normalised performance between 50% and 90% of EU; orange: normalised performance below 50% of EU. Normalised performance uses the data after a possible imputation of missing data and transformation of the data.

Change highlighted in green is positive; change highlighted in light red is negative.

Annex 7. Intellectual Property Definitions

DEFINITIONS The following terms used in this assessment have the following meanings:	
RDI results	All results described in Article 74 of the Ordinance no. 57/2002 on the scientific research and technological development;
Public entities and institutions	All entities described at Articles 7 and 8 of the Law on Scientific Research and Technological Development;
Law on Scientific Research and Technological Development	Ordinance no. 57/2002 on the scientific research and technological development as amended;
Law on Patents	Law no. 64/1991 on patents as republished;
Law on Utility Models	Law no. 350/2007 on utility models as amended;
Law on topographies of Semiconductor Products	Law no. 16/1995 on the topographies of semiconductor products;
Law on Plant Varieties	Law no. 255/1998 on plant varieties as republished;
Law on Ornamental Designs	Law no. 129/1992 on ornamental designs as republished;
Law on Copyright	Law no. 8/1996 on copyright and neighboring rights as republished;
Law on Trademarks and Geographical Indications	Law no. 84/1998 on trademarks and geographical indications as republished;
RO-PTO	Romanian Patent and Trademark Office;
Regulation on Patents	Government Decision no. 547/2008, which established the Regulation on the Law on Patents;
Regulation on Plant Varieties	Government Decision no. 984/2007, which established the Regulation on Plant Varieties;
Regulation on Topographies of Semiconductor Products	Order no. 6/2007, which established the Regulation on Topographies of Semiconductor Products;
Regulation on Ornamental Designs	Government Decision no. 211/2008, which established the Regulation on Ornamental Designs.

Annex 8. The R&D and Business Sectors

The following tables provide information about the R&D industry at the national and local levels in terms of employees and turnover. In addition, they provide information about the top 25 companies active within the municipality of Măgurele:

Table 20. Top 25 R&D Companies and Institutions for the Year 2015, in Terms of Employees

Source: Data provided by Lista Firme/Borg Design S.R.L.

	Company	Location	Employees	Turnover (Euros)
1	RATEN	Mioveni	915	17,478,943
2	ICAS	Voluntari	878	10,781,124
3	HORIA HULUBEI IFIN HH	Măgurele	792	20,339,746
4	Cummins Generator Technologies Romania S.A.	Craiova	733	56,061,570
5	Parexel International Romania S.R.L.	1st Sector	400	26,487,049
6	INFLPR R.A.	Măgurele	327	9,706,976
7	INCDA	Fundulea	306	4,210,139
8	INCDFM	Măgurele	260	7,160,691
9	INCD-T COMOTI	6th Sector	249	7,976,400
10	ICSI Râmnicu Vâlcea	Râmnicu Vâlcea	242	18,354,289
11	ICPE S.A.	3rd Sector	232	5,825,463
12	INCD Victor Babeș	5th Sector	232	2,579,329
13	ICPE-CA (?)	3rd Sector	218	8,334,116
14	INCAS	6th Sector	212	13,511,085
15	ICMET CRAIOVA	Craiova	207	4,020,553
16	ITIM	Cluj-Napoca	200	11,677,078
17	INOE (?)	Măgurele	183	4,664,515
18	INCD-IMT Bucharest	Voluntari	182	5,598,874
19	INCD URBAN-INCERC	2nd Sector	179	3,083,269
20	INCD-TP Bucharest	3rd Sector	172	3,271,620
21	IBNA Balotești	Balotești	157	5,800,760
22	INCD-ITI	1st Sector	157	3,925,739
23	ICECHIM Bucharest	6th Sector	156	3,425,995
24	INCD-MTM	2nd Sector	142	2,710,839
25	INMA	1st Sector	140	1,993,240

Table 21. Top 25 R&D Companies and Institutions for the Year 2015, in Terms of Turnover

Source: Data provided by Lista Firme/Borg Design S.R.L.

	Company	Location	Employees	Turnover (Euros)
1	Cummins Generator Technologies Romania S.A.	Craiova	733	56,061,570
2	Parexel International Romania S.R.L.	1st Sector	400	26,487,049
3	Horia Hulubei IFIN HH	Măgurele	792	20,339,746
4	ICSI Râmnicu Vâlcea	Râmnicu Vâlcea	242	18,354,289
5	RATEN	Mioveni	915	17,478,943
6	INCAS	6th Sector	212	13,511,085
7	ITIM	Cluj-Napoca	200	11,677,078
8	ICAS	Voluntari	878	10,781,124
9	INFLPR R.A.	Măgurele	327	9,706,976
10	Pro Optica S.A.	3rd Sector	65	9,217,420
11	ICPE-CA (?)	3rd Sector	218	8,334,116
12	INCD-T COMOTI	6th Sector	249	7,976,400
13	PSI Pharma Support Romania S.R.L.	5th Sector	91	7,652,248
14	IPA S.A.	1st Sector	125	7,377,892
15	INCDFM	Măgurele	260	7,160,691
16	ICPE S.A.	3rd Sector	232	5,825,463
17	IBNA Balotești	Balotești	157	5,800,760
18	INCD-IMT București	Voluntari	182	5,598,874
19	INOE (?)	Măgurele	183	4,664,515
20	East Electric S.R.L.	3rd Sector	60	4,317,522
21	INCDA	Fundulea	306	4,210,139
22	ICMET CRAIOVA	Craiova	207	4,020,553
23	INCD-ITI	1st Sector	157	3,925,739
24	INCD Geoecomar	2nd Sector	120	3,700,554
25	ICPE Bistrița S.A.	Bistrița	54	3,626,966

Table 22. Top 10 R&D Companies and Institutes in Măgurele for the Year 2015

Source: Data provided by Lista Firme/Borg Design S.R.L.

	Company	NACE	Employees	Turnover (Euros)
1	Horia Hulubei IFIN HH	7219	792	20,339,746
2	INFLPR R.A.	7219	327	9,706,976
3	INCDFM	7219	260	7,160,691
4	INOE (?)	7219	183	4,664,515
5	INCDFM (?)	7219	113	3,019,818
6	ISS	7219	112	3,312,272
7	Optoelectronica 2001 S.A.	7219	28	1,328,122
8	Microwave Technology Lab S.R.L.	7219	1	33,094
9	Bionova Tehno S.R.L.	7219	N/A	27,720
10	INCDFM	7219	N/A	N/A

Table 23. Top 25 Companies in Măgurele for the Year 2015, in Terms of Employees

Source: Data provided by Lista Firme/Borg Design S.R.L.

	Company	NACE	Employees	Turnover (Euros)
1	Urgent Cargus S.A.	5320	1.205	68,940,236
2	Horia Hulubei IFIN HH	7219	792	20,339,746
3	Oscar Downstream S.R.L.	4671	372	339,863,142
4	Belladonna Trade Pharm S.R.L.	4773	356	24,333,558
5	INFLPR R.A.	7219	327	9,706,976
6	INCDFM	7219	260	7,160,691
7	Garden Center Grup S.R.L.	130	215	8,175,634
8	General Next Pharm S.R.L.	4773	204	10,260,597
9	Treiro S.R.L.	4941	186	12,027,386
10	INOE (?)	7219	183	4,664,515
11	Marchand S.R.L.	4632	176	18,433,037
12	Farmacia Județeană S.R.L.	4773	162	10,127,264
13	INCDFM (?)	7219	113	3,019,313
14	ISS	7219	112	3,312,272
15	Action C Prod Impex S.R.L.	4773	109	4,405,124
16	Instal Service Technology S.R.L.	4120	104	7,760,705
17	Druckfarben Romania S.R.L.	2030	87	8,973,050
18	Alfa Security Group S.R.L.	3010	79	562,999
19	Mariserv Consult Prest S.R.L.	7330	65	354,369
20	Inox SA	2550	62	2,271,015
21	BLD Pharma S.R.L.	5210	43	41,072,673
22	SCC Măgurele	5510	45	580,562
23	Sal Trans Exim S.R.L.	3311	41	1,902,070
24	Nuclear & Vacuum S.A.	2813	40	691,421
25	Simultec S.R.L.	6201	36	8,415,121

Table 24. Top 25 Companies in Măgurele for the Year 2015, in Terms of Turnover

Source: Data provided by Lista Firme/Borg Design S.R.L.

	Company	NACE	Employees	Turnover (Euros)
1	Oscar Downstream S.R.L.	4671	372	339,863,142
2	Urgent Cargus S.A.	5320	1205	68,940,236
3	BLD Pharma S.R.L.	5210	43	41,072,673
4	Belladonna Trade Pharm S.R.L.	4773	356	24,333,558
5	Horia Hulubei IFIN HH	7219	792	20,339,746
6	Marchand S.R.L.	4632	176	18,433,037
7	Treiro S.R.L.	4941	186	12,027,386
8	General Next Pharm S.R.L.	4773	204	10,260,597
9	Farmacia Județeană S.R.L.	4773	162	10,127,264
10	INFLPR R.A.	7219	327	9,706,976
11	Druckfarben Romania S.R.L.	2030	87	8,973,050
12	Simultec S.R.L.	6201	36	8,415,121
13	Garden Center GRUP S.R.L.	130	215	8,175,634
14	Instal Service Technology S.R.L.	4120	104	7,760,705
15	INCDFM	7219	260	7,160,691
16	OBO Bettermann Romania S.R.L.	4690	25	5,947,570
17	INOE (?)	7219	183	4,664,515
18	Action C Prod Impex S.R.L.	4773	109	4,405,124
19	Böhler-Uddeholm Romania S.R.L.	4672	20	4,132,035
20	Marchand Muntenia S.R.L.	4613	6	3,953,952
21	ISS	7219	112	3,312,272
22	INCDFM (?)	7219	113	3,019,313
23	Eglo Romania Prodexim S.R.L.	4647	15	2,773,916
24	Mekorot RO S.R.L.	4221	4	2,542,710
25	Schunk Carbon Technology S.R.L.	2790	27	2,517,176

Annex 9. Provisions Within the General Master Plan for Transport and the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region

The following tables list the relevant provisions contained within the General Master Plan for Transport and the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region, including phasing and funding sources:

Table 25. Provisions and Phasing for Road Connections within the General Master Plan for Transport

Source: The General Master Plan for Transport.

	Identifier	Length	Sector	Cost (excluding VAT)	Implementation Period	Funding
Motorway Projects						
The Northern Bucharest Ring Motorway	A0	54.00 km	A1 – A3 – A2	706.86 M. Euros	2021-2023	CF
The Transylvanian Motorway, Bucharest – The Bucharest Ring Road	A3	6.00 km	Bucharest – The Bucharest Ring Road	0.0 M. Euros	2016-2017	–
The Southern Bucharest Ring Motorway	A0	48.00 km	A1 – DN5 – A2	628.14 M. Euros	2021-2023	CF
Expressway Projects						
The Henri Coandă Expressway	DX11	9.00 km	A3 – Henri Coandă Airport	43.11 M. Euros	2016-2018	ERDF
The Northern Bucharest Ring Road Expressway	DXCBN	39.41 km	Overhaul of the Northern Bucharest Ring Road (A1 – DN7, A2 – DN2)	53.80 M. Euros	2016-2017	CF
The Southern Bucharest Ring Road Expressway	DXCBS	35.00 km	Overhaul of the Southern Bucharest Ring Road (A1 – DN6 – A2)	176.00 M. Euros	2016-2017	CF (long list)/ERDF
The Danubius Expressway	DX2	195.00 km	Bucharest – Craiova (phase I + phase II)	764.40 M. Euros	2026-2031	CF (phased project)
Trans Regio Projects						
Overhaul of the Bucharest Adunații Copăceni Sector	DN5	21,80 km	Overhaul of the Bucharest – Adunații Copăceni Sector	8.10 M. Euros	2016	ERDF
Connection Road	C11	14.00 km	Connection between TR11 and A0	0.0 M. Euros	–	–
The Chindia Trans Regio Project	TR11	131.30 km	A1 – Titu – Bâldana – Târgoviște – Sinaia	103.73 M. Euros	2016-2019	ERDF
Euro Trans Projects						
The Vlăsia Euro Trans Project	ET11	55.00 km	Bucharest – Giurgiu – (BG)	41.25 M. Euros	2016-2019	ERDF
Ring Road Projects						
The Mihăilești Ring Road	–	3.00 km	–	6.90 M. Euros	2016	ERDF

Table 26. Provisions and Phasing for Rail Connections within the General Master Plan for Transport

Source: The General Master Plan for Transport.

	Length	Sector	Aim	Cost (excluding VAT)	Implementation Period	Funding
Railway Electrification Projects						
The Bucharest-Odăile Railway (7)	17.00 km	Bucharest – Odăile	Electrification and Overhaul	27.04 M. Euros	2016-2017	CEF
The Odăile-Henri Coandă Terminal Railway (8)	3.00 km	Odăile – Henri Coandă Railway Terminal	Construction	64.23 M. Euros	2016-2017	CEF
The Chiajna-Giurgiu Railway (4)	81.00 km	Chiajna – Giurgiu	Electrification and Overhaul	210.20 M. Euros	2021-2025	CF
The Giurgiu Nord-Giurgiu Border Crossing Railway (104)	6.00 km	Giurgiu North – Giurgiu Border Crossing	Electrification and Overhaul	10.90 M. Euros	–	–
Railway Overhaul Projects						
Railway for the Bucharest North Railway Station	1.00 km	Bucharest North Railway Station	Overhaul	0.00 M. Euros	–	–
The Bucharest-Pitești Railway	99.00 km	Bucharest – Pitești	Overhaul	249.40 M. Euros	2021-2025	ERDF
The Bucharest-Craiova Railway	209.00 km	Bucharest – Craiova	Overhaul	836.00 M. Euros	2021-2025	CF
Higher-Speed Rail Projects						
The Bucharest-Giurgiu Higher-Speed Rail	88.00 km	Bucharest – Giurgiu	Higher Speed and Cadenced Timetables	25.50 M. Euros	2016-2017	ERDF
The Bucharest-Craiova Higher-Speed Rail	209.00 km	Bucharest – Craiova	Higher Speed and Cadenced Timetables	67.98 M. Euros	2016-2017	ERDF
The Bucharest-Pitești Higher-Speed Rail	108.00 km	Bucharest – Pitești	Higher Speed and Cadenced Timetables	37.90 M. Euros	2016-2017	ERDF
The Bucharest-Brașov Higher-Speed Rail	91.00 km	Bucharest – Brașov	Higher Speed and Cadenced Timetables	29.85 M. Euros	2016-2017	ERDF
The Bucharest-Constanța Higher-Speed Rail	225.00 km	Bucharest – Constanța	Higher Speed and Cadenced Timetables	32.13 M. Euros	2016-2017	ERDF

Table 11: **Provisions and Phasing for Rail Connections within the General Master Plan for Transport**

Source: The General Master Plan for Transport.

Table 27. Provisions and Phasing for Road Connections within the General Master Plan for Transport

Source: The General Master Plan for Transport.

	Length	Sector	Aim	Cost (excluding VAT)	Implementation Period	Funding
Inland Waterways						
Improving Navigation on the Danube	0.00 km	Pristol – Călărași	–	205.00 M. Euros	2016-2018	CF
The Bucharest-Danube Canal, Oltenița – 1 Decembrie Branch	0.00 km	Oltenița – 1 Decembrie	–	0.00 M. Euros	–	–
The Bucharest-Danube Canal, Glina – Budești Branch	0.00 km	Glina – Budești	–	0.00 M. Euros	–	–
Ports						
The Zimnicea Port	–	–	–	6.75 M. Euros	2021-2024	ERDF
The Giurgiu Port	–	–	–	111.40 M. Euros	2016-2018	ERDF
The Oltenița Port	–	–	–	6.29 M. Euros	2016-2018	ERDF

Table 28. Provisions and Phasing within the Sustainable Urban Mobility Plan for the Bucharest-Ilfov Region

*Source: http://monitorizari.hotnews.ro/stiri-infrastructura_articole-21372496-centur-feroviar-bucurestiului-reinviata-catre-ministerul-transporturilor-prima-etapa-din-2017-trenuri-urbane-gara-nord-spre-gara-progresu-spre-pantelimon-vezi-planurile.htm [16.04.2017].

	Identifier	Length	Sector	Cost (excluding VAT)	Implementation Period	Funding
General Master Plan for Transport (GMPT) Projects						
Overhaul of the Bucharest-Henri Coandă Airport Railway			Bucharest – Henri Coandă Airport Railway	97.00 M. Euros	FS started in 2008	MT/CF
Overhaul of the Southern Bucharest Ring Road Expressway	DXCBS	35.00 km	Southern Bucharest Ring Road (A1 – DN6 – A2)	176.00 M. Euros	2016-2017	CF (long list)/ERDF
Sustainable Urban Mobility Plan (SUMP) Projects						
Overhaul of the Bucharest Southern Ring Railway*		All three stages: 68.00 km	**First stage 01:** Bucharest Main Railway Station – Domnești –Progresul **First stage 02**: Bucharest Main Railway Station – Băneasa – Pantelimon	200.00 K. Euros	2017	MT/CF
			Second stage: Connection with Metro Line 1 – Preciziei and Metro Line 2 – Berceni	5.00 M. Euros	End of 2017	MT/CF

	Identifier	Length	Sector	Cost (excluding VAT)	Implementation Period	Funding
Sustainable Urban Mobility Plan (SUMP) Projects						
*Source: http://monitorizari.hotnews.ro/stiri-infrastructura_articole-21372496-centur-feroviar-bucurestiului-reinviata-catre-ministerul-transporturilor-prima-etapa-din-2017-trenuri-urbane-gara-nord-spre-gara-progresu-spre-pantelimon-vezi-planurile.htm [16.04.2017].			**Third stage:** Railway connection between Progresul – Pantelimon – Bucharest Main Railway Station	15.00 M. Euros	End of 2018	MT/CF
BRT Corridor		16.00 km	Măgurele – Bucharest Main Railway Station	68.00 M. Euros	2024	Local Budget/ERDF
LRT-7 High Speed Tram Corridor		21.00 km	Bragadiru – Unirii – Voluntari	426.00 M. Euros	2020	Local Budget/ERDF
Implementation of M6 Metro Line		14.00 km	Progresul Railway Station – Bucharest Main Railway Station – Henri Coandă International Airport	1055.00 M. Euros	2016–2023	National Budget/ERDF
Implementation of M4 Metro Line		10.00 km	Bucharest Main Railway Station – Progresul	142.50 M. Euros 807.50 M. Euros	2016–2023 2024–2030	National Budget/ERDF
New Overpasses, Crossings, and Overhaul Projects			Bucharest Ring Road – Măgurele and Bucharest Ring Road – Bragadiru	80.00 M. Euros 50.00 M. Euros Note: The total budget of 130.00 M. Euros covers the projects for the entire Bucharest and Ilfov area.	2016–2023 2024–2030	National Budget/Ministry of Regional Development, Public Administration and European Funds/ERDF
Overhaul of National Roads			National roads that pass through residential areas	50.00 M. Euros 50.00 M. Euros	2016–2023 2024–2030	National Budget/Ministry of Regional Development, Public Administration and European Funds/ERDF
Setting up the Bucharest Metropolitan Transport Authority			Integrated Bucharest-Ilfov Transport System			

Annex 10. International Case Studies

10.1 Relevant Research Institutes

Country	City/Region	Research Partner	Name of Laser Facility
China	Mianyang	CAEP - Chinese Academy of Engineering Physics (Research Center for Laser Fusion)	SG-IV/SILEX-I
China	Beijing	IOP CAS - Institute of Physics of the Chinese Academy of Sciences, Beijing National Laboratory for Condensed Matter	Xtreme Light III (XL-III)
China	Shanghai	SIOM (Shanghai Institute for Optics and Fine Mechanics)	Qiangguang
France	Bordeaux	CEA - French Alternative Energies and Atomic Energy Commission	LMJ - Laser Megajoule
France	Paris	University Paris Sud and CILEX (Centre Interdisciplinaire Lumiere EXtreme)	LASERIX/Apollon CILEX
Germany	Garching	Max-Planck-Institute for Quantenoptik	Petawatt Field Synthesizer
Germany	Darmstadt	GSI Helmholtz Centre for Heavy Ion Research	Helmholtz Beamline - international accelerator project FAIR
Germany	Dresden	Helmholtz-Zentrum Dresden-Rossendorf; ELBE (Electron Linac for beams with high Brilliance and low Emittance) – Center for High Power Radiation Sources.	DRACO (Dresden laser acceleration source)
Japan	Kyoto	JAEA (Japan Atomic Energy Agency) - APRC (Advanced Photon Research Center)	J-KAREN (JAEA-Kansai Advanced Relativistic Engineering)
Japan	Osaka	University of Osaka - Institute of Laser Engineering (ILE)	Gekko XII and LFEX
Russia	Nizhny Novgorod Oblast	VNIIEF - Russian Federal Nuclear Centre, All-Russian Research Institute of Experimental Physics	UFL-2M
Russia	Nizhny Novgorod Oblast	Institute of Applied Physics of the Russian Academy of Sciences	XCELS - Exawatt Centre for Extreme Light Studies
South Korea	Gwangju	GIST - Gwangju Institute of Science and Technology - Advanced Photonics Research Institute (APRI)	-
Spain	Salamanca	University of Salamanca - Center for Pulsed Lasers (CLPU) -	VEGA
UK	Oxford	STFC Rutherford Appleton Laboratory - Central Laser Facility	Astra-Gemini; Vulcan
USA	California (Livermore)	US Department of Energy - LLNL - Lawrence Livermore National Laboratory	NIF - National Ignition Facility
USA	Michigan (Ann Arbor)	University of Michigan - FOCUS Center and Center for Ultrafast Optical Science	HERCULES - High Energy Repetitive CUos LasEr System
USA	California (Berkeley)	US Department of Energy - LBNL - Lawrence Berkeley National Laboratory	BELLA (BErkeley Lab Laser Accelerator)

USA	Nebraska (Lincoln)	University of Nebraska - Extreme Light Laboratory	Diocles laser
USA	Texas (Austin)	University of Texas at Austin - Texas Center for High Intensity Laser Science	Texas Petawatt Laser
USA	New York (Rochester)	University of Rochester - Laboratory for Laser Energetics (LLE)	OPAL

Table 29. Examples of Research Institutes with Petawatt Class Lasers

Source: Danson et al. 2015

Country	City/Region	Name of Nuclear Physics Facility
Finland	Jyväskylä	JYFL - Accelerator Laboratory at University of Jyväskylä
France	Caen	GANIL - Large Heavy Ion National Accelerator
France	Orsay	ALTO - IPN - l'Institut de Physique Nucléaire d'Orsay
Italy	Frascati	DAFNE-Light (at LNF - Laboratori Nazionali di Frascati)
Germany	Bonn	ELSA - Electron Stretcher Accelerator
Germany	Mainz	MAMI - Mainzer Mikrotron
Germany	Darmstadt	GSI Helmholtz Centre for Heavy Ion Research
Germany	Darmstadt	FAIR - Facility for Antiproton and Ion Research
Germany	Juelich	COSY Accelerator (at Forschungszentrum Juelich)
Italy	Trento	ECT - European Centre for Theoretical Studies in Nuclear Physics and Related Areas
Italy	Legnaro	INFN - National Institute for Nuclear Physics
Romania	Măgurele	ELI-NP - Extreme Light Infrastructure - Nuclear Physics
Russia	Dubna	NICA - Nuclotron-based Ion Collider fAcility (at the Joint Institute of Nuclear Research)
Sweden	Lund	MAX-Lab
Switzerland	Villigen	HIPA - High Intensity Proton Accelerators (at PSI - Paul Scherrer Institut)
Switzerland	Geneva	Multiple (at CERN - European Organization for Nuclear Research)

Table 30. Examples of EU Nuclear Physics Research Infrastructures

Source: ESFRI, 2016

Country	City/Region	Research Institutes
Australia,	Jyväskylä	JYFL - Accelerator Laboratory at University of Jyväskylä
South Africa	Multi-site	Square Kilometer Array
Chile	Multi-site	ESO - European Southern Observatory
France	Grenoble	ESRF - European Synchrotron Radiation Facility
Germany, France, Italy, UK	Multi-site	EMBL - European Molecular Biology Laboratory
Switzerland	Geneva	CERN - European Organization for Nuclear Research
UK	Harwell	Diamond
UK	Daresbury	SRS - Synchrotron Radiation Source
USA	California (Berkeley)	LBNL - Lawrence Berkeley National Laboratory

Table 31. Examples of "Big Science" Research Institutes

City/Region	US Department of Energy Laboratory
California (Berkeley)	Lawrence Berkeley National Laboratory
California (Livermore)	Lawrence Livermore National Laboratory
California (Menlo Park)	SLAC National Accelerator Laboratory
Colorado (Golden)	National Renewable Energy Laboratory
Idaho (Idaho Falls)	Idaho National Laboratory
Illinois (Argonne)	Argonne National Laboratory
Illinois (Batavia)	Fermi National Accelerator Laboratory
Iowa (Ames)	Ames Laboratory
New Jersey (Princeton)	Princeton Plasma Physics Laboratory
New Mexico (Albuquerque)	Sandia National Laboratories
New Mexico (Los Alamos)	Los Alamos National Laboratory
New York (Upton)	Brookhaven National Laboratory
South Carolina (Aiken)	Savannah River National Laboratory
Tennessee (Oak Ridge)	Oak Ridge National Laboratory
Virginia (Newport News)	Thomas Jefferson National Accelerator Facility
Washington (Richland)	Pacific Northwest National Laboratory

10.2 FRANCE – Laser Megajoule (LMJ) and PETawatt Aquitaine Laser (PETAL)

SUMMARY

- LMJ focuses primarily on sensitive research related to the maintenance of the French nuclear weapons stockpile, which limits civilian research access and spillovers.
- The Bordeaux region already possessed academic research capabilities in disciplines related to LMJ and PETAL.
- Dual-use laser facilities (PETAL) attract civilian researchers from local and international research organizations.
- Policy efforts have focused on harnessing upstream industrial involvement–i.e., companies involved in the construction of LMJ–as well as the transfer and commercialization of civilian technologies.
- As a result, the Route des Lasers has developed into an industrial cluster focused on instrumentation, lasers, and associated services.

LOCATION

Le Barp, near Bordeaux, Aquitaine

YEAR ESTD.

LMJ: 2014 (initiated 1995)

PETAL: 2015 (initiated 2005)

BUDGET

LMJ: €3 billion

PETAL: €54.3 million (total)

COUNTRY PROFILE

FEATURES

Mega research infrastructure	●
Basic research	●
Laser or nuclear facility	●
Distributed research infrastructure	
International governance	
Less developed ecosystem	
Cluster	●

GDP

$2,839 billion (2014)

GOVERNMENT R&D

0.77% of GDP (2014)

INDUSTRY R&D

1.25% of GDP (2014)

SCIENTIFIC MISSION

The scientific mission of the LMJ-PETAL facilities is primarily linked to military research, with partial time reserved for civilian research.

LMJ is dedicated to the simulation of nuclear tests for military research by studying the behavior of materials at a small scale and under extreme conditions using one of the most powerful lasers in the world.

The mission of PETAL is to conduct fundamental research on nuclear physics and inertial fusion (including laboratory astrophysics, high intensity science, high energy density matter, and radiography) for civilian/academic research.

PATENT APPLICATIONS

Residents: 14,500 (2014)
Non-residents: 2,033 (2014)

PUBLICATIONS

In journals: 72,555 (2013)

HI-TECH EXPORTS

26% of manufactured exports (2014)

BACKGROUND AND GOVERNANCE

LMJ was built in the Bordeaux area due to the existing presence of CEA–the Center for Scientific and Technical Studies in Aquitaine (CESTA)–to support its military-oriented simulation mission. CEA's Military Applications Division (DAM) founded LMJ after France signed the Comprehensive Nuclear Test Ban Treaty (CTBT) in 1996. The laboratory was established as part of the "Simulation" program of the military designed to reproduce nuclear explosions through small-scale fusion reactions and simulations to ensure the safety and performance of the French nuclear weapons stockpile.

In addition to its co-location with CESTA, LMJ was established in the Bordeaux region because of the presence of research capabilities in optics, photonics, and lasers, as well as an existing pool of human capital. For example, the University of Bordeaux has a long tradition in photonics related to the work of physicists such as Alfred Kastler (Nobel Prize for Physics in 1966).

The LMJ-PETAL[69] facility is governed by three bodies: Aquitaine Region (contracting owner), CEA (project manager and prime contractor), and Institut Lasers et Plasmas, or ILP (technical and scientific assistance provider). PETAL is expected to be the French contribution to the European HiPER project. LMJ-PETAL is part of the Pole de Compétitivité - Route des Lasers.

69 This study will focus on PETAL and civilian research.

Table 32. Main Partners and Key Actors Present in the Ecosystem Around LMJ-PETAL in the Context of Civilian Research.
Source: Adapted from AUCAME and PwC

Partners	Description	Year established
Academia, research, and training		
CEA CESTA - Centre d'Etudes Scientifiques et Techniques d'Aquitaine	Military research center and location of LMJ	1965
ILP - Institut Lasers et Plasmas	Research institute that manages allocated time for civilian applications for LMJ and PETAL	2003
PYLA	Training center for optics and photonics	2005
LAPhIA Laser & PHotonics in Aquitaine (and the University of Bordeaux and other research centers)	Cluster of excellence of the University of Bordeaux with multiple laboratories including CELIA	2012
IOGS - Institut d'Optique Graduate School	Branch of Parisian graduate school	2012
Intermediaries and others		
Bordeaux Unitec	Competitiveness pole for high-tech startups	1990
LASERIS	Industrial park	2003
ALPHA - Aquitaine Lasers Photonique & Applications	Association for governance of Route des Lasers	2004
SEML Route des Lasers	Dedicated development agency	2004
Route des Lasers	Cluster for optics and lasers - Pôle de compétitivité	2005
Cite de la Photonique	Technology park	2006
ALPhANOV	Technology transfer center	2007
Inpho Ventures	International convention	2010
SATT Aquitaine - Society for Accelerating Technology Transfer in the Aquitaine Region	Technology transfer services and financing	2012
Regional public institutions		
Aquitaine Regional Council		
ADI - Aquitaine Développement Innovation	Regional development agency	
2ADI - Agence Aquitaine de Développement Industriel	Regional development agency	

RESEARCH EXCELLENCE

Access to LMJ-PETAL is restricted because of its military-oriented mission. However, PETAL has allocated 20%-30% of its research capacity for civilian research. PETAL's facilities' access policy is based on that of LIL, an early prototype of LMJ, which offered research facilities and equipment access from 2005 through 2014, before LMJ was constructed. PETAL plans to implement a robust civilian research agenda for European scientists given that the only other comparable laser facility, Lawrence Livermore National Laboratory, is in the United States.

To facilitate external scientists' use of LMJ-PETAL ILP coordinates LMJ-PETAL access. Scientists submit proposals to ILP; proposals are reviewed and selected by the PETAL Scientific Advisory Committee under four working groups, including internal confinement fusion (ICF), high energy density physics, high energy physics, and laboratory astrophysics5. Proposals are evaluated based on their potential contributions to fundamental science. Use agreements are approved for two years whereby visiting scientists are matched with a local facility liaison scientist. This ensures that the scientific goals of external researchers are well matched with facility capabilities while keeping LMJ-PETAL scientists up-to-date. CEA scientists are included as co-authors on all publications. Once experiments begin, they may be subject to peer-review to understand the feasibility of the experiments and to identify any issues in their design.

Because of LMJ's national security mission, visits to CEA-CESTA require significant planning. Experiments at LMJ-PETAL are generally planned six months in advance and can last for up to twelve weeks. Site access requires a security clearance from CEA, and access is generally granted eight weeks in advance. Clearance is required even if the project has been approved by ILP. Further, the use agreement prohibits the on-site use of Wi-Fi, professional computers, and mobile phones.

During the construction of LMJ-PETAL, the Bordeaux region undertook efforts to strengthen human capital and research capabilities related to lasers, optics, and photonics to promote a "Route des Lasers." For example, the University of Bordeaux offers relevant professional degrees including diplomas, bachelor's degrees, and master's degrees. The French "grande école" Institute of Optics Graduate School (IOGS) has had a branch in Bordeaux since 2012; the university's Laser and Photonics in Aquitaine Cluster of Excellence - LAPhIA coordinates research in the academic community from 20 research groups in 11 major research laboratories around Bordeaux, including CEA-CESTA. LAPhIA focuses on transdisciplinary research across three thematic areas: innovative imaging, photonics and materials, and lasers and high-energy physics.

LAPhIA promotes the reputation of researchers within related fields and engages in knowledge transfer at the local and international levels. For example, LAPhIA organizes an annual symposium and monthly seminars to share and build interdisciplinary knowledge related to lasers and their application. To strengthen international collaboration, LAPhIA works with partners in South Korea (Seoul), Germany (Jena, Darmstadt), Singapore, Belgium (Leuven), Canada (Quebec), and the United States (Stanford) to provide opportunities for student and faculty research exchanges. LAPhIA's Bordeaux Initiative for Excellence (IDEX) similarly provides financial support for international collaboration, and LAPhIA is part of international networks such as Photonics 21 (European) and SPIE (international). Further, the Bordeaux region periodically hosts important conferences on lasers, optics, and photonics.

The Route des Lasers is also home to PYLA, a hands-on, non-academic training facility for individuals working in regional laser, photonics, and optics organizations. PYLA was established in 2005 by the CEA-CESTA and University of Bordeaux and funded by Aquitaine Regional Council and the FNADT ("National Fund for Territorial Development") in response to the growing demand for skilled technicians within the area. PYLA offers non-degree education courses focused on lasers at the University of Bordeaux for subcontractors of the LMJ and for health professionals. PYLA's 40 instructors come from the Université de Bordeaux (33%), CEA (33%), and PYLA's industrial and academic partners.

SCIENCE INDUSTRY COLLABORATION

Established in 2005, the Route des Lasers competitiveness cluster was set up to maximize the social and economic impact of LMJ. The Aquitaine Industrial Development Agency (Agence Aquitaine de Développement Industriel) and the ALPhA association (Aquitaine Laser Photonics and applications) that includes the CEA-CESTA worked together to plan the cluster as well as seek external funding for its implementation. The purpose of the Route des Lasers initiative is to bring together different companies, research labs, technology platforms, and training centers in a clearly defined geographical area (the Aquitaine region) emphasizing specific S&T areas (photonics and lasers).

The Regional Council of Aquitaine, the CEA, the CNRS, the University Bordeaux, and the association ALPhA (Aquitaine Laser Photonics and Applications) established ALPhANOV in 2007 to facilitate technology transfer between academic laboratories and companies in Aquitaine. ALPhANOV was based on experiences with transferring micro-machining technologies from the CELIA laboratory at University of Bordeaux. ALPhANOV is designated as a French Ministry of Research Technological Resource Centre and provides services to SMEs. Further, ALPhANOV receives a Research Tax Credit (CIR) corresponding to the total amount of capital invested in R&D over the year.

In addition to its scientific mission, LAPhIA programs encourage and enable students and faculty to collaborate with the industry. For example, LAPhIA provides internship and industry mentor matching services to students. Further, the LAPhIA passport project offers resources to faculty to help them develop research projects with high commercial potential. Finally, LAPhIA connects faculty and students with the Society for Accelerating Technology Transfer in the Aquitaine Region (SATT Aquitaine), the purpose of which is to manage technology transfer and provide IP services for research centers in the region. SATT was set up in 2012 with a budget of €50 million and is not specific to lasers, optics, or photonics.

BUSINESS INOVATION AND STARTUPS

The business environment related to lasers in the Bordeaux area was initially a product of LMJ construction. Nearly a thousand firms contributed at different stages of LMJ: from the creation of the laser source (Quantel) to its frequency conversion from infrared to ultraviolet and its focusing in the frequency conversion system (e.g., EADS, Thales, Alsyom).

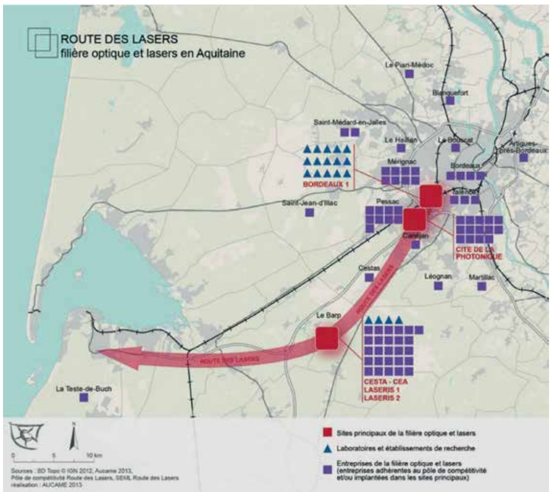
With the creation of Route des Lasers, Bordeaux became one of the largest photonics clusters in Europe. As a "pôle de compétitivité," its core activities include the development of collaborative projects, the expansion of private and public R&D investments, and SME support services. Route des Lasers is home to large and small firms, including the fiber laser company Amplitude Systèmes and optoelectronics-focused subsidiaries of the defense firms Sagem and Thales (both contributed to the development of the LMJ). The instrumentation sector accounts for the largest share of research and industry activities located within the Route des Lasers.

In support of its mission, in 2015, the Route des Lasers managed 41 projects (valued at €62 million), with 17 industrial projects (valued at €51.1 million) and 24 research projects (valued at €10.1 million). The majority of projects were devoted to strengthening the instrumentation sector (€31 million), followed by photonics and health (€14.6 million), while lasers and processes comprised a relatively small amount (€3.7 million). Between 2005 and 2014, Route des Lasers approved 431 projects, with the funding of €359 million for 212 projects, including €168 million from public authorities—i.e., the EU (€3 million), the French government (€128 million), and the Aquitaine Regional Council (€37 million).

The region also offers several programs to promote and support entrepreneurship within the region. ALPhANOV, for example, offers an incubator for startup companies, especially those affiliated with LAPhIA, while SATT provides startup funding to support the commercialization of more mature technologies. To connect startups with other sources of funding, CEA and Route des Lasers organize the Inpho Ventures Summit (previously Invest in Photonics) biennially in Bordeaux. Inpho Ventures brings together early- to late-stage photonics firms from Europe to pitch their companies and associated technologies to an array of investors.

Figure 50. Key Sites at the Route des Lasers

Source: Agence d'Urbanisme de Caen-Métropole, 2013



CEA-CESTA is located in a relatively isolated rural area in Le Barp. Le Barp is 27.5 km from the center of Bordeaux, limiting the accessibility of LMJ though it is situated close to the Basque Coast motorway. The ILP and CEA-CESTA offer visiting researchers office space, internet access, and administrative assistance inside the ILP Campus Building located 2 kms away from the LMJ Control Room at CESTA. This space includes meeting rooms and an amphitheater for workshops. Other facilities such as supermarkets, restaurants, and food services are located 3 kms away in the town of Le Barp. While few hotels are close to CEA-CESTA, more options are available in the cities of Bordeaux and Arcachon.

Despite CEA-CESTA's relatively isolated rural location in Le Barp, the Route des Lasers offers greater proximity to Bordeaux (see Error! Reference source not found.). For example, ALPhANOV is located on the campus of Talence, in the Institut d'optique d'Aquitaine. Since July 2004, it is assessable by tramway. The tramway extension of November 2007 connects the area, with an additional transfer, to the main train station of Bordeaux.

Two science parks are located along the Route des Lasers and provide support services to both small and large firms. The first, La Cité de la Photonique, is a technology park that provides young startups companies with proximity to research facilities in the region, including the research centers affiliated with the University of Bordeaux. The park has 4 buildings with 29,000 sqm of transferable surface, 9,300 sqm of constructed surface, and 1,700 sqm of clean rooms. The second, Laseris Parks, are dedicated to mature companies that specialize in optics, lasers, and photonics. Laseris 1 has 15 buildings that offer 29,000 sqm of constructed surface, 4,000 sqm of clean rooms (of a total of 40 hectares, of which 20 hectares have been fitted out). Laseris 2 is situated on 8 hectares to be sold or built.

The science parks are managed by SEML, a development agency established to promote the development of the industrial cluster. SEML is financed by public and private partners (including region, department, CEA, financial institutions, etc.), and builds, sells, or leases buildings to companies at market prices in Laseris 1 and City of Photonics. Companies can specify their facility needs according to their level of development. Buildings are equipped with shared services, including customer reception, high-speed internet, inter-company catering, equipped meeting rooms, and shared mail service to reduce costs.

The growth of the research community represented by LAPhIA signifies the emergence of robust research capabilities within the region. LAPhIA currently represents some 250 researchers, engineers, and students accounting for 85% of published papers from the Aquitaine region focused on laser and photonics. LAPhIA researchers produced more than 900 publications annually between 2013 and 2015, most of which were published in internationally recognized peer reviewed journals. Most of LAPhIA's 32 projects focus on research, while less than 20% include a technology transfer component, reflecting LAPhIA's interest in building research capacity and promoting research collaboration (4 collaborative projects and 50% inter-lab projects), technology transfer (5 passport projects), and international mobility (4 research mobility projects). In 2015, 13 patents were issued to researchers affiliated with LAPHIA. Further, by 2015, LAPHIA researchers created 20 startups and SMEs (companies with fewer than 10 employees) employing more than 260 people.

Despite its primary focus on sensitive weapons-related research, LMJ-PETAL strengthened its backward linkages with regional companies, especially suppliers, within the region. As mentioned, LMJ-PETAL allocates 20%-30% of its research capacity to civilian research projects linked primarily to science, not industrial concerns, within the region. For example, between 2014 and 2015, the only project that utilized the laser for industrial purposes was financed by SATT. However, LMJ and PETAL have fostered backward linkages with nearly 1,000 firms during the construction of the facility. **The establishment of the LMJ facility in the Aquitaine region led to the creation of approximately 350 jobs at CESTA.** Beyond the CEA, the LMJ facility generated 700 industrial jobs a year during construction, and 150-200 long-term jobs after construction.

Efforts by Route des Lasers to promote and support entrepreneurship have also generated an impact. Twenty-eight startups were established in the Route des Lasers. Several examples from 2015 are illustrative of this establishment: (1) the former head of ALPhaNOV's laser sources and fiber components department leads Spark Lasers, a startup that develops and manufactures picosecond lasers for industrial and scientific applications; (2) a spin-off of Bordeaux's CELIA laboratory, FemtoEasy, focuses on ultra-high-energy laser systems production and metrology; (3) the founder of Irisiome, with applications in dermatology, developed the laser system in the CELIA laboratory; (4) The former chairperson of CELIA heads Moria Lase that specializes in manufacturing surgical and dental material based on pulsed IR-laser technology.

Efforts to improve the regional business ecosystem and the growing reputation of Bordeaux area as a center of photonics, optics, and lasers have attracted a myriad of companies and research partners. After 10 years, Route des Lasers comprised 163 members (with 44 from outside Aquitaine) including 118 companies and 31 training organizations and laboratories. The cluster approved 431 industry and research projects and financed nearly 50% of those projects with €359 million, including public and private financing. The cluster contributed to 6,000 indirect jobs and 1,500 direct jobs.

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10.3 CHILE – Very Large Telescope (VLT)–Paranal Observatory

European Southern Observatory (ESO)

SUMMARY

- VLT is in a remote area of Chile that provides excellent conditions for astronomical observation.
- Research facilities attract scientists from all over the world.
- Policies have focused on increasing the time allocated to Chilean research organizations; these efforts, along with financial support from the ESO, have resulted in an increased research capacity related to astronomy in Chile.
- The fundamental nature of astronomical research and the observatory's remote location means that its contributions to technology transfer or regional economic development are limited.

LOCATION

Cerro Paranal,
Antofagasta region

YEAR ESTD.

1999

BUDGET

€700 million

COUNTRY PROFILE

FEATURES

Mega research infrastructure	●
Basic research	●
Laser or nuclear facility	
Distributed research infrastructure	●
International governance	●
Less developed ecosystem	●
Cluster	

SCIENTIFIC MISSION

The ESO's Paranal Observatory is an advanced ground-based astronomical observation facility. Its mission is to conduct research in optical and near-infrared astronomy.

GDP

$258.7 billion (2014)

GOVERNMENT R&D

0.17% of GDP (2014)

INDUSTRY R&D

0.12% of GDP (2014)

PATENT APPLICATIONS

Residents: 452 (2014)
Non-residents: 2,653 (2014)

PUBLICATIONS

In journals: 5,158 (2013)

HI-TECH EXPORTS

6% of manufactured exports (2014)

BACKGROUND AND GOVERNANCE

The ESO's VLT is in Paranal due to (1) excellent atmospheric conditions supported by (2) incentives offered by Chile to make the observatory more cost-effective. The Paranal Observatory is in one of the driest areas of the world, the Atacama Desert in northern Chile, and experiences more than 300 cloud-free days annually. The observatory is located on a remote site away from light and dust pollution on a 2,635-m high mountain, 120 km south of the town of Antofagasta and 12 km inland from the Pacific Coast.4 Chile's excellent observation conditions have made it a host for international astronomical observatories since the 1960s (11 international observatories are operational, under construction, or planned in Chile.)1 Chile has also offered multiple incentives to international researchers that made it cost-effective to locate observatories like Paranal in Chile instead of in other favorable locations like the Canary Islands or Hawaii. All observatories based in Chile are granted diplomatic status and are offered an exemption from the 19% VAT. Further, Chile exempts telescope construction consortia from customs duties.1

The inter-governmental European Organization for Astronomical Research in the Southern Hemisphere (ESO), which has 16 member states, governs the Paranal Observatory. The ESO is also responsible for the management of the La Silla Observatory and has an office in Chile that coordinates its political and legal interests.

RESEARCH EXCELLENCE

The presence of international telescopes and observatories like ESO-Paranal brought international astronomers to Chile to conduct cutting-edge research. **However, the presence of the international scientific community was not always linked to Chilean science.**

Domestic access to international observatories was largely unavailable until 1997 when Chilean researchers were provided with a guarantee of up to 10% of facility use. This time allocation is guaranteed to researchers at Chilean institutions, regardless of nationality. Astronomers require Chilean research institution affiliation and must maintain residence in Chile for nine months following the time at the observatory, just as postdoctoral researchers are required to include a Chilean faculty member among their advisors. These requirements have strengthened the Chilean astronomy research capabilities since access to the ESO-Paranal telescopes was highly competitive globally, with over 2,000 usage proposals submitted annually with four to six times more proposals submitted than nights available for use. In 2015, Chilean researchers filed two proposals more than the slots available, though this number is rising due to the number of Chilean postdoctoral fellows returning to Chile with the intent to use the telescope.1 However, the 10% observation time reserved for local institutions remains lower than that in comparable astronomy sites, such as Hawaii (15%) and the Canary Islands (20%).

Following requirements that time be allocated to researchers located at Chilean institutions, four universities established new astronomy departments, all with PhD programs, with funding provided by ESO and other international organizations. Moreover, ESO continues to promote astronomy research in Chile through a fund for developing astronomy-related disciplines. The funding supports postdoctoral fellowships and faculty positions at Chilean universities, the development of technological systems for astronomy, conferences, training for science teachers at primary and secondary levels, and astronomy outreach programs for the public. These funding proposals are evaluated by the Joint Committee of ESO and Government of Chile and encourage collaborative proposals among researchers located at different institutions within Chile and abroad.

To promote and coordinate astronomy as a strategic scientific priority, Chile's science agency, CONICYT, founded its astronomy program in 2006.

The astronomy program promotes scientific and technological cooperation, attracts new projects in astronomy, and manages Chilean observation time at the Paranal Observatory. The astronomy program also manages the funding of projects proposed by Chilean institutions, sets up scientific international cooperation agreements, including one with the Chinese Academy of Sciences, and initiated the construction of the Atacama Astronomy Park.

SCIENCE-INDUSTRY COLLABORATION

In addition to the very basic nature of astronomy, science-industry collaboration in Chile is limited because the initiative lacks intermediaries that can connect academic research with the potential needs of the industry. An analysis of R&D-I in Chile shows that economic interests, which are not often well connected with local scientific expertise, have driven government priorities for the development of research capabilities. As a result, few opportunities exist for collaboration, especially in the astro-engineering sector, which has unique technical requirements.

BUSINESS INNOVATION AND STARTUPS

Potential spillovers from the presence of astronomical observatories and telescopes have not been exploited in Chile. Despite the few commercial applications of astronomical observations at the Paranal site, multiple applications exist in the field of astronomy, such as astronomical instrumentation (opto-mechanics, signal processing, digital imaging, adaptive optics, the monitoring of environmental variables, and the accurate forecast of turbulence, clouds, and atmospheric water vapor) and telescopes (precision micro-mechanics, high accuracy tracking systems, cryogenics, actuator controlled platforms, and alignment and phasing systems). These opportunities have not been exploited.

The Chilean industry has largely engaged only in the early construction stages of astronomical observatories with civil works, structural mechanical assembly, the rental of specialized construction equipment, the transportation of astronomical infrastructure (such as mirrors, telescope structural components, etc.), and as providers of goods and services for the daily operation of the observatories. More recently, when procurement calls were open, Chilean companies were involved in more advanced installation, including specialized fiber optics and the integration of the backend technology for signal processing.

BUSINESS INNOVATION AND STARTUPS

As mentioned, the Paranal Observatory is located in the remote Atacama Desert far removed from the nearest town.4 While the location's remoteness and environment provide excellent conditions for an astronomical observatory, they also make it difficult, if not impossible, to attract industrial partners to the location. Further, all resources supporting the observatory must be imported from other regions. The local infrastructure has not been developed. For example, trucks bring 60,000 liters of water daily from Antofagasta, which is 120 kilometers away, to sustain the onsite staff.

EVIDENCE OF IMPACT

Guaranteed access time for Chilean scientists, ESO funding for Chilean astronomers, and the government's purposeful coordination of science has helped develop the Chilean research capacity in astronomy. The number of astronomy researchers in Chile increased from 59 in 2005 to 221 in 2016. Moreover, the number of astronomy students increased from 40 in 2005 to 675 in 2016. The total number of publications doubled from 1,979 to 3,642 from 2005 to 2015, while citations increased from 22,829 to 51,350. The increased availability of observation time since 1997 expanded the astronomy scientific community in Chile beyond larger universities, such as Universidad de Chile and Universidad Católica, to smaller universities, such as Concepción and La Serena.4

However, weak enabling conditions and few opportunities for technology transfer led to few technology spillovers. The CONICYT analysis of the astronomy ecosystem in Chile indicates that the Paranal Observatory has led to two university patents and two spinoff firms (related to cryogenic cameras for astronomy applications and electronic control systems and signal processing for the defense sector).

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10.4 SOUTH KOREA- Advanced Photonics Research Institute (APRI)

Gwangju Institute of Science and Technology (GIST)

SUMMARY

- GIST is a unique research institute established to serve the R&D-related needs of the local industry by offering graduate studies, engineering facilities, and applied technology research services.
- APRI was established within GIST to emphasize the relative recent focus of the region on photonics and optics.
- GIST-APRI exists within a region that established myriad higher education, research, and industrial service organizations over time.
- As a result, the Gwangju region has developed into a dynamic industrial cluster, though future development challenges remain.

LOCATION

Gwangju

YEAR ESTD.

APRI: 2001

Petawatt laser: 2010

BUDGET

COUNTRY PROFILE

FEATURES

Feature	
Mega research infrastructure	
Basic research	●
Laser or nuclear facility	●
Distributed research infrastructure	
International governance	●
Less developed ecosystem	
Cluster	●

SCIENTIFIC MISSION

The scientific mission of APRI is to lead R&D in lasers, optics, and photonics to contribute to the national industry, develop research personnel, and engage in international collaboration.

GDP

$1,411 billion (2014)

GOVERNMENT R&D

0.98% of GDP (2014)

INDUSTRY R&D

3.23% of GDP (2014)

PATENT APPLICATIONS

Residents: 164,073 (2014)
Non-residents: 46,219 (2014)

PUBLICATIONS

In journals: 58,844 (2013)

HI-TECH EXPORTS

27% of manufactured exports (2014)

BACKGROUND AND GOVERNANCE

The development of APRI and its petawatt laser within GIST were part of a concerted strategy to develop the photonics and optics cluster in Gwangju. Gwangju was a relatively underdeveloped city compared to other major Korean cities until the 1980s. In the 1990s, the central government created the Gwangju High-tech Industrial Park (GHIP) to promote high-tech industries in Gwangju. While GHIP was not successful, those efforts created a foundation for efforts by the central government in 2000 to establish an industrial cluster. The regional government and Gwangju chose to focus on building capabilities in optics and photonics even though the region possessed no related industry or infrastructure. Between 2000 and 2003, following this decision, multiple research institutes were established, including the APRI in 2001, and all of the institutes focused on encouraging research and industrial development in optics and photonics.

RESEARCH EXCELLENCE

The central and local government prioritized human capital development first during the efforts to create GHIP and later during the area's focus on optics and photonics. For example, anticipating future collaborations with private firms, the central government established GIST in 1993. While several universities existed in Gwangju (Chonnam University, Chosun University, Honam University, and Gwangju University), GIST was established near GHIP and offered services tailored to industrial needs, including graduate studies, high-quality engineering facilities, and applied technology research. In 2002, GIST implemented a curriculum focused on photonics and optics reflecting the region's recent research and industrial focus.

APRI was established in 2001, along with other research and technology centers, to bolster the laser, optics, and photonics-related research capabilities of the region. The Institute for Basic Science Center for Relativistic Laser Science was established to focus on associated basic sciences, while the Korea Photonics Technology Institute (KOPTI) was established to provide equipment, test certification, photonic products, technology transfer, and a business incubator to encourage and support high-tech entrepreneurship within the region. Research facilities were located inside GHIP to encourage linkages among the different organizations.

Initial regional development strategies encouraged both research-related and industrial collaboration with domestic and international partners. Moreover, APRI spearheaded efforts to encourage international research collaboration by establishing the Asian Laser Center, which included the addition of a petawatt laser in 2010 (equivalent of the Laser Lab Europe), to encourage researchers from Asia to visit and use the specialized facilities. Further, APRI became part of the global network of International Center for Zetta-Exawatt Science and Technology (IZEST) lasers and the Institute of Applied Physics in Bern for laser research with military and aerospace applications to encourage its scientists to learn from network partners and to welcome researchers from partner institutes to come to APRI.

SCIENCE-INDUSTRY COLLABORATION

In addition, GIST focused on changing its internal procedures and regulations to encourage startups and technology commercialization and to foster a more entrepreneurial culture. For example, GIST includes royalty income in professor evaluation criteria to promote startups and spinoffs arising from the commercialization of university research.5 Moreover, GIST also amended personnel regulations in 2014 to create full-time industry-university cooperation professor positions and subsequently recruited and hired individuals with significant industry experience.

Many of the research institutes in Gwangju were established through the Ministry of Knowledge Economy because of its focus on technology development and commercialization. Local policymakers prioritized photonics, optical communications, and liquid electronic displays (LED) technology in their governance policies. Technology development programs were designed based on market attractiveness, feasibility, local human resource capabilities, and local demand while considering local supplier capacities and existing contract relationships.

BUSINESS INNOVATION AND STARTUPS

Multiple organizations in the Gwangju cluster offer industrial development support. The Korea Association for Photonics Industry Development focuses on the photonics industry by encouraging partnerships with the government, promoting joint research, providing marketing assistance, supporting international cooperation, and offering market research and assessment.7 The Korea Association for Photonics Industry Development is also involved in advancing technology standardization. The Gwangju Techno Park helps in technology transfer, facility management, and international exchange. Moreover, KOPTI operates a business incubator center that offers technology transfer and commercialization startups. Incubator services include management support, mentoring, marketing, funding, taxation, facility and equipment support, technology transfer and commercialization, public relations and training, and company promotion. In addition, KOPTI's technology venture center (with a total area of 3,396 m^2) hosted 24 companies in 2011, with 23 having already graduated. Korea Industrial Complex Corporation manages and supervises the industrial complex.

ECONOMIC GEOGRAPHY AND ENABLING FACTORS

A detailed discussion on the economic geography and other enabling factors for development for the photonics cluster is presented in Annex C.

The central government has played an important role in the development of the Gwangju cluster. Specifically, the government helped develop GHIP in the 1990s by creating a robust infrastructure, including roads connecting the site, housing estates for employees and new residents, and urban facilities designed to improve the quality of life in the park area.

Construction was divided into three phases and took place within the existing GHIP infrastructure to maximize the utilization of space and resources. The first phase (2000-2003) comprised a total investment of $335 million including contributions from the central government ($196 million), the local government ($47 million), and the private sector ($92 million).

The first phase focused on constructing the infrastructure necessary to support the technology requirements of optics and photonics. This included developing technology resources to support R&D and technology commercialization, training the workforce in optics and photonics, providing support services for firms, and efforts to provide physical spaces to encourage collaboration between research institutions and companies in the photonics and optics industry ($48 million).

The second phase (2004-2007) included investments of $322 million to address the shortcomings of the first phase and to encourage research and industrial collaboration. This phase focused on establishing services to improve production processes and product development and testing, to increase cooperation and collaboration among research institutes, and to offer firm services, such as overseas marketing. This phase also included $178 million to support firm-level development, particularly that relating **to new** technologies. The third phase prioritized local industry technology capabilities for the commercialization of photonics.

The early stages of cluster development were challenging, as infrastructure development and the construction of large-scale facilities were slow. Yet, firms started to relocate to Gwangju due to incentives offered by the central government, the efforts of the local government, and low initial expenses associated with the region as compared to the capital.

EVIDENCE OF IMPACT

The development of the Gwangju cluster attracted photonics and optics firms to the region. The number of related firms located in Gwangju increased from 47 (in 2000) to 302 (in 2007) and 377 (in 2010), with a turnover increase from $95 million (in 2000) of $709 million (in 2007). The number of employees increased from 1,896 (in 2000) to 4,920 (in 2007) and then to 8,270 (in 2010). Gwangju also built a reputation for research and industrial excellence in the optics and photonics field within Korea.

Institutional support for innovation at the national level, the presence of multiple intermediaries for technology transfer at the regional level, and the focus on technology development and commercialization contributed to substantial technology transfer in the region. By 2016, GIST supported technology transfer for 158 companies (across all sectors) and hosted 48 entrepreneurs (17 faculty, 9 researchers, and 22 students). In addition, KOPTI filed 226 patent applications and registered 121 patent applications between 2009 and 2011. Moreover, KOPTI commercialized 90 technologies between 2003 and 2011, with a majority in LED modules and lighting.

Future growth is dependent on the further development and application of optics and photonics technology to core Korean industries, such as automotive and electronics. Unfortunately, analyses of local industries show that these industries are not currently present in Gwangju. Current efforts are focusing on recruiting and supporting these industries.

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10.5 SWITZERLAND- CERN – European Organization for Nuclear Research

SUMMARY

- CERN has established an international reputation for research excellence through its unique facilities, policies emphasizing openness, collaboration, and the wide dissemination of research data and findings.
- The basic nature of CERN's research agenda and openness creates challenges for technology commercialization.
- Recent efforts have focused on technology transfer, emphasizing no-royalty licensing policies based on a recipient's ability to further develop a technology and targeted policies emphasizing transfer to the aerospace and biomedical industries.

LOCATION

Meyrin,

Geneva area

YEAR ESTD.

1954

BUDGET

$1.3 billion (annual budget)

COUNTRY PROFILE

FEATURES

Mega research infrastructure	●
Basic research	●
Laser or nuclear facility	●
Distributed research infrastructure	
International governance	●
Less developed ecosystem	
Cluster	

SCIENTIFIC MISSION

The scientific mission of CERN is to understand fundamental particles that are the basic constituents of matter. The process of colliding particles close to the speed of light provides insight on how particles interact and on the fundamental laws of nature.

GDP

$707.2 billion (2014)

GOVERNMENT R&D

0.75% of GDP (2014)

INDUSTRY R&D

1.80% of GDP (2014)

PATENT APPLICATIONS

Residents: 1,480 (2014)
Non-residents: 568 (2014)

PUBLICATIONS

In journals: 21,060 (2013)

HI-TECH EXPORTS

26% of manufactured exports (2014)

BACKGROUND AND GOVERNANCE

CERN was established in Switzerland in 1954 after World War II. Switzerland was chosen as the location of CERN given its neutrality during the war. Moreover, CERN focuses on nuclear physics, but policymakers felt that if facilities were in Switzerland, then they were unlikely to be used for military applications.

CERN is governed internationally by 22 states, each of which provides two delegates to the CERN governing council. The council not only provides political representation but also ensures that the scientific interests of member states are considered. The CERN council controls all scientific, technical, and administrative activities and is assisted by the Scientific Policy and the Finance Committees.

RESEARCH EXCELLENCE

CERN is known for its scientific excellence and specialized equipment, thus attracting highly skilled scientists, engineers, and technicians from member states. In addition, CERN's research activities are divided into two categories: Large Hadron Collider (LHC) and non-LHC programs.

Research access at CERN is open to the international scientific community. Researchers can participate in projects at CERN as in-house researchers, staff members, associates for international collaboration, or exchange scientists or through training. Staff policy promotes mobility though fixed-term contracts and formally recognized collaborations and through multiple education and training programs.

The collaborative nature of CERN's scientific research and organizational structure is designed to strengthen networks among participating researchers. Most CERN research projects are conducted in teams and within an open working environment. Further, CERN's emphasis on international cooperation and scientific exchange ensures that the culture remains open to diverse scientific perspectives and backgrounds, including a diversity of experience. For example, PhD students in CERN's member states can apply for in-house research fellowships lasting up to 36 months.

Further, to promote openness and collaboration, CERN prioritizes open science. Since 2014, all data collected during experiments at CERN are uploaded to an online data portal, and all CERN researchers are required to publish in open-access journals. Some technologies developed at CERN are made available through open-source licenses.

SCIENCE-INDUSTRY COLLABORATION

CERN's emphasis on fundamental research and its open scientific culture present a challenge to technology commercialization strategies. CERN's charter mandates that all activities related to its fundamental scientific mission shall be made freely available to the public.[70] Thus, CERN offers no financial incentives for researchers to use formal mechanisms, such as patents, to protect IP generated from their research. When technologies are patented, these belong to CERN or its collaborating institutions, and employee inventors obtain no royalties. Further, CERN scientists are reported as being especially motivated by the pursuit of knowledge rather than commercial gains; CERN's research culture is rooted in openness and collaboration. However, over time, CERN has recognized the value of patents in occasionally mitigating investment risks to develop technologies stemming from (and perhaps supporting) CERN's research missions.

70 Paragraph 2, Article II: "The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available."

For this reason, and to improve social and economic impact, CERN established a Knowledge Transfer Office to help researchers develop and commercialize technologies derived from their research. The Knowledge Transfer Office offers advice and legal support relating to, when appropriate, formal IP protection. The Knowledge Transfer Office also connects researchers with other collaborators from the public or private sectors. Collaborations often involve consulting agreements with companies interested in developing CERN technologies. The Knowledge Transfer Office prioritizes applications in two areas: medical and biomedical technologies and aerospace applications.9

BUSINESS INNOVATION AND STARTUPS

A variety of policies and programs incentivize industry to develop technologies stemming from CERN research. For example, CERN offers royalty-free licenses to industrial partners that have the highest likelihood of developing applications that will provide social and economic benefits. Further, CERN provides consulting and other industrial services to improve technology transfer and help companies develop CERN technologies. Finally, CERN encourages the establishment of spinoff companies in CERN member states based on derivative technologies.

In 2011, CERN also established the Knowledge Transfer Fund to support projects with potential positive social impacts. While the fund supports a variety of projects, emphasis is placed on technical areas with a high likelihood of short- and medium-term effects, such as aerospace, medicine, and data preservation, among others. Funding for the Knowledge Transfer Fund comes from commercial consulting and joint R&D agreements. Funding also supports member-state spinoffs and SMEs utilizing CERN technologies, as these companies can utilize one of CERN's nine business incubation centers (BICs) located in member countries throughout Europe. Through these incubators, CERN offers technical visits, technical support, and licenses at a preferential rate for resident companies. The BICs also offer mentoring, space, access to networks, and support for accessing financing.

EVIDENCE OF IMPACT

CERN possesses unique scientific facilities, such as its LHC, and has made significant contributions to the scientific community. In 2016, CERN published 1,184 scientific and technical articles, including 743 academic journal articles with the remaining published as conference proceedings, reports, books, or book chapters. In addition, CERN has over 2,500 employees with 13,000 fellows, users, students, and apprentices affiliated with the facility. In 2016, CERN also contributed to the completion of 232 PhD theses.

While CERN's international mandate emphasizes international collaboration, it also plays an important scientific role in Switzerland. Researchers from all 12 Swiss universities participate in CERN projects and in the development of CERN infrastructure; CERN employs 200 Swiss nationals. Further, Switzerland earns up to three times its annual CERN membership fees in the form of industry or service contracts for Swiss firms.

Because of its open-access policies, CERN's technology transfer contributions are difficult to measure. For example, CERN industry-related contributions to Internet, medical imaging, cancer treatment, and industrial processes are not well captured by its patent records. Traditional indicators of technology transfer are less relevant within the CERN research context. Studies show that CERN innovations have led to important long-term economic and social impacts in society.

With that said, in 2016, CERN was awarded 49 patents in electronics, particle detectors, vacuum systems, and cryogenics. Further, CERN licensed over one hundred technologies that provide a limited revenue stream (0.1% of CERN's annual budget)1 but, more importantly, have been passed on to companies interested in developing these technologies. In addition, BICs hosted nine companies in 2014 with applications including sensors for robotics, automation, and coatings for electricity generation and cooling.9 The Knowledge Transfer Fund financed 38 projects between 2011 and 2016, with 21 already completed. These led to 20 peer-reviewed publications and eight PhD projects. Moreover, the projects received 306,000 CHF in internal seed funding from the fund, as well as EUR 5 million in external funding.

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10.6 UNITED STATES OF AMERICA - LLNL

BACKGROUND AND GOVERNANCE

Lawrence Livermore National Laboratory was established in 1952 by two researchers from the University of California (UC) Radiation Laboratory in Berkeley **to complement nuclear-weapons-related research** conducted by the US national laboratory in Los Alamos, New Mexico, the home of the Manhattan Project, which developed the first nuclear weapon. While early research initially mirrored the radiation laboratory at UC Berkeley, the laboratory became known for and prioritized applied research in support of national defense goals. For example, LLNL's first breakthrough came with the design of a thermonuclear warhead for missiles that could be launched from submarines. The lab concurrently established programs in fusion energy and advanced computation.

While the US Department of Energy's (DOE's) National Nuclear Security Administration (NNSA) owns LLNL, Lawrence Livermore National Security (LLNS) manages LLNL under contract. It is a limited liability company comprising several large organizations, including Battelle, the University of California, Bechtel, Babcock and Wilcox, and the Washington Division of URS Corporation. This public-private approach was originally put into place by the Atomic Energy Commission, the predecessor to NNSA, which provided civilian control over the design and development of US nuclear weapons and nuclear energy research.

Later, LLNL developed non-weapon-related programs in biotechnology; the environment; lasers; bio, explosive, and nuclear detection; and energy security. In addition, following further advances in information technology, it developed programs in supercomputing and advanced simulation. The DOE Office of Science funds missions related to LLNL's basic science mission just as the DOE Office of Environmental Management funds its environmental protection mission. Other public sponsors include the National Aeronautics and Space Administration (NASA), the Nuclear Regulatory Commission, the National Institutes of Health (NIH), and the Environmental Protection Agency (EPA), as well as State of California agencies and industry.

RESEARCH EXCELLENCE

LLNL fulfills its national security and R&D missions through an array of unique scientific facilities. For example, the laboratory is home to one of the world's fastest supercomputers. The LLNL scientists and engineers have developed robust capabilities in computation and simulation for several national security, scientific, and industrial-related phenomena. Moreover, LLNL operates two specialized laser facilities: Titan petawatt laser used for high-energy physics experiments (e.g., to understand the science of fast ignition for inertial confinement fusion energy) and the National Ignition Facility, a laser-based inertial confinement fusion research device used to study physical processes in conditions that only exist within stars and in exploding nuclear weapons. Further, LLNL operates facilities that support to other R&D missions, including an accelerator mass spectrometry facility, a bioscience and nanoscience laboratory, and a high explosives application facility, among others.

Furthermore, LLNL attracts significant scientific and engineering talent: 6,300 employees work at LLNL, 2,726 of whom are scientists and engineers. Further, approximately 220 postdoctoral fellows work onsite, many of whom (65%) go on to work at LLNL, not to mention the wide range of in-house educational programs for students and teachers. Employees and postdocs are attracted to LLNL based on their ability to access unique scientific facilities, just as LLNL's underlying national security mission ensures that these facilities are relatively well maintained and periodically upgraded. Depending on their research area, scientists are encouraged to publish, attend conferences, and otherwise stay active within their scientific field. Further, a range of training and compensation benefits as well as its location in the San Francisco Bay Area have led to LLNL being named to the Forbes list of best employers in the United States in 2016, ranking 102 out of 500, and ranking among the top 10 employers in the region.

Access to much of LLNL is restricted for outside scientists because of the laboratory's national security-focused mission: to maintain the safety and performance of the US nuclear-weapons stockpile. **However, LLNL regularly engages scientists and students from outside of LLNL to support its wide range of civilian research missions** from biotechnology to supercomputing to ensure the laboratory stays up-to-date scientifically and to provide access to LLNL's unique scientific facilities. For example (as discussed below), LLNL established the LVOC, an open, unclassified R&D facility designed to promote collaboration with all sectors, including basic scientific research collaboration with universities and other national laboratories within the US and beyond.

SCIENCE-INDUSTRY COLLABORATION

Despite protocols to guard against the dissemination of sensitive national security-related research, since 1982, **LLNL, among other national labs, has worked within a policy framework that allows and encourages collaboration with industry and other scientific partners.** In 1982, the US Congress passed the Stevenson-Wydler Act that enabled national laboratories to enter CRADAs. Though scholars have not thoroughly studied these partnerships, LLNL has undertaken hundreds of CRADAs since 1982 and has, over time, developed several intermediaries to support public-private R&D partnerships.

In August 2009, LLNL, in cooperation with Sandia National Laboratory, established LVOC, an open, unclassified R&D facility designed to promote collaboration with industrial and academic partners outside the laboratory. The goal of the facility is to increase engagement between the laboratories and the private sector to help develop solutions in areas such as high-performance computing, energy and environmental security, cyber security, economic security, and non-proliferation. Further, LVOC was designed to help LLNL scientists stay at the forefront of science, technology, and engineering fields, while providing opportunities to openly engage with the broader scientific community.

BUSINESS INNOVATION AND STARTUPS

The LLNL's IPO prepares staff to work with the industry to find areas of common research, understand the applicability of existing research for industrial applications, and explore ways to further commercialize promising civilian technologies. Specifically, IPO trains LLNL staff in the fundamentals of business relationships, entrepreneurship, and technology commercialization. Working with Sandia National Laboratories, IPO develops and hosts the National Labs Entrepreneurship Academy, taught by the University of California at the Davis Graduate School of Management. Finally, IPO works with Silicon Valley entrepreneurship and angel investment groups to inform them of promising technological opportunities.

In addition, LLNL is part of the DOE High Performance Computing for Manufacturing (HPC4Mfg) Program designed to improve industrial competitiveness within the US. In FY 2016, the program provided $11.4 million to support 28 projects involving 23 US companies and Lawrence Livermore, Lawrence Berkeley, and Oak Ridge national laboratories. At LLNL, the program is managed by the High Performance Computing Innovation Center, which provides companies with access to LLNL's supercomputers, laboratory personnel with capabilities in software development and specific domain expertise, and experience in the application of high performance computing to solve specific industrial problems. Thus, LLNL works directly with manufacturing industry partners emphasizing the potential of high-performance computing to better understand manufacturing processes and the benefits that accrue from their application. High visibility successes in the program relate to improvements with semi-truck fuel efficiency, software code efficacy, and energy conservation.

ECONOMIC GEOGRAPHY AND ENABLING FACTORS

Geographically, LLNL is in one of the most entrepreneurial regions in the world, the San Francisco Bay Area, otherwise known as 'Silicon Valley.' While the roots of Silicon Valley were in microelectronics and information technology, the region has evolved to emphasize myriad technological focus areas, from alternative energy and software to biotechnology and services. Thus, LLNL is well positioned to take advantage of robust partnerships with numerous companies and spinoffs. The region is also home to excellent research universities, including Stanford, UC San Francisco, and UC Berkeley, and a dynamic high-technology industrial base that attracts talented scientists and engineers from all over the world.

However, its Silicon Valley location also presents significant challenges for LLNL. The area is densely populated, and there is little room for expansion for the laboratory and related partnership infrastructure, such as incubation or shared industrial facilities. Further, the rapidly-growing and dynamic regional economy means that commercial real estate is very expensive; 2015 saw real-estate prices reaching an all-time high, surpassing the pre-2008 price levels. Further, minimal subsidized space exists for small startups and similar ventures.

EVIDENCE OF IMPACT

In 2016, LLNL won three R&D 100 awards, recognizing the year's 100 best technological innovations, bringing the total to 158 of such honors since 1978. While two of the awards related to stockpile maintenance, LLNL shared its third award with five universities and three other national laboratories. The team developed the Carbon Capture Simulation Initiative toolset, which includes a suite of computational tools and models to accelerate the development of carbon-capture technology for manufacturers and businesses.

Relating to industrial partnerships, LLNL has more than 1,000 ongoing formal agreements with the industry and more than 1,000 active patents and existing applications. In FY 2016, for example, LLNL obtained 97 new patents, asserted 93 new copyrights, and licensed 20 new technologies. Licensing income for the year totaled approximately $8.4 million with an estimated $300 million of company sales attributed to LLNL technologies.7

Finally, LLNL has several outreach programs that have positive effects on the community, especially relating to scientific education. For example, LLNL's Partnerships in Education program hosts teachers and college students studying teaching to help them bring state-of-the-art science into their classrooms from biotechnology and high-performance computing to 3D printing and astrophysics. In FY 2016, LLNL hosted more than 100 teachers from California and 500 students from across the nation. Further, LLNL employees and retirees participate in Fun with Science Programs, an entertaining introduction to scientific phenomena at the LLNL Discovery Center, as well as street fairs, science festivals, and other special events. More than 10,000 students have participated in the program.

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10.7 CZECH REPUBLIC - ELI

BACKGROUND AND GOVERNANCE

The reasons for locating the project on the site at Dolní Břežany are (1) its ability to meet the technical requirements of the ELI Beamlines facility, especially in terms of security and stability, (2) the possibility for future expansion, (3) its connection to required infrastructures, and (4) the presence of utilities and site accessibility.

ELI Beamlines is a pan-European project jointly operated, along with three other complementary research facilities, under the single governance of a European Research Infrastructure Consortium. Two of these other complementary and specialized facilities are in Hungary (ELI-ALPS) and Romania (ELI).

RESEARCH EXCELLENCE

A focus on researchers guides the access to ELI Beamlines. Once operational, the facility will provide open-access to users based on scholarly merit as determined through a peer-review process, backed by guidelines from the ESFRI and the European Commission.

Several synergies exist between Czech scientists, existing laser facilities in the Czech Republic, and the ELI Beamlines facility. The Beamlines project is overseen by the director of the Czech Institute of Physics (FZU) of the Czech Academy of Sciences. The FZU has been active in the field of laser physics and includes a new national-level HiLASE laser center that has the main goal of creating a national R&D platform of new laser technologies with breakthrough technical parameters.

In 2016, the FZU and ELI Beamlines were awarded two projects, ELIBIO and High Field Initiative (HIFI), by the Czech Ministry of Education, Youth and Sports. In partnership with the Biotechnology and Biomedicine Center of the Academy of Sciences and Charles University in Vestec (BIOCEV), the ELIBIO project plans to build an interdisciplinary center of excellence at ELI Beamlines, combining photon physics and biotechnology and biomedical research, with potential applications related to health and disease. The HIFI project will develop theoretical aspects including theoretical support and technological upgrade of the lasers to potentially realize new experiments. Finally, ELI Beamlines comprises a significant part of their R&D strategy within Central Bohemia. Three research initiatives, ELI Beamlines, HiLASE, and BIOCEV, as well as the future relocation of FZU to the region, will serve to anchor the region's science and technology advanced region or "STAR Cluster."

ELI Beamlines plans to engage in different outreach and collaboration activities to promote the development of scientific capacity and raise the reputation of the region. It organizes lectures at local high schools and universities and hosts conferences, workshops, and summer schools that involve local and international students. ELI Beamlines has an international research scope because of its mission as a shared European research infrastructure. By early 2017, ELI Beamlines set up scientific collaborations through contracts and a memoranda of understanding with 28 research institutions and universities around the world.

SCIENCE-INDUSTRY COLLABORATION

The overall enabling conditions for science-industry collaboration in the Czech Republic have been weak. This is reflected in the main areas of weakness identified by the National Research, Development and Innovation Policy of the Czech Republic 2016–2020:8 a system for managing science and research, the public sector, the collaboration of the public and private sectors, innovation in enterprises, and the strategic targeting of support. Contract research is limited because academics and the industry have different perspectives regarding the value of scientific results and IP.

BUSINESS INNOVATION AND STARTUPS

ELI Beamlines plans to support knowledge and technology transfer by establishing an active industry outreach function and a technology transfer facility. In contrast to the nearby HiLASE center, which focuses on practical scientific applications, ELI Beamlines is focused on basic research. Yet, ELI Beamlines endeavors to obtain 10% of its annual income from industry and plans to do so by accommodating both academic and industrial users.9 Market plans include visualizations, leaflets and success stories, newsletters, and participation in trade fairs and events.

ELI Beamlines also works with the CITT, a regional economic development-focused intermediary that offers multiple services relating to technology transfer and industrial research collaboration. Once ELI Beamlines is fully operational, CITT will promote and allocate laser beam time to industrial companies so that they might test and develop their own technologies. Further, ELI Beamlines offers vouchers to companies to take advantage of the laboratory and its various services. It also participates in multiple Danube regional projects that seek to understand the social and environmental impact of R&D on the region's development.

The STAR Cluster governing body hopes to spur industrial development around Dolní Břežany by focusing on the recruitment and development of companies and suppliers specializing in the key areas of the region: biomedicine, biotechnology, material sciences, optics, laser technologies, and related fields. While the EU currently finances ongoing projects, STAR plans to cooperate with banks and private equity funds to spur economic development and provide access to early stage financing. Further, STAR works with CzechInvest to coordinate and apply investment strategies, promote available business space, and manage entrepreneurship strategies within the region.

BUSINESS INNOVATION AND STARTUPS

The ELI facility is in the small town of Dolní Břežany, adjacent to Prague's Southern administrative border. The location is proximate to the international airport (15 min. drive), the Prague outer ring, and the European motorway network. The STAR Cluster, including the ELI Beamlines, HiLASE, and BIOCEV footprints, encompasses an area of 6 km^2 including several towns proximate to Prague, including Dolní Břežany, Hodkovice, and Vestec. Moreover, STAR plans to coordinate infrastructure development relating to public transport, road access, housing, conference rooms and necessary utilities, IT infrastructure, energy, etc. In addition, STAR invested 10 billion CZK in research and startup infrastructures, 3 billion CZK in supporting infrastructure, and 1 billion CZK in high-tech companies.

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10.8 HUNGARY- ELI-ALPS

BACKGROUND AND GOVERNANCE

The ELI-ALPS is a pan-European project jointly operated along with three other complementary research facilities under the single governance of a European Research Infrastructure Consortium. The ELI-ALPS project will be a unique attosecond facility that provides ultra-short light pulses between a THz (1012 Hz) and X-ray (1018–1019 Hz) frequency range with high repetition rate for developers and end-users. Two of these other complementary and specialized facilities are in the Czech Republic (ELI Beamlines) and Romania (ELI).are in Hungary (ELI-ALPS) and Romania (ELI).

RESEARCH EXCELLENCE

Hungary has been active in laser research for decades. At the national level, Hungarian universities have conducted research in laser-related science. Scientists working on laser research are part of long-standing formalized research networks in Hungary. These networks include the Committee of Laser Physics and Spectroscopy within Hungarian Academy of Sciences and the Quantum Electronics Group of the Roland Eötvös Physical Society. Hungarian laser scientists have also been active in the international scientific community through initiatives, such as LaserLAB Europe and EuLASNet. **Further, ELI-ALPS is part of the national R&D plan that aims to increase R&D expenditures up to 1.8% of GDP as outlined by the Hungarian National RDI Strategy 2013–2020.**

The Szeged region has also been involved in lasers since 1968. Szeged ranks second only to Budapest in R&D investments and is home to several R&D organizations, including the University of Szeged, the Biological Research Center of the Hungarian Academy of Sciences, the Research Institute for Biotechnology of the Bay Zoltán Foundation for Applied Research, and the Cereal Research Non-Profit Company. Together, these organizations employ around 2,000 R&D professionals and researchers and have an annual R&D output of EUR 20–40 million.

Related to ELI Beamlines, the University of Szeged has one of the strongest PhD programs in optics and laser physics in the country. The University of Szeged led multiple domestically funded projects between 2011 and 2013 related to the ELI for training laser scientists and for developing laser research to strengthen the domestic scientific capacity to engage more actively with the ELI-ALPS facility. These projects included 15 new lecture courses meeting the needs of ELI, three laser teaching laboratories, graduate seminars from internationally acknowledged foreign experts, and joint training.

SCIENCE-INDUSTRY COLLABORATION

The ELI-ALPS research will have potential application to the biomedical sciences, chemistry, climate research, energy, the development of new materials, semiconductors, and optoelectronics. To exploit these applications and promote science-industry collaborations, the Hungarian National Government, the City of Szeged, and the University of Szeged plan to build a science park in the vicinity of ELI, the ELIPOLIS Technology and Industrial Park. The aims of the science park will be to support knowledge transfer between the university and companies, to guarantee land supply to research institutes and companies, to establish an incubator that will encourage and support startups, and to provide services, such as market research and assessment.

ECONOMIC GEOGRAPHY AND ENABLING FACTORS

Szeged is the fourth largest city in Hungary. It is close to the Serbian and Romanian borders. It is 170 km from Budapest (and the airport) and approximately 1.5 hours by motorway or by train. The ELIPOLIS is planned as a major infrastructure development project in Szeged with an allocated budget of €16 million between 2014 and 2020. **The ELIPOLIS Technology and Industrial Park construction is planned in multiple phases that are focused on various infrastructure investments.** The science park encompasses 24 ha (59 acres) surrounded by green space available for companies and their employees. The park will offer a wide range of ownership, leasing, and building options.

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10.9 SOUTH KOREA – GWANGJU PHOTONICS CLUSTER

Development of the Photonics Cluster in Gwangju, South Korea: Temporal and Spatial Aspects

- Photonics cluster development in Gwangju is driven by central government initiatives to achieve 'balanced' economic development across South Korea;
- Development of the cluster is part of a multi-decade, multi-phase process with evolving efforts by national and local governments to promote research and industry;
- To offset the lack of existing photonics R&D in the city, various tax incentives and low rents are used to incentivize firms to set up in Gwangju along with creating new research institutes for building highly skilled human capacity;
- Efforts to build different infrastructures and improve accessibilities, largely driven by central government investments, ran parallel to the development of the cluster.

TIMELINE OF DEVELOPMENT

Unbalanced economic development in Korea

Gwangju, one of the six Korean metropolitan cities, is located over 250 km from Seoul and is the largest city in southwestern Korea. Gwangju was largely overlooked by location-specific economic policies of the 1960s and 1970s that prioritized industrial exports from the capital and southeast regions to the west and Japan, leading to rapid but 'unbalanced' growth in the country. Much of the industrial and economic development policies that followed were driven by the central government's priority to rebalance growth.

1970s–1980s: Early stages of economic modernization - Industrial complexes

In the 1970s and 1980s, local efforts to promote industrialization of Gwangju emerged to transform the economy from consumption-driven to production-driven. The local government, the Gwangju Chamber of Commerce and Industry (GCCI), and the Urban Activation Movement of Gwangju Area (UAMGA) led these initiatives. In particular, UAMGA was key to raising local capital to develop large infrastructures that could host both large firms and SMEs and generate local employment. Gwangju built three industrial complexes on the outskirts of the city. (i) The Bonchon Industrial Complex (937,000 m^2) and (ii) the Songam Industrial Complex (394,000 m^2) were funded by local capital for privately owned complexes and (iii) the Hanam Industrial Complex, with the first stage built with World Bank funds and sold in lots (1,485,000 m^2), and a second stage built using capital from the first stage (1,980,000 m^2).

The local government in Gwangju played a key role in mobilizing the central government and its policies to attract firms in the three industrial complexes. The national government designated Bonchon and Songam as industrial enterprise zones at the behest of the local government. Industrial zone policies enabled the use of public funds for essential facilities, such as access roads, water supply and drainage, and communication. Furthermore, companies located in these industrial zones benefited from corporate tax incentives, including tax exemptions (acquisition tax, registration tax, and property tax for five years) and special depreciation for company buildings. These two industrial parks hosted 167 firms (including large confectionary factories, a brewery, and a Coca-Cola factory) and employed 7,000 workers in the first eight years of operation, contributing significantly to the economic development of the city. Attracting firms to Hanam was more challenging and required the local government to seek financial support and GCCI to widely publicize the complex. The GCCI publicized the industrial complex, emphasizing Gwangju's abundant and high-quality workforce, location advantages, etc. By the late 1980s, Hanam was home to multiple electronic corporations (e.g., LG, Daewoo, and Samsung) and other SMEs.

Despite the significant economic and industry development that accompanied these industrial complexes, the city's GDP growth was lower than that of all other major cities in Korea (Seoul, Busan, Daegu, and Incheon). Much of the industry was driven by low value-added consumer goods or service industries with low R&D investments.

1990s–2000s: Toward high-tech industry - GHIP

The Korean central government's priorities of 'balanced' economic development and advancing the technology sector led to the initial emergence of the high-tech industry in Gwangju. The central government planned to design national high-tech research and industrial complexes coherent with regional development strategies and modeled on US and Japanese industrial parks. In this context, the GHIP was developed to bring in research and industry, with space for new high-tech industries.

The central government, rather than the local development, directed the development of GHIP to bring in a critical mass of research and industry. Although many universities already existed in the city, the central government established the GIST in physical proximity to GHIP with the specific intention of creating human capacity for advanced science and engineering and thus enabling university-industry collaborations with GHIP firms. To attract industry to GHIP, the central government offered firms tax benefits on industrial or commercial property to incentivize relocation to Gwangju.

Despite the central government's large investment of $550 million to bring in research and industry to the high-tech industrial park, the GHIP did not meet expectations. This happened for two reasons. First, the development costs were high, as they primarily went into the purchase of private land, thus increasing land prices. Second, many of the high-tech research institutes, associated researchers, and consequently, the firms were already well established in the Seoul capital region within a more flourishing innovation system. These researchers and firms were hesitant to move to a new location with less-established research networks and customers.

The Asian and Korean financial crisis of 1997, with several bankruptcies, the lukewarm response to the 'supply-driven' GHIP with few local customers, and a non-conducive environment for profit-driven industry threatened the future of the high-tech industry in Gwangju. The government was forced to reconsider public investments.

2000s: Development of the photonics and optics industrial cluster

After the financial crisis in 1997, the central government revised its model for stimulating regional economic development through industrial clusters. In the new approach, the central government actively cooperated with local governments to consider regional contexts and strategic regional priorities for industry development. In 2000, the central government chose Gwangju (and three other locations) for establishing new industrial clusters. The local government in Gwangju chose the photonics and optics industry, even though it had no research or industry history in photonics and optics. The cluster development followed the bankruptcy of Asia Motors, one of the largest employers in Gwangju, and the government chose photonics to develop a new industry given the growing global market for technologies, such as liquid electronic displays (LED), optical communication, and solar power systems.

The development of the industrial cluster was divided into three phases. **The first phase (2000–2003) focused on constructing the infrastructure necessary to support the technology requirements of optics and photonics.** This included developing technology resources to support R&D and technology commercialization, piloting and testing support (e.g., KOPTI), training the workforce in optics and photonics (e.g., via the Photonic and Optical Education Center), providing support services for firms, and encouraging collaboration between research institutions and companies in the photonics and optics industry.

The second phase (2004–2007) focused on addressing challenges from the first phase and on establishing priority technology areas related to optical communications and LEDs, called 'LED Valley.' The cluster established services to improve production processes and product development, to increase cooperation among research institutes and industry, and to provide firm services, such as overseas marketing. In 2006, firms could rent space in the integrated photonics complex at about $1.50/m2, and the city also offered financing for construction, equipment purchases, and operations and maintenance costs.

The third phase prioritized building local industry technology capabilities for the commercialization of new research and future technology trajectories in photonics. Firms relocated to Gwangju due to low initial expenses associated with the region compared to the capital region, along with incentives offered by the central government and the efforts of the local government. Over time, different synergies were developed between industry and research. However, the early stages of cluster development were challenging, as infrastructure development and the construction of large-scale facilities were slow. Furthermore, many of the potential customers for new photonics products were in the Seoul metropolitan area, making it more difficult for new firms to gain a critical mass that would connect with markets.

In addition to the development of high-tech industry and photonics clusters, Gwangju also began the development of a large cultural project, Hub City of Asian Culture, that aimed to establish Gwangju as a city of culture to attract tourism and to host cultural festivals and exchanges with other Asian countries.

Looking forward (2010s–): Integrating various high-tech research and industry sectors

In 2011, the Korean government designated Gwangju as an 'Innopolis Project' (or R&D special zone) by linking different optics-related research and industries located in the metropolitan area (i.e., next generation photonics/optics/light-related technology, a smart grid, eco-friendly automobiles, design and culture technology, and biomaterials). The Innopolis also aimed to promote Gwangju as an attractive destination for industry and investment based on its two most prominent features: "culture" and "light."

The new Innopolis offered the following multiple tax incentives to promote the relocation or generation of new firms: (i) at the national level, the exemption of income tax and corporate tax for three years and a 50% reduction of those taxes for two years thereafter; (ii) at the local level, the exemption of acquisition and registration tax for seven years and a 50% reduction of those taxes for three years thereafter. The Innopolis also had a variety of specific tax incentives and subsidies targeted toward attracting foreign direct investment (FDI). For additional details on FDI incentives, see the section on Gwangju Innopolis – Incentives.

TYPE OF FACILITIES

The photonics cluster benefited from the existing infrastructures of the GHIP. The central government invested in urban infrastructures and in improving the quality of life of new residents by building roads connecting the GHIP, new housing estates, and other urban facilities. Cluster development took place within the existing GHIP infrastructure to maximize the utilization of space and resources.

Table 33. Planned Arrangement for GHIP that Acted as a Precursor to the Development of the Photonics Cluster

Source: Based on (Seo, 2013)

Infrastructure	Area	Details	Investment
Phase I	9,834,000		$550 million
Education and research	1,947,000	28 national and private research institutes, and a new national institute of science and technology (GIST)	
Industries	2,013,000	50 high-tech firms (in precision chemistry, aerospace, and new materials)	
Housing	1,617,000	Housing for 30,000 people (personnel and new residents)	
Commercial and public institutions	891,000	Hospitals, department stores, a science center, an exhibition center, an art gallery, and public administrative agencies	
Open spaces	3,366,000	5 public parks including a central park	

Table 34. Main Partners and Key Actors in the Development of the Photonics Cluster in Gwangju

Source: Adapted from (Seo, 2013)

Partners	Description	Year Established
Gwangju Chamber of Commerce and Industry (GCCI)	Local industry association that provides membership services and promotes corporate investment	1936
Korea Industrial Complex Corporation	Korea's national industrial management and cluster development organization	1964
Ultrafast Fiber-Optic Network Research Center	Research center for optics technology	1993
Gwangju Techno Park	Science park for strategic high-tech industries	1999
Photonic & Optical Education Learning Center	Training and education facility	2000
Photonic Research Facility Center	Equipment for light- and laser- related research	2000
Korea Association for Photonics Industry Development	Industry association engaging with different local, national, and international stakeholders and setting standards	2000
Advanced Photonics Research Institute (APRI)	Advanced R&D in photonics and lasers	2001
Optical Communication Research Center	Testing and packaging technologies for optical communication	2001
Korea Photonics Technology Institute (KOPTI)	Government-based research institute specializing in photonics, supporting testing and commercialization of products, including through incubation services	2001
Optical Industry Support Center	Supporting system for production technology and precision measurement	2003
Photonics Integration Complex	Low rentals and the establishment of R&D labs and organizations	
Gwangju Technology Transfer Center	Technology transfer office	2011
Gwangju Innopolis	Coordinating research and industry activities and urban aspects	2013

The first phase of the photonics cluster development comprised a total investment of $335 million, including contributions from the central government (59%), the local government (14%), and the private sector (27%). The costs included hard and soft infrastructures, the infrastructure development of facilities and equipment ($172 million), a new site for the Photonics Integration Complex to integrate photonics and optical industries ($48 million), and new training facilities ($11 million) as well as R&D and support services, technological research and commercialization ($50 million), and firm support services ($44 million). (See Table 42 for a list of major facilities.) The second phase of the photonics cluster development included investments of $322 million. This phase included $178 million to support firm-level development related to the development of new technologies.

In addition, KOPTI was the most "pivotal facility" in the photonics cluster. It was designed in three blocks that integrated optics and photonics research and industry from the public and private sectors. The different blocks/zones at KOPTI are (i) the head office/BIC for administration, (ii) the foundational facility for R&D, testing, and certifications, and (iii) the research production facility for building the infrastructure of the photonics industry. Three different physical zones separate these three functions and are arranged from: public to semi-public to private. As described above, in the high-tech industrial park (GHIP) and the photonics cluster, firms were incentivized to relocate to Gwangju due to tax incentives and low rents.

CONNECTIVITY AND ACCESSIBILITY

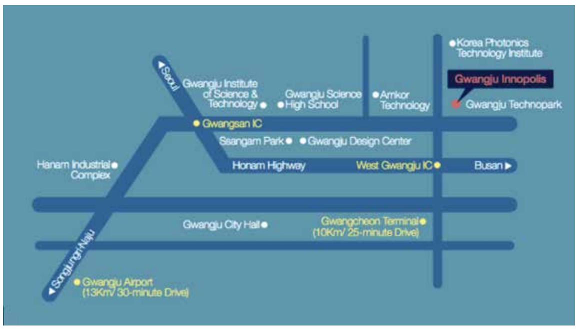
Additionally, GHIP was developed with 9,834,000 m2 of privately owned land close to the city center. The location of GHIP in the metropolis area and its accessibility were a central part of GHIP planning, with the site located close to the highway, railway station, airport, and even the seaport2 (Figure 51).7

The growing industry and central-regional cooperation also paved the way for better connectivity, as the Gwangju train station was included as a stop along Korean high-speed rail services while the local subway network first partially opened in 2004. Gwangju is the only metropolitan city in the southwest region of Korea and is an important node in the nation's transportation network.

Gwangju's additional prominence as a hub of culture attracts tourists and visitors throughout the year, especially during festivals and events, such as the Gwangju Biennale and the World Kimchi Culture Festival.

Figure 51. Connectivity of Different Research Institutes, Industry, and Other Facilities in Gwangju

Source: Gwangju Innopolis, 2013



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Annex 11. R&D FrameworkExecutive Summary

Objective of the survey research

The purpose of the current study, "Research and innovation framework in Romania" (RIFR) is two-fold: on the one hand, it is to collect, aggregate, and analyze some of the existent perceptions of the research and scientific community on challenges they are confronted with in terms of human resources, research infrastructure, and financing; on the other hand, the purpose is to take stock of the existent perceptions of impacts of the Extreme Light Infrastructure – Nuclear Physics (ELI-NP) in Romania and its potential externalities. The data were collected through an online sociological survey that is part of the Romania Laser Valley, a technical assistance project conducted by The World Bank for the Ministry of Research and Innovation. This project aims to support the Romanian Government to frame the enabling conditions for the occurrence of economic spillovers and backward and forward linkages that could emerge from the ELI-NP.

Research Questions

The diagnosing of the current challenges of R&D in Romania from within, by its own researchers, is guided by a set of research questions, hypotheses, and categories or sections of analysis. The research questions are as follows:

1. "What is the quality of the organizational environment in R&D in Romania under the aspects of infrastructure, the management of human resources, and regulations on financing and cooperation?"

2. "What are the perceptions regarding the sustainability of the project and the externalities to the rest of the scientific environment: scientific research, financing, cooperation, technological capacity, and local and regional development?"

Research Hypotheses

- H1 - ELI hypothesis. The first hypothesis stipulates the expectation that working in an organization directly involved in ELI activities has a positive impact on perceptions referring to the quality of equipment and a negative impact as far as it concerns perceptions of the quality of regulations related to R&D practices:
- H1a. The satisfaction with organizational equipment is expected to be higher in organizations that are closer to ELI activities. These are newer and with larger likely support by international funding etc.
- H1b. Perceptions on internal and government regulations are expected to be more critical towards people working in organizations that are closer to ELI activities due to higher levels of aspirations.
- H2- University hypothesis. Working in universities is expected to be more critical of available equipment, the management of human resources, and financing facilities.
- H3 - Experimental development hypothesis is focused on the probable impact of R&D combinations of activities for the same person: experimental development in the activity profile of a specialist is a favoring condition for proactive orientations in obtaining funds for competitive projects.
- H4 - Migration experience hypothesis posits a significant amount of criticism towards organizations and their resources for researchers or academics with work/study experience abroad or with intentions to go abroad. People in this category are expected to have higher levels of aspirations and more reference points to evaluate local situations.

The research questions and hypotheses are tested via two categories or sections: a) perceptions on the organizational environment and b) R&D practices and their subjective dimensions. The specific sections of analysis associated with these two dimensions or categories are mentioned below. They structure the survey data analysis. The executive summary will present, after some methodological details, a short summary of the findings related to perceptions and practices in the area of R&D as a result of the data analysis.

Perceptions/ evaluations of respondents regarding the organizational environment	Perceived quality of the equipment/infrastructure
	Efficacy of organizations in the management of human resources
	Effectiveness of regulations in R&D at the organization and government level
	Perceptions on ELI-NP
	Cooperation practices and evaluations
R&D practices and their subjective dimensions	Supply and proactivity in the funding of research activities
	(Re)organizing R&D via spin-offs, technological transfer, and entrepreneurship
	Potential mobility to other institution or abroad
	Attractiveness of Măgurele for researchers

Data collection methodology

An online survey was conducted for data collection. The resulting sample of 224 respondents was primarily formed by researchers in R&D (77%) who are directly involved in in ELI activities (33%) or in activities that are closely connected to ELI (33%) and who working in the Măgurele area (57%).[71] This means that the typical respondent is a researcher who is directly or indirectly involved in ELI activities in the Măgurele area. **The starting sampling frame of email addresses and the selectivity of answers could not assure the representativeness of the sample for the R&D researchers and academics in Romania.**

The data allow for relevant comparisons among researchers in Măgurele (50%), researchers out of Măgurele (approx. 25%), and university academics (approx. 20%). **The larger and the most homogenous subsample consists of researchers from Măgurele. In terms of the function of these characteristics it could be considered of having the highest degree of representativeness compared to the other two subsamples. The higher representativeness of the subsample of researchers from Măgurele who are better informed and involved in ELI activities, is in accordance with the institutional purpose of the research.**

Data analysis methodology

The fact that the sample in not representative for the whole area of R&D in Romania but has three structured subsamples (researchers in Măgurele, researches out of Măgurele, and academics in or out of Măgurele) involves the use of different techniques of data analysis that are able to provide probabilistic comparisons among these subgroups or the others that are derived from them. This is why we frequently used the type of institutions (Table 59), the type of activity, and the location of the job (i.e., in the Măgurele area outside of the area as privileged predictors in cross-tabulations or in multivariate regression models. The role of this approach is to help generate results that are not affected by the fact that the sample is not representative by Măgurele versus non Măgurele jobs, research vs. university activity, and subdomains of R&D fundamental research-applied, research-experimental development.

The small volume of the sample and its semi-probabilistic nature also allowed for the use of multiple indicators for latent variables in order to reduce the error probabilities in measurement and appropriate techniques for controlling certain variables when identifying the specific or "net effects" of predictors of interest.

71 Percentages in this paragraph are not cumulative as the reference categories are partially overlapping.

Key findings conclusions

Perceptions of organizational environment

Research Infrastructure. There is a very good perception of accessibility and operability of the existing infrastructure (with over 85% out of the total sample). The positive perceptions are lower in regard to how internationally up-to-date the equipment (77%) is or how updated or new it is (65%). The data do not support the first hypothesis (H1), which focused on people working in organizations who are directly involved in ELI and their higher satisfaction with equipment. The second hypothesis, which predicted individuals' lower satisfaction with the quality of the equipment in universities, is confirmed. Those that work abroad are more critical of the modernity (international up to date) of the equipment in their organization, in accordance with H4. A self-defensive attitude on the part of managers was recorded here: they are significantly more inclined to positively appreciate the quality of equipment in their organization.

The management of human resources in organizations seems to be perceived negatively to a higher degree than the quality of infrastructure. Attracting and maintaining talent in research projects is perceived as problematic by about 37%-39%. Interviewees from universities, from some organizations that are directly involved in ELI, and also those that are in top professional positions (meaning high expertise) are the most dissatisfied with attracting top researchers. Researchers from the Măgurele area are significantly more satisfied than those in other locations from this point of view.

Effectiveness of R&D Regulations. The degree of dissatisfaction with R&D regulations is higher than it is for infrastructure, management, and human resources. The degree of dissatisfaction is particularly high (over 80%) on the government procurement policy regarding R&D. The internal regulations (on intellectual property, spinning-off, and licensing) of organizations are very high, especially for those that cooperated with a company in the past.

The highest positive impacts of ELI in the future are the are related to the science progress in general (38%), the advancing of Romanian fundamental research (18%), and the enhancing scientific cooperation between Romanian and international organizations (17%). Immediately in the series is the perception of "the economic development of the Măgurele town and area" (9%).

Practices in R&D and their subjective dimensions

Cooperation practices with other organizations are rather widespread (about two-thirds of the interviewees were involved in such practices in the last four years), and managers and top professionals tended to mention them the most frequently. H3 is supported by data on this topic: specialists who are involved in experimental development activities in association with other R&D activities have a higher probability to be involved in cooperation relations. Three major factors are perceived as obstacles for better cooperation - absence of interest from industry, high costs and poor interaction between R&D and firms.

The institutional supply of funding is perceived as being highly dissatisfying, in accordance with H2, for universities; it is perceived as rather good for people who are cumulatively involved in experimental development activities. Specialists working in Măgurele are also significantly dissatisfied with the institutional arrangements of funding R&D.

The awareness on spin-offs practices is very low (17%), and tends to increase with working abroad experience, directing doctoral dissertations and working in an area outside of Măgurele.

Potential migration abroad has a higher probability for the specialists who are more dissatisfied with the work environment because of its infrastructure and, also, due to the poor quality of management. The propensity for migration from Măgurele is impacted by the same factors, in addition to migration experience abroad: people who worked abroad are more oriented to re-migrate from Măgurele out of the country (a finding which supports H4). The finding signifies a lower competitiveness for Măgurele as a place of residence for attracting highly skilled specialists.

The policy implications of the research, as formulated by the interviewees, are summarized in Tables 67 and 68.

Introduction

The research is intended to provide an exploratory diagnosis of the situation and prospective dynamics of R&D in Romania, with a special focus on R&D taking place in relation with ELI-NP. The online survey involving over 200 specialists is the basic instrument that provides the input data for the evaluation. The way the sample was designed allows for systematic comparisons among researchers from the ELI project located in Măgurele area and researchers in R&D in Romania but out of Măgurele as well as specialists in R&D from Romanian universities. **Neither the sample nor the subsamples are representative. In spite of this fact, the data are highly consistent as provided by a consistent sample of experts in R&D.** The consistency results from the large number of significant relations (from a statistical and substantive point of view) that were measured by quantitative multivariate models connecting perceptions and behaviors in R&D. A representative survey at the national level would allow for a reliable specification of percentages and correlations among different variables. However, it would not include as many experts in R&D as in the case of this survey on the research and innovation framework in Romania (RIFR).

The RIFR is guided in its design and analysis by three frames of reference: research questions, hypotheses, and categories of analysis, as presented in the executive summary. The key research question is an exploratory one: What are the main factors influencing the perceptions of researchers involved in a ELI-NP project on their work environment and future performances of the project? Answers are provided in a comparative manner by considering the answers to the same questions addressed to R&D specialists from organizations that are less involved or not involved in ELI activities.

The research hypotheses are supported and nuanced by the data analysis. Factors such as the type of organization, the type of R&D activities, and managerial, professional, and migration experience are all powerful predictors for the majority of the investigated perceptions and behaviors. In some cases, there seems to be a rather high consensus on the nature of the problems associated with R&D in Romania. This consensus is particularly evident in respondents' views of the key problems concerning the future dynamics of ELI-NP.

Examples of highly consistent suggestions for solving existing and future problems for ELI-NP appear in Table 67 (Diagnosis and possible solutions for a high performing ELI-NP).

Methodology for Data Collection and Analysis

The survey on research and innovation framework in Romania (RIFR) was conducted in April and early May 2017 and involved an online method. A limited budget and the time given to implement the study factored into the survey instrument selection. Public research organizations (including research institutes and universities) were initially selected to target relevant or related fields of research on nuclear physics (ELI-NP). All the institutes on the Măgurele platform were invited to disseminate the survey throughout their organizations. Additionally, targeted emails were sent to a database of researchers formed of email addresses taken from websites (1,130 addresses) of targeted institutes and universities.

The initial email addresses that invited persons to answer the questionnaire targeted specialists from R&D organizations. The potential respondents were informed on the introductory page of the questionnaire that the World Bank project supporting the research "aims to support the Romanian Government to frame the enabling conditions for the occurrence of economic spillovers and backward and forward linkages that could emerge from Extreme Light Infrastructure – Nuclear Physics (ELI-NP)."

Of the collected sample of 224 respondents (subjects),[72] a total of 181 persons are from research and development institutes from Romania, and 40 respondents are from Romanian universities (2 persons are from companies with Romanian ownership and 1 person is from a university abroad). The subsamples from working organizations range from 2 persons to a maximum 34 persons (only two organizations provided this maximum figure of respondents). Table 60 from the appendix provides more information on the diversity of the organizations where the respondents work.

The sample is significant for people working in R&D and for those with direct or indirect knowledge about ELI-NP. (See Table 59 for this topic. Only 10 respondents claimed to not know anything about ELI-NP.) Neither the sample nor the subsamples are representative in any way. The implication of this fact is that the results of the data processing are indicative for the sample per se. The answers of the more than 200 experts in R&D are, on the other hand, highly relevant for exploring the situation in Romania on the topics transformed into questions. **The clear advantage of this sample is that it provides information from a large number of experts. Their strong knowledge of the subjects compensates for their total number.**

A second important characteristic of the sample is that it could be analytically structured according to relevant status (age, gender, activity, professional performance) and institutional groups. The comparisons among such groupings are also relevant.

The heterogeneity and the small size of the sample obliged to using a variety of techniques of data analysis for information extraction. The simple tables crossing two variables could be read for "a first impression" on the possible relations among those variables. At times, figures in the tables are quite small. This is why the established associations between the values of the variables or hierarchies among cell frequencies are interpreted mainly for extreme values (maximum and minimum). The figures in the category "other" should not be interpreted as they are computed on rather small frequencies. Parts of the key findings are based on a more elaborate technique (adjusted standardized residuals) that assesses the degree of association among the column and row values of the variables. We do not present the technical details for this approach but openly convey where it was used. Its advantage is that of allowing decisions associated with a specific statistical significance level. Text that is highlighted introduces findings that are based on the above-mentioned technique of adjusted standardized residuals or on a multiple regression analysis.

72 The large majority of respondents (200 or 89% out of the total sample of 224 completed interviews) were reached by the online survey starting from a sampling frame. The rest were contacted by the public registration and self-involvement of respondents. The sampling frame consisted of a list of 1,130 email addresses of specialists from the R&D area, with a large representation of those from the Măgurele platform. The rate of response for those in the sampling frame was 18%. The rest of the addressed people did not answer (about two-thirds out of 930 cases), refused to answer, were not eligible, formulated partial answers, etc. The sampling frame is structured in accordance with the dominant interest of the research for R&D experts who are directly or indirectly connected to ELI-NP. However, at the same time, it is an availability sampling frame. This is the reason it cannot be used for constructing a weighting variable.

In fact, the basic findings of the research are generated by multiple regression analysis (OLS or logistic) after bootstrapping the standard errors. Such an analysis is necessary to pass from gross effects that could be identified through a cross-tab analysis to net or specific effects. Bootstrapping was adopted to compensate for the fact that we do not know the characteristics of the population from which the sample is extracted. It is the only way to reach robust standard errors that are necessary for the specification of significance levels (p values).

In fact, the report was elaborated in a first stage on the basis of applying common standard errors. The final, current version of the report worked with bootstrapped standard errors (1,000 extractions, in SPSS). The comparisons of the results between asymptotic (usual) standard errors and the bootstrapped ones could be considered as a sensitivity analysis. The majority of the regression coefficients were significant (for $p < 0.10$) in both versions of analysis. We kept the results that are based on bootstrapping because they are methodologically more adjusted to the situation of sampling from an indefinite population and also because this second version provides higher consistency with the theoretical expectations in interpreting the results.

We strictly followed the rule of having at least 10 cases per independent variable in the regression models (see Box 3 for technical details). The rules for reading regression coefficients are in Box 4.

Annex 5 provides tables with descriptive statistics for all the dependent and independent variables that are used in all the multiple regression models of this report.

The data reduction of several variables to a single index uses factor scores that are, again, presented as results, rather their technical aspects.

The more than 200 persons involved in the survey on R&D are experts. Large segments in the sample are formed by top professional positions (56%), managers (40%) in research and development institutes or universities, and specialists that worked abroad (57%) or studied abroad (45%). Their views on specific topics are not mere opinions; rather, to a large degree, they are expertise evaluations. About one-third of the respondents (35%) come from institutes directly involved in ELI-NP activities; a somewhat higher percentage of the respondents are from institutes that are rather close to ELI-NP by activities (38%); smaller segments are from universities (18%) or from other, more heterogeneous, organizations (9%). The average indices of publications and citations performances for the first three segments of the sample are rather high and similar: between 13 and 14 means per group of institutions for the Hirsh citation index (by Google Scholar sources) and between 11 and 12 for the Hirsch index (by *Web of Science sources*) (see Table 64).

Box 3. Technical Note on the Sensitivity of the Regression Models in This Study

The regression models in Table 37 are using 17 predictors. The practice of using a large number of predictors in the regression models of this research report is adopted on a large scale. Is it an over-fitting of the models? In other words, is the complexity of the regression models beyond what the data are allowing? Recent literature in the area[73] allows for the answer that in this case there is not an overfitting situation.

To illustrate this view, we will use a short example of sensitivity analysis[74] for the case of the regression model with the index of perceived quality of equipment as the dependent variable. The OLS model in Table 37 uses a set of 17 predictors on a data set of 218 cases. This translates to approximately 13 subjects per variable (SPV), which is more than required by the rule of thumb of a minimum 10 SPV.[75] It is also much more than what Austin and Steyerberg (2015) specified by reliable simulations as an acceptable threshold (2 SPV).

We worked with a large set of predictors (but with an SPV higher than 10) throughout the entire research report because we targeted a good specification of the models on theoretical grounds but observed the rule of thumb on SPV in the area. It is fundamental to control for the type of organization, the type of R&D activities, migration experience, and basic demographics as to avoid statistical artifacts due to the fact that the sample is non-representative.

There is a low sensitivity of analysis as proved by changes in the number of predictors. We could illustrate the idea with one example in particular. The model of predicting the index of the perceived quality of equipment (Table 37, Model 5) uses 17 predictors and is summarized by R2 = 0.134 and the adjusted R2 = 0.061. We run the same model but only with only 13 predictors (excluding the previous 4 predictors in the model regarding work organization). The significant predictors in the two models (for $p < 0.10$), for the common predictors, are the same in the full and restricted models. All of these are indicative of the low sensitivity of the model associated to changes in the number of predictors. In both models, the VIF for collinearity is smaller than 5.

There is also a low sensitivity by regression coefficients and pseudo R2 for the case of Model 1 in the same table operating with a logistic regression model.

73 Austin, P. C., & Steyerberg, E. W. (2015). The number of subjects per variable required in linear regression analyses. Journal of Clinical Epidemiology, 68(6), 627-636.

74 Treiman, D. J. (2014). Quantitative data analysis: Doing social research to test ideas. John Wiley & Sons.

75 Harrell, F. (2015). Regression modelling strategies: With applications to linear models, logistic and ordinal regression, and survival analysis. Springer.

Findings

Perceptions of the Organizational Environment

Perceived Quality of the Equipment/Infrastructure

Context: Romania has updated its research infrastructure through structural funds. As per https://erris.gov.ro/, an online registry of the existent research infrastructure in Romania, the country has 1,407 infrastructures with 7,506 research services, 61 technological services, and 19,851 pieces of equipment. Access to a research infrastructure for conducting experiments is essential to science, and it depends on several factors, such as the existence of the infrastructure and the operability of it—determined by the available budget of the research institute who owns it and the policy of access to the infrastructure for researchers. Even with a good stock of equipment, if the infrastructure remains underused because of either operability or access issues, then the positive impacts are minimal.

In this context, through some of the questions in the survey, we wanted to gain insight into the accessibility, obsoleteness, operability, and access to the research infrastructure in Romania.

The quality of the equipment/infrastructure for research and development activities (R&D) is assessed in this survey by the way it is perceived. Even if not objective, it conveys significant information if well connected to the job characteristics of the evaluators. RIFR asked the interviewees to assess whether the equipment they use for research in their organization is operable, accessible, up to international standards, and outdated. Two types of measures were used to assess the perceived quality of the R&D equipment in their own organization: percentages of those giving "yes" answers to the questions and a synthetic index combining all the answers to the four questions (Table 35).

Apparently, there are no consistent differences in the evaluation of the quality of the work equipment if one looks at the last column of the table below. In fact, if one considers the last row of the table, one can see that there is high dissatisfaction regarding how outdated the equipment (35%) is and how the equipment is does not comply with international standards (23%).

Table 35. Perceived Quality of Equipment in Own Organization by the Degree of Involvement of Own Institution in ELI-NP Activities

Source: RIFR 2017. Example: 82% of the persons involved in ELI-NP activities regard their equipment as meeting international standards .

Type of institutions function of their involvment in ELI activities	How would you describe the equipment you use for research in your organization? (%)				Index of perceived quality of equipment (average)
	operable	accesible	up to international standards	not old and outdated	
R&D directly involved in ELI-NP	86	91	82	71	52
R&D close to ELI	83	83	77	65	49
Universities	85	88	63	54	48
Other far from ELI	90	81	86	67	51

Professional experience seems to significantly differentiate the perceptions of the equipment in organizations (Table 36). Professional experience is measured by the staff category, the scientific or managerial role of coordination, the years worked in the current organization, participation in international projects, working abroad in the past, and the intention to go abroad for study or for work. The relations among different types of professional experiences and the evaluations of the infrastructure are different:

- Highly experienced professionals demonstrate a strong tendency to evaluate equipment in terms of how up-to-date it is. About 83% of respondents who worked abroad in their main field of activity assessed that the infrastructure in their organizations is up to international standards, compared to only 68% out of the subsample of respondents that did not work abroad. The situation is similar if professional experience is measured by other criteria such as attending international conferences, being in a top professional position, and the number of years worked into organization. The interpretation of the finding is that experienced professionals work in better-equipped organizations. It could also be a reverse effect – institutions with better professionals have to be stimulated from within to improve their infrastructure.

Table 36. Perceived Quality of Equipment by Professional Experience Indicators

Source: RIFR 2017. Codes in the first left column indicate the corresponding question in the survey questionnaire. Example: 87% out of the total interviewees who are not in a top professional position consider that the equipment in their organization is operable. Highlighted cells indicate significant positive associations (for p = 0.05) between row and column values. Example: There is a significant positive association, measured by the correlation coefficient (r), between being in a top professional position and considering that equipment in one's own organization is internationally up to date.

Professional experience (past and expected)		How would you describe the equipment you use for research in your organization? (%) (A8)			
		operable	accesible	up to international standards	not old and outdated
Top professional position (C7 recoded)	no	87	89	69	59
	yes	84	85	83	70
Management or scientific coordination position (C4)	no	84	86	71	60
	yes	88	88	87	73
Years worked in the current organization (C8 recoded)	15 or yes	87	90	73	66
	16 or more	83	83	80	64
Participation in international scientific programs, last 4 years (A4)	no	79	83	68	55
	yes	87	88	80	68
Worked abroad in the main field of activity (C15)	no	86	84	69	66
	yes	85	89	83	65
Potential migration abroad (for study or work), next five years (C7)	no	87	86	79	66
	yes	79	88	70	60

- The hierarchy is different if one considers the probable professional experience as indicated by potential professional migration abroad: The persons who intend to go abroad for study or work are less satisfied with the international standards of their equipment in the current work organization (70% compared to 79% for those who do not intend to migrate). However, here, as in the previous case, the probable causal relation is also in the reverse direction: People who are less satisfied with the work environment from the point of view of equipment quality are more inclined to leave.
- The dissatisfaction of the potential migrants is also higher compared to the dissatisfaction of potential stayers, regarding how outdated and operational the equipment is in the organization.

- Top professionals (i.e., first degree researchers, first degree technology development engineers, full professors) have views similar to those of managers regarding infrastructure. Both categories consider that the infrastructure in their institutions is modern (meets international standards, not outdated).

The specific effects of different organizational and individual level factors on perceptions of the quality of work infrastructure are presented in a more accurate way in Table 37. Simplified rules for reading such tables in this report are presented in Box 4 below.

Box 4. Rules for Reading Tables with Results of the Regression Analysis

This research report is using a large number of tables with results of the regression analysis (RA). The box presents simple rules for how to read it which is particularly useful for those who are unfamiliar with the reference statistical method.

Before rules, the reason: RA is strictly necessary to measure the specific or "net" effects of different factors (e.g., age, type of institution, type of activity, gender, managerial position, etc.) on different perceptions or evaluations that are of interest in this research. This is one of the very few ways to handle weak data that could not be weighted to reach representativeness. All the models of regression analysis are run in SPSS using the bootstrapping procedure (1,000 bootstrap samples) in order to obtain stable standard errors.

Description of RA tables: Each of these tables contains a measure of the influence of the independent variable (in rows of the table) on the dependent variable as specified in a column and, close to it, in another column with the significance levels of the coefficients.

The level of measurement of the dependent variable differentiates the rules of reading regression coefficients. The first rule is valid for all the regression coefficients, irrespective of the way the dependent variable is measured (as a continuous, ordinal, or dichotomic variable). Age, for example, is a continuous variable. Satisfaction on a certain aspect (1 = very satisfied.........5 = highly dissatisfied) is an ordinal variable. Attending cooperation projects (1 yes, 0 no) is a dichotomous variable.

First rule for the statistical significance of the regression coefficient: If the value in the column labeled p is lower than 0.10, the coefficient close to it on the left is statistically significant and deserves further analysis. The reference value of 0.10 is conventional; it is adjusted for the case of small samples that might be affected by severe sampling errors. (For representative samples, the reference values are $p = 0.05$, $p = 0.01$, or $p = 0.001$). For easier reading, we highlighted all the significant coefficients.

Second rule for the sign or sense of the relation: Between the row independent variable (x) and the column dependent variable (y): if the regression coefficient is positive, the relation is of direct proportionality (the higher the value of x, the higher the value of y), and if its value is negative, the relation is of inverse proportionality (the higher the value of x, the lower the value of y).

Example from Table 11. 3: The regression coefficient for the impact of age on the perception that the equipment is internationally up-to-date is coefficient = -0.007, and the significance level for this coefficient is $p = 0.778$. Considering the value of p, which is larger than 0.10, and the first rule, the regression coefficient is non-significant. The regression coefficient is negative (coefficient = -0.007), meaning that the relation between age and satisfaction with the modernity of equipment is negative or inverse proportional. In fact, being a non-significant coefficient, the sense of the relation does not count for interpretation.

The following people have a structured tendency (Table 37) to have good perceptions of the international up-to-date equipment in their own organizations:

- Managers and those who have worked abroad;
- Those are primarily conducting applied research, applies and fundamental research, and research combined with experimental development;
- Those are not working in Romanian universities.

Why are the lances of managers (persons with a leadership role) in an organization different from that of non-leaders? Before formulating an interpretative hypothesis, it might be useful to mention that about 40% out of the total respondents have managerial positions. Additionally, in a descriptive way, it is also relevant to mention that the differences in perceptions between leaders and non-leaders are consistent. There is a difference of 16 percentage points between the two categories: 87% out of the managers declare that the equipment in their organizations in up-to-date in regard to international standards, compared to only 71% for the non-leaders. It is likely that the managers took a more defensive position (considering the beneficiary of the survey) supporting the highly optimistic view of the equipment in their organizations. Moreover, with a lower probability, one could mention the possibility that the managers, who are more familiar with how difficult it is to obtain high standards international equipment, might be more inclined to assess that the local infrastructure in their organization is quite good.

Respondents who worked abroad assessed the modernity of the equipment in a more positive way (83%) than those who did not work abroad (69%). The difference could by related to the better information on international standards for those that worked abroad.

The satisfaction of people from universities regarding the quality of their equipment is much lower (52%) than for the case of people from non-university units of R&D (81%). This seems to be a difference in reality without the significant impact of subjective factors.

Table 37. Predicting the Perceptions on Equipment Quality

Source: RIFR 2017. Logistic regression for Models 1 to 4 and OLS regression for Model 5. Strictly significant predictors are for the significance level p <= 0.05. Here, we decided to use as significant level p <= 0.10, considering the small size of the sample and the data collection method. Significant predictors for this conventional rule are marked by highlights. Acronyms for the main organizations with respondents in the survey are explicated at the bottom of Table 38. *Variables are coded with 1 for the presence of the attribute and 0 for its absence (dummy variables). LASER National Institute for Laser, Plasma & Radiation Physics, MATERIALS National Institute of Materials Physics, NUCLEAR Horia Hulubei National Institute for Physics and Nuclear Eng. Technical details for those who are interested in the sensitivity analysis of the regression models are in Box 4. Bootstrapped standard errors.

Predictors		Dependend variable: perception of the equipment of own institutions as being ...								Dependent variable: the index of the perceived quality of equipment (Model 5)	
		up to international standards (Model 1)		not outdated or old (Model 2)		operable (Model 3)		accesible (Model 4)			
		Coef.	p	Coef.	p	Coef.	p	Coef.	p	Coef.	p
Socio-human capital of the respondent	manager*	1.089	.040	.760	.052	.177	.759	.425	.399	4.221	0.060
	top professional position	.349	.496	.516	.232	-.213	.711	-.673	.221	0.078	0.974
	studied abroad*	-.099	.829	-.152	.684	-.413	.446	.051	.924	-1.375	0.510
	worked abroad*	.877	.053	-.287	.456	.-1-	.983	.446	.347	1.525	0.533
	degree of information on ELI	-.166	.426	-.031	.845	.470	.053	.141	.569	0.727	0.491
Control variables	works in Măgurele area*	-.264	.621	-.513	.284	-.658	.318	1.031	.128	-0.961	0.719
	age	-.007	.778	-.033	.076	-.011	.696	-.002	.958	-0.117	0.261
	men*	.713	.119	.033	.913	.306	.553	-.142	.778	1.482	0.480
Main activity (reference others)	research & experimental develop.	1.948	.031	1.764	.024	1.868	.025	1.843	.041	10.939	0.021
	fundamental & applied research	1.773	.049	.299	.668	.384	.599	1.040	.238	6.449	0.167
	fundamental research	1.153	.236	.247	.740	-.481	.519	-0.16	.932	1.218	0.802
	applied research	2.353	.011	.466	.537	.171	.743	1.666	.060	7.888	0.089
	applied research & experimental development	1.141	.263	-.300	.680	-.522	.517	.308	.726	1.003	0.841
Work organization (refrence others)	NUCLEAR	.253	.719	.674	.249	-.213	.760	-.899	.220	-0.248	0.941
	LASER	-.595	.401	-.034	.965	.188	.806	.042	.613	-1.378	0.694
	MATERIALS	.197	.798	.294	.687	-.078	.886	-1.226	.159	-1.179	0.769
	Universities from Romania	-1.569	.016	-.585	.245	-.216	.762	-.544	.450	-5.176	0.098
	constant	-.381	.757	1.830	.075	1.172	.330	.550	.648	46.29	
	R2 (Nagelkerke or for OLS in the model 5)	0.261		0.175		0.171		0.162		0.134	
	N	218		218		218		218		218	

The causal profile for perceptions on how outdated the organizational equipment is, is not so rich (Table 37) as for the case of perceptions on international standards of equipment. Some factors play here in the same way as to explain perceptions on international up-to-datedness (management, operability, and accessibility).

Age is the key factor that intervenes as an effective predictor in the second regression model from Table 11. 3: senior researchers are more convinced than their younger colleagues that the equipment in their organizations is outdated. More research experience in the first case compared to the second case could explain the situation.

Only the type of activity differentiates the accessibility to the equipment in organizations: this is significantly higher for the specialists from applied research and for those doing complex work of applied& fundamental& experimental development activities (Table 37).

Model 5 provides a synthetic view of the topic, where the dependent variable is the index of the perceived quality of the equipment:

- The type of activity introduces significant variations in these perceptions. People working in applied research or in cumulative activities of any type of research plus experimental development describe the equipment their organization uses mainly in positive terms (up-to-date at the local or international scale, operational, and accessible).
- The perceptions on the quality of work equipment do not seem to differentiate significantly according to the organizations or, more exactly, by the organizations that had a consistent number of interviews involved in survey. The exception comes from universities where the quality of the research infrastructure seems to be lower.
- Managers tend to have a more positive view on the quality of the equipment/infrastructure compared to their non-manager colleagues. This could have several hypothetical explanations, as previously detailed (defensive attitude, better comparative information, better personal access to it, etc.).

There were only few instances in which researchers did not have access to the infrastructure needed for conducting research (3 of our 224 cases). Two reasons were mentioned in regard to not being able to access available infrastructure: managers' decisions and, in another case, the fact that the institute did not have collaboration agreements with institutes where the research infrastructure existed. This raises two interesting points: criteria for access to the equipment might not be set and might depend on the manager's decision, and the lack of collaboration agreements might impede researchers from using equipment available elsewhere in the country.

The perceptions on the accessibility, up datedness, and operability of the infrastructure are important for internal and intra-organizational policy options. The research institutes (which tend to be the majority of the sample) tend to be satisfied with the research equipment (with differences in view based on the rank in the organization or the type of activity performed). However, respondents from universities do not tend to have the same degree of satisfaction with the research infrastructure. More efficient use of equipment could be determined by clearer procedures on access to equipment for both internal staff and external researchers and also by incentivizing collaborative agreements between institutes for use of the infrastructure. (Findings reported in this paragraph are bases on a full regression model that is not showed here.)

Efficacy of Organizations in the Management of Human Resources

Context: Public investment in science and technology might not be effective without access to quality human resources. This is the motivation behind the questions asked in the RIFR survey on whether the public research organizations are able to attract and maintain talent and workers.

Attracting and retaining researchers and technicians is one of the most severe problems of human resources for obtaining performance in the area of R&D. There is a considerable amount of support on this view among the interviewees (Table 38).

Table 38. The Most Important Human Resources Problems in Organizations

Source: RIFR 2017. Reading example: 56% out of the interviewees from universities regard their organizations inability to retain talent in research projects as the most severe problem in the management of human resources. All the figures from the first four rows are percentages out of the totals for each column. Figures from the last row are index values. The efficacy in human resources management is computed as a factor score of five items on the ability of their organization to attract and maintain effective researchers and technicians for research projects, plus the ability to assure opportunities for career development. The factor score is transformed to have a variation between approximately 0 and approximately 100 by a Hull transformation (mean 50 and standard deviation 14).

Which of the following do you consider to be the most problematic (for your organization)	Type of institutions function of their involvment in ELI activities				Total
	R&D directly involved in ELI-NP	R&D close to ELI	Universities	Other far from ELI	
Attracting talent in research projects	36	45	29	48	39
Retaining talent in research projects	38	23	56	48	37
Attracting and retaining technicians	15	19	10	5	15
Other or none of these	10	13	5	0	9
Total	100	100	100	100	100
Efficacy in HR management (mean of the index, see Annex 5)	49	54	43	49	50

Universities have the lowest efficacy in human resources management (a similar position to the hierarchy of institutions from the point of view of the quality of work equipment – Table 35). The best situation, with a maximum performance in efficacy in human resources, seems to be for the organizations that are "close to ELI-NP in R&D."

The people who are the most dissatisfied with their organizations' capacity to attract top researchers in their organizations (see column 1 in Table 39) are as follows:

- Respondents from universities and The National Institute for Laser, Plasma & Radiation Physics;
- Those who do not work in Măgurele;
- Mostly young men in top professional positions.

Behind each of the identified factors is a configuration of causal contexts that can be approximated by interpretation but not measured as such. Income conditions for youth, support for career advancement, and the quality of the equipment could be such contextual factors.

Table 39. Predicting R&D organizations' ability to hire/retain quality professionals

Source: RIFR 2017. Logistic regression for Models 1 to 5 and OLS regression for Model 6. Strictly significant predictors are for the significance level p <= 0.05. Here, we decided to use as significant level p <= 0.10, considering the small size of the sample and the data collection method. Significant predictors for this conventional rule are marked by highlights. Acronyms for the main organizations with respondents in the survey are explicated at the bottom of Table 37. *Variables are coded as 1 for the presence of the attribute and 0 for its absence (dummy variables.). The models included 17 predictors. The set of 5 predictors that referred to the main activities of the interviewees were excluded from the table presentation, as none of them is significantly associated to any of the dependent variables.

Predictors		Dependend variable: concerns with the ability of the organization to...										Depend. var: efficacy of organiz. in the management of human resources (Model 6)	
		attracting top researchers (Model 1)		maintaining top researchers (Model 2)		attracting top technicians (Model 3)		maintaining top technicians (Model 4)		support career development for young researchers (Model 5)			
		Coef.	p	Coef.	p	Coef.	p	Coef.	p	Coef.	p	Coef.	p
Socio-human capital of the respondent	manager*	-.449	.287	-.455	.266	-.221	.566	-.336	.393	-.567	.199	1.834	.408
	top professional position	.542	.230	.353	.398	.432	.253	.401	.303	.767	.161	-3.778	.148
	studied abroad*	.030	.941	-.204	.545	.211	.495	-.040	.915	-.269	.495	.847	.690
	worked abroad*	.179	.642	.286	.402	.125	.701	.328	.346	.042	.919	-2.655	.201
	degree of information on ELI	-.472	.021	-.402	.018	-.130	.461	-.251	.185	-.480	.014	2.871	.011
Control variables	works in Măgurele area*	-1.211	.020	-.320	.476	.450	.309	.009	.987	-.287	.552	2.679	.312
	age	-.056	.010	-.029	.107	.002	.916	-.006	.731	-.055	.011	.229	.037
	men*	1.233	.003	.538	.134	-.060	.850	.138	.687	.758	.058	-3.032	.144
Work organization (refrence others)	NUCLEAR	.416	.534	.514	.375	.064	.924	.292	.638	.013	.985	-2.058	.561
	LASER	2.089	.001	1.178	.034	.567	.327	.789	.176	.216	.761	-10.540	.007
	MATERIALS	-.603	.402	-1.209	.076	-.827	.222	-1.192	.086	-2.129	.018	4.904	.105
	Universities from Romania	1.150	.053	1.534	.003	1.491	.002	2.144	.001	1.464	.014	-14.645	.001
	constant	2.627	.027	1.626	.134	-1.288	.164	-.265	.786	2.069	.086	35.636	.001
	Nagelkerke R2	0.279		0.175		0.171		0.162		0.134		0.207	
	N	218		218		218		218		218		218	

A very specific factor influencing the perception on the efficacy of the organization to manage its human resources is the perception of the respondents on the higher education system in Romania (Table 40) to provide "enough highly-skilled graduates for the research needs in our country" (question A15_1 into RIFR). People who are dissatisfied with the ability of the Romanian education system to provide the high-skilled graduates the R&D needs in Romania also tend to be systematically dissatisfied with ability of their organization to effectively manage human resources in their organization. In a more simplified way, the respondents answered by with a statement such as "Yes, we are dissatisfied the way our organization manages the necessary stock of human capital, but this is largely also due to the fact that the education system in Romania does not provide the necessary output in terms of specialized graduates."

Table 40. Perceptions of Problems in the Management of Human Resources at the Organization Level and Perceptions of the Quality of the Higher Education System

Source: RIFR 2017. Reading example: 47% of the persons who believe that the higher education system does not provide graduates with adequate skills are also convinced that their organization does not have the ability to attract researchers of top potential.

Type of institutions function of their involvment in ELI activities	Persons supporting the view that high education system in the relevant areas for R&D in Romania (A15.1)	
	is good	is problematic
To attract researchers of top potential	26	47
To mentain researchers of top potential	38	47
To attract technicians of top potential	41	55
To mentain technicians of top potential	37	44
To support career development for young researchers	21	31

A total of 80% of the respondents regarded attracting and retaining top academic talent as the most problematic issue in human resources. An open-ended question provided valuable information about the factors that contribute to this problem:

- Unpredictability of funding: This is by far the most common answer. The basic financing (through the Nucleu Program) is not enough to ensure predictability. The funding for research for a public research organization is organized through competitions for short-term projects, and this type of financing is not sufficient for attracting top talent. Additionally, the lack of predictability in organizing such competitions and delays (the calendar of the competitions is not respected and a delay of at least 3 months occurs most of the time) are affecting the predictability of inflow of financial resources in the organization. In relation to the same topic, the quality of evaluators for national competitions is assessed to be low and mediocre, resulting in a lack of understanding of the content of the research proposals. In universities, there is no "Nucleu" program to support the research;
- Low financial incentives and opportunities abroad: Researchers are aware of the fact that much higher financial incentives are offered to researchers abroad. Researchers seem to believe that the majority of students leave after graduating high school and there are subsequent relocations after graduating undergraduate studies or doctorate programs;
- Non-harmonized legislation regarding the recognition of diplomas and relevant experience (a researcher mentioned that a senior researcher from abroad is only recognized as a level 1 Scientific Researcher (CS1) in Romania);
- Bad management and a lack of recognition of research teams;
- Criteria for professional promotion tend to be focused on non-applied research;
- Another factor that the researchers mentioned is the lack of a supply of quality talent from universities as well as a decrease in quality of the staff in universities;
- Graduates' low regard for research careers;
- Lack of role models;
- A handful of researchers mention that there are no incentives for non-top researchers to want to attract top talent;
- Lack of visibility/international recognition of Romanian teams in international networks.

For the lack of technicians, signaled as the main problem by only 10% of the sample, the factors involve the lack of vocational schools for specialized fields (chemistry, nuclear), the financial incentives, and opportunities in the private sector for better pay.

The above findings signal important issues for public policy. A more in-depth look at the pipeline for researchers in certain specialized fields is necessary. Moreover, some of the assumptions mentioned above were tested to determine whether they were incentives to pursue a researcher career in PROs in Romania. Both internal policies at the level of the institutes/universities and national policies can impact the attraction and retention of talent, which can affect the sustainability of investment in R&D.

To the degree the efficacy of the management of human resources is well measured, one can expect for it to be a significant factor in the potential professional mobility. It is exactly what we will do in the next section.

Effectiveness of Regulations in R&D at the Organization and Government Levels

Context: One way in which research can contribute to economic development is through the transformation of research outputs into new products or processes. In order for this to happen, research commercialization, which is a multi-stage process, needs the right conditions and incentives and complementary factors to succeed. Through the questions regarding technological transfer, we try to assess the researchers' perceptions on the effectiveness of internal policies.

Additionally, we attempt to test the assumption that research institutes see changes in the procurement policy at the government level (through the adoption of the new law on public procurement) as ineffective.

The respondents of the RIFR convert dissatisfaction with the work environment in R&D organizations into evaluations on the policies in the area (Table 41). The highest degree of dissatisfaction is associated with government policies on procurement related to R&D: More than one-third of the total interviewees consider that these government policies on procurement in R&D are inadequate, and more than half of them assess that this policy needs improvements.

The dissatisfaction at the organization level is much lower than at the government level, but three kinds of policies are considered here as highly dissatisfactory (inadequate or with needed improvements): those referring to the spin-offs, intellectual property, and licensing. The use of the research infrastructure and the collaboration with other organizations, which were discussed above, are among the most appreciated policies.

Table 41. Effectiveness of Regulations of Organizations and Government Policies in R&D

Source: RIFR 2017. Reading example: 37% of the total respondents consider that government procurement policies regarding R&D are inadequate. Non-answers and inapplicable answers are eliminated from the computations in this table.

What is your perception regarding the effectivness of the regulations provided by the following policies? (A22)		Policies...			Total
		are inadequate	need improvement	are effective	
Government procurement policy regarding R&D		37	53	10	100
Internal policy of your organization regarding...	The spin-offs	21	56	23	100
	The intellectual property	12	51	37	100
	The use of research infrastructure	11	31	58	100
	The licensing	10	51	39	100
	The collaboration with other organizations	7	31	61	100

More than 60% of the respondents perceive internal policies regarding spin-offs, intellectual property, and licensing as inadequate or as at least needing improvement.

A quarter of the sample does not report the percentage of royalties assigned to researchers in their respective organizations (even if they responded previously that their organization has an internal IP policy). This, in relation to the high variation of answers to the open-ended questions, is an indication of the lack of knowledge or incentives for researchers to know the internal policies in regard to IPR.

In response to the question "What is the main barrier your institution is facing regarding spin-offs?", some of the researchers acknowledge that they do not know, while others report different barriers:

- Lack of knowledge on the subject;
- General negative attitudes regarding spin-offs;
- Suspicion of conflict of interest;
- Lack of entrepreneurial spirit;
- Lack of knowledge on legislation and the legal framework for researchers;
- Lack of demand from the industry in Romania for applied technology;
- Lack of specialists.

An exploration into the roots of dissatisfaction on R&D policies starts with the cooperation experience (Table 42). Having such an experience consolidates the criticism of organization policies. About two-thirds (61%) of the interviewees who attended collaboration projects with other organizations are dissatisfied with their organization's policy on intellectual property, versus only 42% who are dissatisfied in the category of those that were not involved in cooperation actions. The situation is similar for the spin-offs and licensing policies, with a much higher dissatisfaction for those involved in collaboration projects compared to those who did not participate in such projects.

Table 42. The Degree Dissatisfaction on Different Policies in R&D Function of the Cooperation Experience (%)

Source: RIFR 2017. Reading example: 81% of the total respondents view government procurement policies on R&D as inadequate. Percentages are computed out of the total sample, including non-answers.

What is your perception regarding the effectiveness of the regulations provided by the following policies? (A22)		Cooperated with a company in the last four years (A19)		Total
		no	yes	
Government procurement policy regarding R&D		82	80	81
Internal policy of your organization regarding...	Intellectual property	42	61	54
	Spin-offs	37	58	51
	Licensing	33	51	45
	Use of research infrastructure	29	44	39
	Collaboration with other organizations	26	39	35

The highest degree of dissatisfaction in the organizations that are directly involved in ELI-NP concerns the policies of intellectual property (55%) (Table 43). In the institutions that are close to ELI-NP activities, the highest dissatisfaction is related to intellectual property and spin-offs (about 50% for each of them). In universities, the dissatisfaction is generalized and extended to intellectual property, licensing, spin-offs, and research infrastructure. The "other" category is very heterogeneous, with very small subsamples; consequently, the figures are too unstable to be analyzed.

The perceptions on the R&D policies are difficult to explain with the existing data from RIFR. An analysis operating with several predictors simultaneously (as in Table 39, for example) reveals the following:

Table 43. The Degree of Dissatisfaction on Different Policies in R&D Function of the Type of Organization (%)

Source: RIFR 2017. Reading example: 79% out of the total respondents consider that government procurement policies regarding R&D are inadequate or to be improved. Percentages computed out of the total sample, including non-answers.

What is your perception regarding the effectiveness of the regulations provided by the following policies?		Cooperated with a company in the last four years (A19)			
		directly involved in ELI-NP	close to ELI-NP activities	Universities	Other far from ELI
Government procurement policy regarding R&D		79	81	76	95
Internal policy of your organization regarding...	Intellectual property	55	50	54	71
	Licensing	44	37	56	57
	Spin-offs	47	51	54	57
	Collaboration with other organizations	35	26	39	62
	Use of research infrastructure	37	26	54	67

- Those who were involved into cooperation projects, compared to their colleagues that were not involved in cooperation activities with other organizations, were highly dissatisfied with each of the five policies at the organizational level on R&D topics (intellectual property, spin-offs, licensing, collaboration, and infrastructure) .
- Older researchers are more dissatisfied with the policy of intellectual property and with the government policy on procurement for R&D.
- The dissatisfaction with the licensing policy is higher for researchers working out of the Măgurele area.
- Specialists from universities are more satisfied with government policies on procurement in R&D compared to those working in research institutions.
- Specialists from the institutions that are close (bot not directly involved) to ELI-NP activities are more satisfied with the policies on collaboration and research infrastructure.
- Other factors that were tested in the same series of prediction models of satisfaction with R&D policies proved to be non-relevant (experience abroad, professional position, management position, and intentions to migrate).

For spin-offs, IPR, and licenses, the respondents to the research came across as unaware of the national or internal policies or the benefits associated with this topic. Such perceptions are related to the ineffectiveness of current legislation/incentives for technological transfer and the lack of knowledge in creating an entrepreneurial culture or working with specialists in the field.

Perceptions on the Impacts and Future Problems of ELI-NP

The perceptions of ELI-NP are rather well informed, as 16% out of the total respondents of the support survey for this research have been involved in activities related to ELI, 24% expressed that they were well informed even if not involved in ELI activities, and 38% viewed themselves as having "a rather general knowledge about ELI-NP" (22% have little or no knowledge about the project) (see details in Annex 1).

Respondents of the survey associated the main positive effects of ELI-NP with the scientific cooperation between Romanian and international scientific organizations, the advancing of fundamental research in Romania, and the development of the Măgurele area (Tables 10 and 11). Two areas are regarded as negatively influenced by ELI-NP: improving science-industry collaboration and "building the technological capacity of local firms in relevant fields through accessibility of sophisticated experimentation instruments."

Table 44. Perceptions on the Impacts of ELI-NP

Source: RIFR 2017

What is your perception of ELI-NP's impact in the following areas...? (B3)	Highly positive impact	Positive impact	No impact or negative impact	Total
Enchancing scientific cooperation between Romanian and international research organizations	46	47	7	100
Advancing Romanian fundamental research	43	49	9	100
The economic development of the Măgurele town and the surrounding region	41	47	12	100
Science discovery and progress in general	35	57	8	100
Attracting additional research funding from European and international sources	35	57	8	100
Improving the capacity of Romanian scientific communities in associated scientific fields	26	61	13	100
Advancing Romanian applied research	23	58	19	100
Enhancing scientific cooperation among research/academic organizations in Romania	20	60	20	100
Improving science-industry collaboration and technological transfer	16	46	39	100
Building technological capacity of local firms in relevant fields through accessibility of sophisticated experimentation instruments	14	49	37	100

Table 45. The Perceived Most Important Positive Effects of ELI-NP

Source: RIFR 2017.

The most impotant positive effect	%
Science discovery and progress in general	38
Advancing Romanian fundamental research	18
Enhancing scientific cooperation between Romanian and international research organizations	17
The economic development of the Măgurele town and the surrounding region	9
Attracting additional research funding from European and international organizations	9
Improving the capacity of Romanian scientific communities in associated scientific fields	5
Advancing Romanian applied research	2
Other	2
Total %	100.0
N	176

The degree of information on ELI-NP does not significantly influence the estimation of negative or positive effects of the project.[76]

The basic conclusion of a more in-depth analysis indicates that opinions on the impacts of ELI are significantly rooted in the professional spaces of the researchers, their migration abroad experience, and the perceptions they have on the institutional environment of their work (Table 12):

- Top professionals do not believe (statistically speaking, not case by case) that ELI will contribute to better scientific cooperation with international organizations or to attracting more international funds from abroad for R&D;

76 The statement is based on the analysis of correlations between the degree of information on ELI-NP, on the one hand, and on each of the 10 supposed effects, on the other hand. None of the 10 correlations is significant for $p = 0.10$.

Table 46. Factors Favoring the Quality of Perceptions on ELI-NP Impacts

Source: RIFR 2017. All the dependent variables are of dummy (indicator) type, coded as 1 for the presence of the attribute and as 0 for its absence. All of the five models are logistic regression, bootstrap results from 1,000 bootstrap samples. Demographics on age, gender, and residence in Măgurele were included into all the five models but are not presented here as none of them were significant for p<0.10.

Predictors		Dependend variable: perceptions on positive impacts of ELI-NP on ...									
		Scientific discovery and progress (Model 1)		Advancing Romanian fundamental research (Model 2)		Scientific cooperation with international organizations		Attracting additional international research funding		Economic development of the Măgurele town and area	
		Coef.	p	Coef.	p	Coef.	p	Coef.	p	Coef.	p
Socio-human capital of the respondent	manager*	-.195	.692	.364	.417	.543	.241	.281	.556	-.175	.721
	top professional position	.381	.467	-.104	.824	-.968	.063	-.593	.216	.023	.965
	studied abroad*	-.571	.200	-.138	.746	-.696	.111	-.284	.575	-.280	.530
	worked abroad*	.301	.554	-.061	.885	-.030	.945	-.478	.347	-.498	.280
	degree of information on ELI	.286	.305	.025	.928	.348	.247	.519	.070	-.066	.848
Work organization (refrence other)	NUCLEAR	.350	.576	1.136	.091	1.447	.051	.227	.748	.353	.622
	LASER	-.707	.306	.082	.901	.390	.550	-.198	.772	-.460	.500
	MATERIALS	-1.750	.017	-.291	.728	-.327	.690	-.042	.939	-.849	.271
	Universities from Romania	.933	.208	1.220	.072	.683	.315	.850	.202	.891	.215
Contextual perceptions	Efficacy of human resources in organization	.020	.219	.043	.014	.036	.062	.007	.686	.046	.011
	Positive perception of institutional supply of R&D funding	.000	.989	.000	.975	.001	.676	.004	.136	-.003	.271
	Proactive in terms of obtaining funding	.004	.101	.002	.383	.003	.252	.002	.309	.001	.723
	constant	-2.758	.079	-1.974	.199	-3.097	.070	-3.021	.065	-3.112	.067
	Nagelkerke R2	0.178		0.189		0.260		0.181		-.186	
	N	155		155		154		153		151	

- Surprisingly, people working in Măgurele are rather neutral, as opposed to optimistic or pessimistic, about the consequences of ELI. This means that the project per se and the information that is distributed on it are not yet sufficient for them to trust the future of ELI as far as it concerns the five types of consequences detailed in Table 12.
- The explanation for this surprising finding could be that perceptions on the future consequences of ELI activities are more related to other perceptions. Experts who are more inclined to believe in predominant positive consequences of ELI are, at the same time, persons who have a positive perception on the institutional efficiency in the management of human resources in R&D.
    - The data seem to suggest that higher trust in the good future of ELI derives not so much from information on ELI per se but from what R&D organizations did to effectively manage their human resources (attract and maintain good researchers and technicians, provide opportunities for professional promotion, etc.).
    - Another factor that plays in the same register is the proactive orientation of researchers in terms of obtaining competitive funds. Those who are already active in this direction are also optimistic about future positive consequences of ELI.

A better understanding of the content of positive expectations associated with ELI could be obtained by reading the answers to the open-ended question, "Why do you think that ELI-NP will impact this area the most?" (B4b), and by considering each of the aspects mentioned in Table 13. The most frequent expectation, i.e. that ELI-NP will provide better scientific cooperation between Romanian and international scientific organizations, is motivated by expectations clustering positive views on infrastructure, incoming foreign researchers in Romania, better circulation for cooperation abroad, and an international standards management. The weak point in this possible causal cluster seems to be, according to several respondents, related to the management: "The management has been focused so far on the financing of a team of researchers and people coming from among the relatives and friends of the employees of the Ministry … Due to the fact that by this management mechanism the other points will not be reached, by the pressure of completing certain projects and experiments, the only option to supply some results that are able to calm sponsors will be the cooperation with foreign research institutes that could carry out the respective experiments" (Respondent over 40 years of age, working in Măgurele, and having migration-abroad experience). In spite of such concerns, the majority of the respondents strongly support the positive expectation for international cooperation.

Several survey respondents explicitly supported the expectation of putting Măgurele on a spiral of development on the ELI-NP project. One example of answer in this logic is here: "Due to the aims of ELI-NP, more specifically attracting internationally recognized and highly-valuable researchers, in order to be able to keep this highly qualified personnel, the regional infrastructure must be improved, both the access roads and the transport means to the area, as well as the locally provided range of services" (Respondent under 40 years of age who worked abroad and has a job outside of Măgurele).

Once the question is more specified (M3: "What type of changes or improvements do you think are needed to make Măgurele a more attractive area for researchers?" (all of the respondents to this question work in Măgurele)), the answers are not more optimistic. On the contrary, their perspectives are conveyed in the following examples :

- "As Măgurele suffers from the same illnesses as the whole country, the improvements should be many and on a large scale" (person older than 40 years of age, working in Măgurele and having international migration experience).
- "1. Improvement of the transport infrastructure; 2. Cleaning the town and the adjacent areas; 3. Modernization of the town center, including building new hotels/restaurants and a new sports base; 4. Building a standard villa neighborhood with enough green space (at least 500 sqm); 5. Improving the level of the students of the School of Physics; 6. Carrying out an interdisciplinary training program for young researchers, with professor-researchers from all the institutes on the platform; 7. Carrying out integrating projects between the research institutes, based on specific competences" (person older than 40 years of age, working in Măgurele and having international migration experience).

The interviewees regard the future of ELI-NP not only in terms of possible impacts but also in terms of possible problems confronting the project. The scanning of the possible problems confronting the accomplishment of the project is done through the medium of a set of 15 items as specified in Appendix 3.

Apparently, data from Table A7 in the appendix suggest that the evaluations of the future problems for NP are different if the evaluators are working in Măgurele or out of Măgurele. Researchers from Măgurele are mainly concerned about "local entrepreneurial and innovation ecosystem conditions" and "access to competent local technical staff," and the researchers from other places are concerned about "access to local research funding" and " local entrepreneurial and innovation ecosystem conditions." In fact, if the analysis goes beyond the simplistic contingency table analysis (using correlation coefficients between working or not working in Măgurele and each of the 15 items of evaluating ELI future probable difficulties), the conclusion is that there are not significant different views on the problems facing ELI implementation if one compares researchers from Măgurele with those working out of Măgurele.

The perception of problems that ELI-NP will face is well structured in concerns referring to the availability of human resources, the availability of relevant local industries or suppliers in application areas, the regulatory environment for technological transfer, and cooperation with local research institutes. There is a low variation of these concerns by the type of organization and the type of activity or residence (results of regression analysis that are not shown here).

Practices and Their Subjective Dimensions

Cooperation Practices and Evaluations

The practice of cooperation with people from other institutions is high in the organizations having respondents in the survey on research and innovation (Table 13). About two-thirds of interviewees participated in an R&D project in which at least one company was involved in the last four years.

The patterns of cooperation are also highly differentiated according to institutions and professional characteristics. Managers and people in top professional positions typically cooperate much more than those who are not in such positions. The type of professional activity also has a very high impact on these patterns:

- Fundamental research, when practiced in isolation, without applied research or experimental development activities, brings very low proportions of cooperation;
- Applied research is also less favorable for cooperation with an out of own organization;
- People involved in experimental development activities, combined with any type of research, have higher shares of cooperating activities;
- People from universities are less cooperative than people from R&D institutions;
- Researchers directly involved in ELI-NP (see Table 60 in Annex 11) have a high rate of cooperation out of their organization but the rate is somewhat lower (62%) than the researcher in units that are close to ELI-NP activities.

The findings above are purely descriptive and do not include any evaluative connotations. The rate of involvement in between-organizations' cooperation derives from several conditions. It could be the content of activity, resources, network capital, mentality, etc.

Table 47. Percentage of People Who Participated in at Least One R&D Cooperation Project with Another Institution in the Last Four Years (A19)

Source: SRIF 2017. Reading example: 67% out of the total managers working in institutions directly involved in R&D for ELI-NP attended cooperation projects in the last four years.

		Manager		Top professional position		Total
		no	yes	no	yes	
Type of institution	Other far from ELI	75	85	56	100	81
	R&D close to ELI	62	85	53	83	69
	R&D directly involved in ELI-NP	58	67	67	58	62
	Universities	52	70	72	52	61
Type of activity	Fundamental & applied researchand and experimental development	75	100	81	92	88
	Applied research and experimental development	87	80	75	89	83
	Fundamental & applied research	71	73	59	80	72
	Only applied research	67	69	70	65	67
	Other	57	60	57	60	58
	Only fundamental research	8	17	15	6	10
	Total	60	75	61	70	66

The variations in the cooperation behavior of R&D researchers are difficult to explain with the data this survey provides. The only factors that proved to be relevant are related to age, doctoral programs, and the type of activity. The significantly higher rates of cooperation are for leaders of doctoral programs, youth, and researchers who practice complex activities (research and experimental development) or only applied research.[77]

Part of the above-mentioned relations are easy to identify in Table 14. Over 90% of total researchers that lead doctoral programs and are under 40 years of age have been involved in cooperation programs in the last four years. The rate of participation in cooperation projects is the minimum for the researchers who do not lead doctoral programs and are older than 40 years.

Table 48. Percentage of People Who Participated in at Least One R&D Cooperation Project with Another Institution in the Last Four Years (A19) by Age and Leadership Position in Doctoral Programs

Source: RIFR 2017

Leader of doctoral program	Age	% involved in cooperation programs
no	under 40 years old	65
no	over 40 years old	56
yes	under 40 years old	92
yes	over 40 years old	76
Total		66

Practices of cooperation are in interaction with perceptions (ideologies) of cooperation. Having a negative image on the possibilities to develop inter-organizational cooperation actions could reduce the intensity in the adoption of the cooperation practices. One can also expect the reverse effect of having the practices' impact on the ideologies in the area. Aspects of these interactions are introduced in the next paragraphs.

Respondents attribute the cooperation difficulties to three main causes: the industry's lack of interest (58%), high costs (55%), and the absence of interaction between R&D institutions and other companies (42%). Researchers with cooperation experience are much more dissatisfied than those without cooperation experiences in regard to the above-mentioned factors (Table 15).

Table 49. Perception of Difficulties Related to Cooperation with Other Companies Based on Previous Cooperation Experiences

Source: SRIF 2017. Reading example: 70% out of the total respondents with experience in cooperation believe that difficulties in cooperation with SMEs stem from the lack of interest from the industry.

In your opinion, what difficulties occur when collaborating with small and medium-sized companies? (A21)...	Cooperated with a company in the last four years (A19)		Total
	no	yes	
Absence of interest from industry	37	70	58
Finance and costs	25	70	55
Absence of interaction between RDIs and firms	29	48	42
Unclear questions from companies	5	14	11
The deadlines	3	14	10
Matching the technical level requested to fulfil the work	3	10	8
Other	4	7	6

77 The findings are supported by a logistic regression (not shown here) with involvement in cooperation programs as a dependent variable. The predictors are gender, leadership position in doctoral programs, and type of activity (see operationalization of the indicator in Table 41). The pseudo R2 is 0.238.

A supplementary analytical focus on the topic could help to support such policies. In terms of who views the interactions in this area as poor, Table 16 (below) provides additional information on the topic:

- Researchers from universities perceive the three basic reasons for poor cooperation (absence of interest from the industry, high costs, and the absence of interaction with firms) as sources of poor cooperation;
- Researchers involved in complex activities combining research and experimental development are the most sensitive to the difficulties of cooperation associated with the three main categories. It is very likely that their higher concern stems from the fact that they are also the most involved in cooperation activities. Their dissatisfaction derives from involvement in or a previous experience with cooperation.

Table 50. Perception of Difficulties Related to Cooperation with Other Companies by Type of Institution and Type of Activity

Source: SRIF 2017. Reading example: 76% of the total respondents from universities consider that difficulties in cooperation with SMEs come from the lack of interest from industry.

		Absence of interest from industry	Finance and costs	Absence of interaction between RDIs and firms	Unclear questions from companies	The deadlines	Matching the technical level requested to fulfill the work
Type of institutions	Universities	76	62	57	10	10	10
	R&D close to ELI	64	52	39	13	13	7
	R&D directly involved in ELI-NP	56	54	32	20	5	7
	Other, not connected to ELI	49	56	45	5	10	8
Type of activity	Fundamental and applied research and eperimental development	76	71	51	12	15	12
	Applied research and experimental development	66	58	45	19	9	13
	Other	60	63	47	10	10	3
	Only fundamental research	58	50	42	0	8	0
	Only applied research	51	53	35	9	14	5
	Fundamental and applied research	29	23	26	0	3	0
	Total	58	55	42	11	10	8

The analysis considering the simultaneous influence of several factors on the perception of difficulties related to cooperation could bring us closer to the following aims (Table 17):

- Higher cooperation experiences bring, as the previous analysis suggested, a higher awareness of the fact that the key obstacles for cooperation come from poor interaction with firms, high costs, and the industry's lack of interest;
- Higher concern about poor interactions with firms as a source for low cooperation is specific for those who do not work in Măgurele and consider the procurement policy as inadequate.
- Another possible impact of holding/having a positive opinion of an organization's human resources is improved cooperation prospects. The collected data suggest that those who are satisfied with the human resources of their organization are, at the same time, less concerned about the cooperation prospects of their enterprise as related to the industry's lack of interest in cooperation.
- Researchers working in Măgurele organizations are less concerned about the above-discussed obstacles for cooperation. This could be an effect of better resources for cooperation in Măgurele institutions as well as a better-structured culture for cooperation in their case.

Table 51. Explaining the Perceptions on Cooperation Difficulties

Source: RIFR 2017. Logistic regression models. Bootstrap standard errors.

Predictors		Difficulties of cooperation with SMS enterprises as dependent variables					
		Absence of interactions with firms (A21_6)		High costs (A21_1)		Absence of interest from industry (A21_5)	
		Coef.	p	Coef.	p	Coef.	p
Control variables	works in Măgurele area*	-1.100	.018	-.399	.365	-.551	.258
	age	-.002	.904	.001	.963	-.004	.823
	men*	1.437	.001	.254	.477	.635	.091
Work organization (refrence other)	NUCLEAR	.013	.987	-.181	.796	1.273	.058
	LASER	1.030	.122	.682	.283	.332	.636
	MATERIALS	2.706	.003	.280	.724	1.108	.152
	Universities from ROmania	.031	.967	-.563	.321	-.418	.448
Contextual perceptions	Efficacy of human resources in organization	-.021	.187	-.022	.116	-.030	.038
	Equipment in organization is operational	.052	.907	-.293	.555	1.360	.004
	Equipment in organization is up to international standards	-.084	.733	-.074	.779	.089	.726
	Equipment is not old	-.326	.302	-.317	.288	-.008	.967
	Procurement policy inadequate	1.060	.035	-.182	.706	.398	.446
Cooperated with other organization		1.178	.004	1.911	.001	.903	.021
	Constant	0.020	.992	1.876	.274	-3.979	.027
	Nagelkerke R2	.366		0.296		-.232	
	N	211		211		211	

Supply and Proactivity in the Funding of Research Activities

Previous sections introduced three of the major conditions in R&D efficacy related to infrastructure, human resources, and organizing regulations. A forth component of the institutional environment for R&D activities related to funding. The survey investigated the perceptions of the interviewees on seven items related to funding (Table 18). A simple view on the below table indicates a clear break in the degree of satisfaction or of positive evaluations in the area: The proactive behaviors of the researchers are evaluated more effectively than the organizational supply. More than 80% of the interviewees declared that they feel "highly motivated to look for competitive project funding" for their research. This is why they are "actively applying for national competitions" or for "Horizon 2020 funds." More than 60% of them feel that they have "full control over the funds" they are receiving from these competitions.

Table 52. Positive Evaluations about the Funding of Research Activities in Own Organizations

Source: RIFR 2017. Reading example: 45% of the total respondents consider that nucleus public funding in their organization is stable and predictable. Percentages computed out of the total sample, excluding non-answers.

Dimensions in funding evaluations	To what extent do you agree with the following statements about the funding of research activities in your organization? ...	Type of organization				
		ELI-NP involved	Close to ELI-NP	Universities	Other far from ELI	Total
Proactive behaviours for competitive funding	Researchers in your organization are actively applying for national competitions	99	98	95	81	96
	Personally, you feel highly motivated to look for competitive project funding for your research	73	90	88	71	82
	Researchers in your organization are actively applying for Horizon 2020 funds	59	74	62	62	66
	Researchers in your organization have full control over the funds they mobilized from these	44	76	77	57	63
Adequacy of institutional funding for research	Part of the funding in your organization is coming from delivery of high tech services to firms	46	59	21	57	47
	The funding mechanisms for your institute are appropiate for conducting effective research	42	43	26	57	41
	The Nucleus public funding for research in your organization is stable and predictable	45	41	18	57	40

On the supply side, the satisfaction is much lower. Only 40% of the interviewees are of the opinion that "The Nucleus public funding for research in ... organizations is stable and predictable." Moreover, the percentage of those who view the mechanisms for their institute as "appropriate for conducting effective research" is also around 40%. It is somewhat higher for (47%) the percentage of the persons declaring that part of the funding in their organization "is coming from the delivery of high tech services to firms."

The perceptions among researchers on pro-activity components of evaluations are consistently variables within the same type of organization. This is the case, for example, for researchers within organizations directly involved into ELI-NP activities. Over 70% of them feel highly motivated to look for funding for competitive projects, but only 44% feel that they are in full control of the funding after receiving it. The gap between motivation for applications and the feeling of controlling the obtained funds is somewhat smaller for other types of organizations (indirectly involved in ELI-NP or from universities) but goes in the same direction.

For target purposes, policy makers could consider the reduction of the percentage gap between being motivated to obtain competitive projects and the lower percentage of those who feel they have full control of the obtained funds. It is very likely that dissatisfaction associated with having limited control over obtained funds is a source of demotivation for new applications for competitive projects.

The perceptions of researchers in searching for competitive funding could be summarized, as Table 18 suggests, in two dimensions or indices regarding a) the supply of a normative frame for funding and b) proactive behaviors "when searching for funds."[78]

The most proactive researchers in accessing competitive funding are (Model 1, in Table 19) young managers that worked abroad. It is also specific for these proactive-oriented researchers in obtaining funding to work in institutions with an effective management of human resources.

Researchers giving better evaluations to institutional supply of funding (Model 2a) are less specified by their profile. This is normal, considering the fact that there is a kind of generalized dissatisfaction with the institutional arrangements for accessing competitive funds. They are persons that work in research institutions (not in universities). The good assessment of the management of human resources in their organization(s) goes together with the good assessment of institutional arrangements to facilitate access to R&D funding. Model 2a in Table 53 shows that being proactive-oriented to obtain funding goes together with a high criticism of institutions for critical mechanisms to access funds for research.

In spite of the rather negative evaluations of the institutional arrangements for accessing competitive funding, large shares of respondents consider that there is consistency between the competitive funding of the projects and the scientific programs of their institutions (29% to a great extent and 49% to some extent).

78 The two indices were constructed as factor scores from the seven indicators in Table 19 (all the items of question A13 in the questionnaire, without any recoding. Their grouping by factors is exactly as it appears in Table 18. Technically speaking, it is an acceptable factor analysis: PCA, VARIMAX, KMO = 0.68, principal components explaining 52% out of the total variation in the correlation matrix. The two indices (factor scores) are multiplied by 100 for easier interpretations in the derived tabulations.

Table 53. Predicting Perceptions on Funding for R&D

Source: RIFR 2017. OLS regressions. The dependent variables are the two factor scores as described in the footnote on factor analysis, multiplied by 100, with a variation between -270 and 280. Significant predictors for p = 0.10 are highlighted. Positive and negative signs of the regression coefficients indicate positive and, respectively, negative relations between the dependent variable and predictors. Bootstrapping estimations of standard errors.

Predictors		Proactive oriented in getting funding (Model 1)		Positive perceptions on institutional supply of funding (Model 2a)		Positve perceptions on institutional supply of funding (Model 2b)	
		Coef.	p	Coef.	p	Coef.	p
Socio-human capital of the respondent	manager*	36.661	0.17	5.747	.729	12.945	.419
	top professional position	26.591	.132	-6.628	.666	-1.407	.913
	studied abroad*	14.786	.295	-4.257	.751	-1.354	.913
	worked abroad*	26.210	.073	-23.853	.097	-18.707	.167
	degree of information on ELI	-1.508	.847	10.534	.138	10.238	.164
Control variables	works in Măgurele area*	6.479	.721	-17.782	.364	-16.510	.409
	age	-1.252	.105	-.389	.572	-.635	.355
	men*	-19.789	.163	-6.887	.651	-10.772	.467
Main activity (reference others)	research & experimental develop.	57.423	.169	43.741	.273	55.015	.189
	fundamental & applied research	39.463	.321	28.261	.481	36.009	.389
	fundamental research	53.758	.211	18.319	.642	28.873	.503
	applied research	62.380	.129	66.879	.079	79.127	.058
	applied research & experimental development	51.295	.264	61.051	.112	71.122	.089
Work organization (refrence others)	NUCLEAR	-46.389	.055	27.876	.188	18.768	.382
	LASER	-62.860	.004	-24.649	.276	-36.991	.128
	MATERIALS	8.913	.738	5.362	.856	7.112	.784
	Universities from Romania	19.092	.464	-74.958	.002	-71.209	.001
index of the efficacy in the managemnt of human resources at organization level		2.249	.002	2.712	.001	3.154	.001
cooperated with other organizations		5.894	.708	1.641	.927	2.798	.844
proactive-oriented in getting funding						-.196	.006
	constant	-127.694	.012	-153.033	.004	-178.104	.002
	R2 (Nagelkerke or for OLS in the model 5)	0.265		.347		0.374	
	N	201		201		201	

(Re)organizing R&D using Spin-Offs, Technological Transfer, and Entrepreneurship

The awareness of the spin-offs practices is rather limited in the surveyed communities (17%). It is mainly for those that worked abroad, are directing doctoral programs, and do not work at Măgurele institutions for R&D that the awareness on spin-offs is spread.[79] Better connections with international communities of practice[80] in R&D seem to be a source for awareness regarding the use of spinning off.

Those that were not aware of "any tech that have been licensed to or spin off" (A23) from their own institutions were asked, as a part of the survey, "What is the main barrier your institution is facing regarding spin-offs?" (A23a). The list of answers to the question and the associated frequencies are in the table below (Table 54, regrouped answers). According to the interviewed persons, while poor information and a lack of experience in the area are factors, other factors exist as well, such as poor management and entrepreneurial culture, a certain deficit of creativity to produce applied researches with results that are stimulating for the spinning off, a lack of strategies in the management of organizations, low market demand, etc.

Table 54. Barriers to Promoting Spin-Offs

Source: RIFR 2017.

What is the main barrier your institution is facing regarding spin-offs?	%
Poor management and entrepreneurship culture	16
Regulations, laws	13
Costs, financing	9
Poor interest of researchers and managers	8
Poor information	6
Lack of experience	5
Bureaucracy	5
Poor innovation capabilities	5
Market demand	4
Poor targeted research	2
Lack of policies or strategies	2
Other	9
Do not know	16
Total %	100
N	128

The perceptions on institutional barriers to spin-offs are highly differentiated between those that lived abroad for work or study and those without migration experience. Former migrants connect difficulties discouraging spin-offs to poor management, poor entrepreneurial culture, and inadequate regulations. The reading of the detailed statements of interviewees suggests the existence of a kind of vicious cycle: Managerial culture seems to be, predominantly, reluctant to the idea of spin-offs. This is consolidated by the widespread mentality of the researchers without migration experience abroad that "spin-offs are not good;" regulations that do not encourage the emergence of spin-offs come from the management but also from the government. "People (who are not managers–our specification) feel it is risky, due to complicated regulation, and lack of expertise in starting a spin-off company." Some managers are not only unprepared to stimulate spin-offs but prefer to interact with "phantom companies providing functional and administrative services with 'friends' of leadership of remarkable incompetence." The dominant answer of the non-migrants to the open-ended question on barriers to spin-offs is "I do not know."

The situation is much better with the interest of organizations for technological transfer (patenting and licensing) and contracting research projects with the industry. More than half of the interviewees

79 Findings from a multivariate regression analysis that is not presented here, using predictors from Table 19 (except the last three ones in the list) and awareness of spin-offs as dependent variable. Pseudo R^2 = 0.20.

80 Wenger, E. (1999). Communities of practice: Learning, meaning, and identity: Cambridge University Press.

noted that such practices are criteria for promotion in their institutions (Table 21).

A very important aspect in the discussion on what makes the difference in the management favoring performance R&D is related to this connection between achievements in technology transfer and professional promotion. This is a managerial practice that should be encouraged. It is present especially for the case of institutions that are directly involved in ELI-NP. The type of activity in R&D is not associated in any way with the professional promotion function of achievements in technological transfer.[81]

Table 55. Barriers to Promoting Spin-Offs

Source: RIFR 2017.

Institution and activity		Are achievements from technology transfer (such as patenting, licensing) and volume of contract research with industry criteria for promotion in your institution? (A24)			
		no	yes	no answer	Total
Type of institution	Directly involved in ELI-NP	65	27	8	100
	Close to ELI-NP	61	30	10	100
	Universities	41	54	5	100
	Other far from ELI	38	57	5	100
Type of activity	Fundamental research	61	26	13	100
	Fundamental and applied research	61	28	10	100
	Research and experimental development	59	41	0	100
	Applied research	51	44	5	100
	Applied research and experimental development	47	43	10	100
	Other	58	33	8	100
	Total	57	36	8	

Potential Mobility to Other Institution or Abroad

About 9% of the total interviewees commented that they would like to move to another institution (i.e., work place, in Romania and abroad) in the next two years. A similar percentage (10%) would like to migrate abroad from Măgurele institutes in the same period. The potential migrants abroad, for work or for studies, out of the total sample, is approximately 19%. These job and cross-country movements are of great interest in the context of this analysis as markers of job or local dissatisfaction.

To the degree that the measures we constructed for the perception of the quality of equipment and for the efficacy of human resources management in organizations are valid, one could expect having them as relevant predictors of job and territorial mobility. The hypothesis is confirmed by the data in Table 22:

- The lower the value of the index of human resources efficacy at the employment organization, the higher the probability of migration abroad as well as for the potential job mobility;
- The intention to leave the Măgurele area to another country in the next two years is favored by those with previous working abroad experience . This is a specific characteristic of the mobility abroad from Măgurele;
- Potential migrants living in other parts of Romania, different from Măgurele, are more dependent on their studies abroad for this option. The probability to have a migration intention is higher for those who studied abroad and are not from Măgurele;
- People who are better informed about ELI activities tend to have stable jobs and residences in Romania. It seems that this is not necessarily important information, though it is evidence of increased involvement in ELI activities;

81 Findings that are grounded on an analysis of adjusted standardized residuals not shown in the text.

Table 56. Predicting Intentions of Institutional Mobility and of Migration Abroad

Source: RIFR 2017. Logistic regression models. Bootstrapped standard errors.

Predictors		Intention of institutional mobility (C9) (Model 1)		Intention of migration abroad from Măgurele (M2) (Model 2)		Intention to migrate abroad from Romania (C7) (Model 3)**	
		Coef.	p	Coef.	p	Coef.	p
Socio-human capital of the respondent	manager*	36.661	0.17	5.747	.729	12.945	.419
	top professional position	26.591	.132	-6.628	.666	-1.407	.913
	studied abroad*	14.786	.295	-4.257	.751	-1.354	.913
	worked abroad*	26.210	.073	-23.853	.097	-18.707	.167
	degree of information on ELI	-1.508	.847	10.534	.138	10.238	.164
Control variables	works in Măgurele area*	6.479	.721	-17.782	.364	-16.510	.409
	age	-1.252	.105	-.389	.572	-.635	.355
	men*	-19.789	.163	-6.887	.651	-10.772	.467
Work organization (refrence others)	NUCLEAR	-46.389	.055	27.876	.188	18.768	.382
	LASER	-62.860	.004	-24.649	.276	-36.991	.128
	MATERIALS	8.913	.738	5.362	.856	7.112	.784
	Universities from Romania	19.092	.464	-74.958	.002	-71.209	.001
index of the efficacy in the managemnt of human resources at organization level		2.249	.002	2.712	.001	3.154	.001
	constant	-127.694	.012	-153.033	.004	-178.104	.002
	Pseudo R2	0.265		.347		0.374	
	N	201		201		201	

- Institutional and cross-country mobility is important for the younger specialists.

All the above reasons of professional mobility or migration abroad are inferred by the results of the regression analysis. The causal picture of the process could be detailed if one considers the motivations mentioned by the potential movers to other institutions. Even if the absolute figures are small (19 potential movers to other institutions), the hierarchy of frequencies for reasons to move gives some information (Table 23). Work organization, for example, as a key reason to move, is part of the efficacy in the management of human resources at the organization level.

Table 57. Reasons to Move to Another Institution

Source: SRIF 2017. Total persons intending to work for another institution in the next two years - 19

Reasons for institutional mobility	Number of choices for the reason (several choices possible)
Work organization	14
Training	9
Research infrastructure	8
Promotion opportunities	8
Income	7
Work content	3
Other	4

Is It Preferable to Stay in Măgurele or to Leave Măgurele?

The dynamics of residence in Măgurele is expected to be affected by the dynamics of ELI-NP, at least for those working in R&D. The survey data could not provide information on the prospects for coming to Măgurele from other localities but did offer some information on out-migration from there. About 58% (N = 130) of the total respondents in this survey on R&D are working in Măgurele. During the survey they were asked, "If you would have the option, would you work in Măgurele, or would you prefer to work somewhere else?" (M2). Approximately three quarters of them (73%) were in favor of the continuity of working in the same place. About one-fifth (17%) would like to migrate abroad, and one-tenth (9%) of them would like to migrate somewhere in Romania.

Why is it that a rather large segment of researchers working in Măgurele intend to migrate abroad? The analysis in Table 14 already provided part of the explanation: Their potential migration is significantly associated with their dissatisfaction with the management of human resources and with the quality of infrastructure in the work organization. The analysis also considers age and migration experience, age and migration experience—for instance, youth that lived abroad are more inclined to emigrate.

A reconsideration of previously analyzed data provides additional information on the specific profile of the researchers working in Măgurele:

- They are more satisfied, compared to the others in the sample, with the abilities of their organizations to attracting top researchers. They do not feel that they have better or worse equipment for work compared to their colleagues working out of Măgurele.
- They do not perceive finances and costs as a difficulty source for cooperation with SMEs. On the contrary, they perceive lower costs than their colleagues working out of Măgurele.
- They have a rather negative perception on institutional arrangements in regard to accessing competitive funding.

What would make Măgurele more attractive for researchers?The open-ended question (M3) was asked at the end of our R&D questionnaire. The topic of the question proved to be of high relevance for the interviewees: More than 100 of the total respondents from Măgurele gave their views.

The needed improvements in the view of respondents mainly refer to easy access to Bucharest, social infrastructure, housing and local administration in Măgurele, new management in R&D institutions, and a better general institutional frame. Below (Table 24) are illustrations of these requirements to present Măgurele as a town for researchers.

It is difficult to establish a hierarchy of needs as they are expressed in fuzzy terms and respondents are simultaneously asking for several changes for a better life. The basic needs as expressed by the first suggested changes in the sentences are (in the decreasing frequency) related to institutional changes, transport infrastructure, social (basic) infrastructure, and public transport (connecting Bucharest to Măgurele, in particular).[82] A better Măgurele for researchers would mean, according to this reading of the qualitative data, consistent improvements in transport infrastructure, public transportation, social services, and infrastructure and public management in the local administration and local research units. This is also what the selections from Table 24 are illustrating.

82 Thanks to our colleague Marcel Ionescu Heroiu, who contributed to clarifying the complexity of needs to increase the attractiveness of Măgurele as a place of living for researchers.

Table 58. Challenges to Making the Măgurele Area More Attractive for Researchers Reasons to Move to Another Institution

Source: SRIF 2017. Total persons intending to work for another institution in the next two years - 19

Easy access to Bucharest	Infrastructure of transport and the public transport between Măgurele and Bucharest.
Social infrastructure in Măgurele	To make the town attractive for young families (school, kindergartens, parks, sport grounds, cultural houses, etc.)
	The Bucharest-Măgurele road is a disgrace. No subway, the general public uncleanliness and the transport possibilities (microbus or RATB) are a big minus.
	Măgurele needs a better infrastructure (streets, an ecological public transportation system, modern and affordable apartments, cleaner streets, and more English schools for the children of foreign researchers who work at ELI-NP.
	There are no facilities exclusively dedicated to researchers, such as a cafeteria, a kindergarten, a relaxation center with a fitness center and pool, etc.
	Schools with a more motivated and involved teaching staff.
	Development and improvement of the student hostels; connection of the airport; transport by the railroad on the ring line.
	Construction of a conference center to be used jointly by all the institutes on the platform.
Housing	Many of the young researchers who remained in the area and tried to build a house still have no electricity after 5 or 6 years. Fictive works are made. The houses are completed, but because they cannot connect to the electricity grid, they still rent a place in Măgurele or in Bucharest and have to commute.
Local administration	The illnesses of Măgurele are the illnesses of the local administration in Romania.
Changing institutional frame in R&D institutions	Depoliticization of the management.
	Uniform regulation of holding management positions in research and the organization of transparent contests with commissions from abroad for directors.
	Real control of the coordinating ministry over the activity of the research and development institutes
	Limitation of the control of universities over the research budget.
	Establishment of de facto conflict of interests in the national research and development institutes towards the employees of the ministry and the funding agencies
	Elimination of honorific, political positions within the Măgurele Platform
	Using reason and responsibility in opening future "results" or comparisons with other research areas in the world
	Total foreign management.
	Changing the management in the institutes on the platform.
	Decent wages.
	Researcher models are needed, as well as a new understanding of the research process.
	Freedom from the yoke of business-like efficiency and economy.
	Changing how the research staff is appraised and promoted.Direct access to purchasing, to research equipment.
	Independence of thought and expression without fear of professional and human consequences.
	Re-organization of the research structure.
	Let's learn to communicate scientifically, to get closer as humans.
Restructuring in the institutional frame for R&D	Predictability of funding; stable and clear legislative framework; less red tape; the system of funding and access to domestic and foreign funds, the lack of reliable funding, change of the rules from one competition to another, enormous time for assessment, and not lastly the management of the institutions
	Ensuring a stable and predictable fiscal, legislative, and economic environment

Conclusions: Connecting Perceptions, Behaviours and Policies

The executive summary introduced the research and included objectives, structuring frames, and key findings presented in analytical categories. Here, in this final section, we focus more on interrelations between perceptions and behaviors or between different perceptions or different behaviors. The conclusions are more relations- oriented.

Perceptions on the positive and negative impacts of ELI-NP as strenghts and weaknesses of the project that could be relevant for policies in the domain

Approximately 40% of the total interviewees consider themselves to be well informed about ELI-NP due to either direct or indirect involvement in the specific activities of the project (see details in Annex 2). The highest positive expectations are related to advancing the Romanian fundamental research, better scientific cooperation between Romanian and international scientific organizations, and the economic development of the Măgurele town and area. The list of positive expectations, though at a lower frequency, continue with regard to attracting additional research funds in Romania from international organizations, advancing Romanian applied research, and fostering cooperation between R&D units and the industry in Romania. A more detailed analysis on who supports positive and negative views could indicate some points of concern:

- Top professionals are pessimistic about attracting international funds and establishing better cooperation with international organizations.
- Leaders of doctoral programs and persons that intend to go abroad are pessimistic about ELI's positive impact on Romanian fundamental research.
- Those who worked abroad or intend to leave the country are less convinced that Măgurele will become the next Silicon Valley. Interviewees' statements clearly convey the reasons for pessimism towards the economic future of Măgurele region.

Roads to R&D policy as advised by R&D practitioners

The table below, detailed in the body of the report, provides information regarding what survey respondents consider as inadequate in the regulations for some specific R&D policies.

Source: RIFR 2017. Reading example: 58% of the total respondents that attended cooperation projects with another organization consider that the spin-offs policy of their organization is unsatisfactory (inadequate or needs improvements). Percentages computed out of the total sample, including non-answers.

What is your perception regarding the effectiveness of the regulations provided by the following policies? (A22)		Percent of dissatisfied respondents on specific regulations in R&D, in the reference category		Total
		did not attend a cooperation project	attended a cooperation project	
Government procurement policy regarding R&D		82	80	81
Internal policy of your organization regarding...	Intellectual property	42	61	54
	Spin-offs	37	58	51
	Licensing	33	51	45
	Use of research infrastructure	29	44	39
	Collaboration with other organizations	26	39	35

An overwhelming majority assess that government policy on procurement in R&D is inadequate or needs improvements. As far as it concerns the policies at the level of their organizations, the dissatisfaction is lower but consistent. More than 50% of the total interviewees regard the policies of their organizations on intellectual property and spin-offs as dissatisfactory (i.e., as inadequate or needing improvements). The dissatisfaction with policies regarding licensing, research infrastructure, and collaborations with other organizations are also considered as dissatisfactory to a large degree (between 35% to 45%).

There is a large gap concerning the dissatisfaction with the organization policies. The researchers who were involved in cooperation projects with other organizations are much more dissatisfied with the policies of their organization.

Applications to obtain funding are viewed as more significant than economic behaviors. They have strong creative and competitive components.

A large share of interviewed researchers (80%) stated that they "feel highly motivated to look for competitive project funding" for their research projects. This is one of the indicators of the proactive orientation of obtaining research funding by competitive projects in for the measurement of the attitude of proactive orientation in attitudes in the practice of R&D. Its roots are not strictly personal, coming from education or context at a very general level. Proactive researchers who seek funding for competitive projects typically have one or more of the following characteristics :They are from universities and research institutes that are close to ELI-NP activities;

- They work in areas of applied research or are practicing a mix of experimental development and research;
- They work in institutes that effectively manage human resources;
- To a large degree, they are persons that studied abroad;
- They are managers;
- They are all of the above, and are more likely to be young women.

The motivation and creativity associated with applying for funds include a mix of education in highly competitive environments, employment in well-managed institutes, and involvement in frames marked by experimental development or applied research.

The findings for this particular case could suggest that having a large number of very active researchers apply for competitive funds in an institute involves a good management of human resources, promoting communities of practice with large contacts with other performant professional communities, and also stimulating activity mixes that involve applied research and experimental development.

Difficulties of cooperation between R&D and industry units are also rooted in national procurement regulations and the quality of the management for human resources at the level of research and development organizations.

Understanding the equation for cooperation could also help to increase the performance in this area. The practice of cooperating with researchers from other organizations is widespread (66% of the total interviewees) and highly differentiated according to the type of institution and the activity. The dissatisfaction with the difficulties in that practice is much higher for those who participated in cooperation projects. The key areas of discontent are related to finance and costs, absence of interest from industry and poor interactions between R&D organizations and firms. Respondents perceive management and regulations at the government level as key factors in the process:

- The inadequate government policy for procurement in R&D is perceived as a contributing factor to the industry's lack of interest regarding cooperation with R&D units;
- A good management of human resources at the organization level contributes to the reduction of difficulties in cooperation regarding interactions with firms and the interest from the industry in cooperation. The finding implies a low interest on the part of the industry to cooperate with R&D units comes not only from industry per se but also from the quality of human resources in the research and development organizations.
- Higher levels of aspirations for better cooperation at the level of youth and potential migrants contribute to higher dissatisfaction with obstacles for good cooperation between R&D and firms.
- Dissatisfaction with the costs of cooperation is lower for those working in Măgurele organizations.

Focusing on cooperation patterns brings supplementary institutional factors into the picture, in addition to what was mentioned in relation with the determinants of the propensity to finding funding through competitive projects. The inadequate government policy for procurement in R&D is explicitly identified as a significant predictor for lower performance in inter-organizational cooperation.

A lack of effective human resources management and a negative perception on the quality of the work infrastructure result in the higher probability of leaving the organization for a job abroad.

The attractiveness of organizations for their employees is another key indicator of the quality of the work environment. A total of 19% (one-fifth) of interviewees would like to go abroad, for study or for work, in the next five years. The intention to leave Măgurele for another country (for an unspecified time horizon) does not differ significantly from the figure for the whole sample. The level of potential migration is less important in this frame as far as we cannot assess the representativeness of the sample. What does count for the diagnosis analysis is the identification of the predictors that counts in a significant way for the potential institutional mobility and for the potential emigration:

- A positive perception of the quality of human resources management is a discouraging factor for any recorded type of territorial mobility (emigration from Romania, emigration from Măgurele, and relocating for a job in Romania).
- Potential migrants abroad are stimulated to be migrants not only because of bad or inadequate management in their organization but also because of a negative perception of the quality of the work infrastructure in their organization.
- ELI-NP per se comes across as a stability factor that provides better information about ELI, which significantly contributes to reducing the probability of mobility/migration abroad. For work or for study abroad.

At the individual level, as expected, age and migration experience are significant factors. Younger persons who already worked abroad are more inclined to leave.

Stemming from the issues, there are two structures and three patterns of behaviors that are less functional.

The whole set of answers to a large array of topics when filtered by the analytic grid of this report brings us to the conclusion that the diagnosis of R&D problems is formulated in five key terms by those working in the area. There are three large families of action or behavioral problems that derive from interrelations among them as well as from two key structural sources. Frequently, researchers referring to management, creative experiences, and cooperation patterns locate the behavior problems. As previously mentioned, researchers, based on their quantitative and qualitative answers, are interconnecting these three families of behavioral problems among them but are also connecting them to regulations and financing related to regulations and financing. The way the five families of problems—i.e., poor management, a lack of creative experiences, poor cooperation, inadequate regulations, and those related to financing—emerge and interrelate derive from some basic characteristics of researchers and their organizations: types of institutions, type of activity, migration abroad experience, professional and managerial position, and demographics (age, gender, and residential location in Măgurele or in another area). The summary of the analysis results will follow lines derived from the above-described scheme of approach.

In consideration of policy makers with an interest in this study, it is important to mention that there is no principal cause and no unique hierarchy of problems to be followed in the strategic approach for policy regulations in the area. A hierarchy of problems and of solutions could be generated only after a larger survey on the whole community of R&D people in Romania. Policy makers could benefit from this exploratory study reading its conclusions as well as other detailed findings in the report.

Appendix 1: Clustering Respondents' Institutions

The 224 surveyed persons are distributed in about 30 institutions ranging from 2 to 34 respondents. Some of the procedures to identify patterns of behaviors or attitudes will be identified by a simple crosstab analysis or by a multivariate analysis. For all of them, an institutional context of practices in the area of RDI is important. However, a number of small cases in the analytical categories for independent variables have negative effects on the reliability of the approach. This is why it is necessary to regroup the respondents' institutions by clusters. The hypothesis we are using for this regrouping is as follows:

a) Behaviors and attitudes in the area of RDI are significantly dependent on the human capital stocks that could be specific for the employment organization;

b) The proximity of the employment institution to ELI and university activities favors higher human capital stocks of a probable positive impact on performances in the RDI domain.

The 41 interviewees working in universities form, according to the above methodological hypothesis, one of the groups for which we are searching. The proxy variable we are using to determine the rest of the grouping is constructed from the answers to the question, "To what degree are you informed about the Extreme Light Infrastructure – Nuclear Physics (ELI-NP)?".

The self-estimated degree of information on ELI-NP seems to be a good measure of information about the subjects related to the topic (Table 59). The last column of the table below indicates that 16% of the interviewees consider themselves as being "very familiar" with ELI-NP activities. The hierarchy of opinions on the topic, as noticed in the first column of the table, is fully supported by the hierarchies of activities related to ELI, as mentioned in columns B, C, and D of the same table. Those that stated they are highly familiar with ELI-NP activities are, at the same time and to a large degree (figures into the first row of the table below), the people that read White book of ELI, collaborated with it, or have applied to ELI calls for proposals.

Table 59. Self-Estimation Degree of Information on ELI-NP Activities

Source: RIFR 2017, April-May 2017.Reading example: 16 % of the 224 interviewees are "very familiar" with the activities of ELI-NP, according to their self-estimations.

"To what degree are you informed about the Extreme Light Infrastructure - Nuclear Physics (ELI-NP)?"	Means of those in the row category declaring...				Distribution of answers to the question in column A, out of the total sample (%)
	I know about the scientific program in the ELI-NP Whitebook (1 yes, 0 no)	I already collaborated with the ELI-NP team (1 yes, 0 no)	I have applied to ELI-RO calls for proposals through the Institute of atomic Physics (1 yes, 0 no)	I have the intention to develop research projects in relation to ELI-NP (1 yes, 0 no)	
A	B	C	D	E	F
I am very familiar as I've been involved in various activities of ELI-NP.	0.81	0.78	0.53	0.58	16
I am well informed, even though I haven't been involved in ELI-NP activities.	0.56	0.07	0.15	0.48	24
I have general knowledge about ELI-NP.	0.21	0.05	0.01	0.30	38
I have very little knowledge about ELI-NP.	0	0	0	0	17
I have almost no knowledge about ELI-NP.	0	0	0	0	4

There are 176 interviewees that have a rather general knowledge on ELI. Only they have been interviewed by the B, C, D, and E questions from the columns of the table. Only 36 of them declared that they are very familiar with ELI-NP and only a share of 0.81 of them (=29 interviewees) read the White Book of ELI-NP.

If one considers the "natural breaking points"[83] in the series of hierarchies from columns B, C, and D from Table A.1, one can go with the proposal of getting a synthetic variable of information degree on ELI with the categories of highly informed (regrouping "very familiar" and "well informed"), medium informed (= "rather general knowledge") and low informed (very little and no knowledge).

83 The concept of a "natural breaking point" is borrowed from the procedures used to segment continuous variables in MAPINFO.

Table 60 presents the distribution of interviewees by employment institutions and the above-mentioned three categories of information on ELI-NP.

Each source's institution for providing respondents to the WB-ELI survey is allocated to one of the four categories of the table below and include two criteria RDI- university -other and the share of respondents in the categories of high-medium-low information on ELI for non-university organizations (see Table 60).

Table 60. Distribution of Survey Respondents by Types of Employment Institutions

Source: RIFR 2017.

Type of institution	Institutions	Individual degree of information on ELI			Total	
		1,00 high	2,00 medium	3,00 low	per institution	per category of institutions
RDI directly involved in ELI-NP	Horia Hulubei National Institute for Physics and Nuclear Eng	19	9	6	34	78
	National Institute for Laser, Plasma & Radiation Physics	18	13	3	34	
	ELI-NP	3	0	0	3	
	National Institute for Research and Development in Optelect	3	2	2	7	
RDI close to ELI-NP	National Institute of Materials Physics	5	11	3	19	84
	Institute of Space Science	5	8	2	15	
	National Institute for Research and Development of Isotopic	4	6	6	16	
	National Institute for Research and Development in Microtech	4	6	2	12	
	National Institute for Earth Physics	3	4	0	7	
	National Institute for Chemical - Pharmaceutical Research	0	2	0	2	
	National Research and Development Institute for Cryogenic	1	8	4	13	
Universities	University of Bucharest - Department of Physics	8	3	0	11	41
	Alexandru I. Cuza University - Iași	3	0	1	4	
	Babeș Bolyai University - Cluj Napoca	2	2	0	4	
	Other University in Romania	1	0	1	2	
	Politehnica University of Bucharest	5	5	6	16	
	University from other country	1	1	2	4	
Other institutions that are far from ELI by activity profiles	Other research organization in Romania	1	2	2	5	21
	National Institute for Research & Development in Chemistry	1	1	2	4	
	National Institute of Aerospace Research ELIE CARAFOLI - INC	1	1	2	4	
	National Institute of Research and Development for Technical	1	0	3	4	
	Geological Institute of Romania	1	2	1	4	
	Total	90	86	48	224	

The weak point of the procedure is related to the fact that subsamples of respondents are not representative by institutions. Consequently, it is possible that there are error classifications associated with a certain organization due to the fact that the shares by degree of information could be inaccurate estimations for the population distribution. The only way to correct such possible errors is to consult local experts to confirm or falsify the proposed classification. As such, we asked local experts to judge the proposed classification.

The use of this classification of employment organizations will be tested by adding microdata variables to the survey that refer to the dominant profile of activity in an organization and its involvement in cooperation projects, etc.

Appendix 2: Classifying the Interviewees according to the Clusters of RDI Activities in which They Are Involved

The WB-ELI survey respondents are mainly involved in applied and fundamental research (Table 63). They are also working on experimental development activities. It is very likely that their opinions and behaviors also differ according to the combination of these activities.

Table 61. Involvement in RDI Activities in the Last Four Years

*Please indicate all the research development and innovation activities you have been involved with in the last four calendar years..." (multiple options possible)		% involved in RDI activities of...
Applied research		81
Fundamental Research		64
Experimental Development	Prototyping of products	17
	Product development	15
	Technology testing	14
	Technology transfer	11
	Prototype testing	10
	Support in patenting and licensing	6
	Production process	2
	Market research for commercialization	1

Table 62. Distribution of Interviewees by Types of RDI Activities Attended in the Last Four Years

	%
Fundamental and applied research	30
Only applied research	19
Fundamental & applied research and experimental development	18
Only fundamental research	14
Applied research and experimental development	13
Other	5
Total	100

Source: RIFR 2017. Reading example: 81% of the 224 interviewees mention applied research as an activity in the last four years, meaning only applied research or applied research in combination with other activities (Table 63); the percentage of interviewees that conducted applied research only is 19% (Table 64).

As expected, the type of activity has a very high impact on the professional outcomes (Table A5). The h index using the Web of Science citations is the maximum for those working in the area of fundamental research or combining fundamental and applied research. Applied research by itself or in combination with experimental development activities brings lower performance results.

Table 63. Professional Performances by Types of Activity

Source: RIFR 2017. * Small number of cases and, implicitly, irrelevant averages.

	Averages by type of RDI activity						
Professional performance indicators	Research and non-research	Fundamental and applied research	Fundamental research	Applied research	Applied research and non-research	Other*	Total
Total numbers of publications in international scientific journals in the last four years	26.1	17.9	15.5	23.8	13.1	54.6	21.2
Total number of publications in Romanian scientific journals in the last four years	4.9	3.3	2.4	4.6	3.4	6.1	3.9
Your h index (Hirsch) of citations using Google Scholar	15	14	12	7	13	24	13
Your h index (Hirsch) of citations using Web of Science	12	13	14	7	8	15	12
Total Number of International patents	.52	.19	0.00	.17	.95	.22	.32
Total number of Romanian patents	4.4	0.8	0.1	1.7	3.7	2.2	2.1

Surprisingly, the type of employment organization does not differentiate among the average values of the h index of citations (A6). Supplementary analysis is needed to see if the record is related to the small sizes of subsamples provided by employment organizations or if it reflects reality.

Table 64. Averages of the h Index of Citations by Type of Institution

Source: RIFR 2017.

Type of institution	h index (Hirsch) of citations using Web of Science	h index (Hirsch) of citations using Google Scholar
ELI_RDI	11	14
Close to ELI_RDI	12	13
Universities	12	13
Other, far from ELI	9	9
Total	12	13

Appendix 3: Expectations of Problems Confronting ELI-NP

Table 65. Expected Problems to Confront ELI-NP in the Future

Source: RIFR 2017.Reading example: 58% of the total interviewees working out of Măgurele consider that access to local funding will be one of the main problems (to a great extent and to a certain extent) that will confront ELI-NP in the future. The corresponding percentage for interviewees working in Măgurele is ten percentage points lower, of only 48%.

Expected problems in the ELI accomplishment process	To what degree you expect ELI-NP to be confronted with problems related to the following? (B5, several choices)			Which of the following do you expect to be the main problem ELI-NP will be confronted with: (B6a one choice)		
	Works		Total	Works		Total
	out of Măgurele	in Măgurele		out of Măgurele	in Măgurele	
Local entrepreneurial and innovation ecosystem conditions	58	53	53	6	0	2
Access to local research funding	58	48	52	18	17	17
Inconsistencies between local and international management	55	50	51	5	6	6
Availability of relevant local industries / supplieres	56	48	51	8	8	8
Access to competent local technical staff (vocational fields)	44	54	50	10	6	7
Attracting human resources from abroad to live and work	48	50	49	10	11	10
Procurement of services and material	52	45	48	8	10	9
Collaboration possibilities with local firms/industry	52	41	45	10	5	7
Availability of intermediary/support institutions (TTOs)	50	39	43	2	2	2
Access to competent research management staff	41	43	42	10	7	8
Access to competent local researchers in Romania	35	43	40	6	17	13
Intellectual property and technology transfer regulatory environment	35	29	31	2	1	1
Collaboration possibilities with local research institutions	23	21	22	2	2	2
Collaboration possibilities with local academic institutions	24	19	21	0	1	1
Collaboration possibilities with foreign firms	21	20	20	2	2	2
Other / No answer				3	7	5

Table 66. Factor Analysis of the Items Measuring Problem Expectations for EL-NP in the Future

Source: RIFR 2017.

B5. To what degree you expect ELI-NP to be confronted with problems related to the following	Human resources	Local research	Local industries and foreign firms	Normative (regulations) environment
B5_2 Access to competent local technical staff (vocational fields)	.899	.056	-.042	.000
B5_1 Access to competent local researchers in Romania	.859	-.096	-.054	-.066
B5_3 Access to competent research management staff	.593	-.051	-.020	.236
B5_13 Attracting human resources from abroad to live and work in Romania	.357	-.046	.168	-.044
B5_14 Access to local research funding	.311	.023	.095	.110
B5_6 Collaboration possibilities with local research institutions	.027	-.911	.056	.013
B5_7 Collaboration possibilities with local academic institutions	.040	-.854	.028	.115
B5_10 Availability of relevant local industries / supplieres in application areas	.063	.154	.737	.243
B5_9 Collaboration possibilities with foreign firms	.069	-.170	.683	-.130
B5_8 Collaboration possibilities with local firms / industry	.027	-.229	.487	.316
B5_5 Intellectual property and technology transfer regulatory environment	-.040	-.225	-.098	.635
B5_4 Availability of intermediary / support institutions (TTOs, accelerators, incubators, etc.)	.135	-.020	.104	.582
B5_12 Local entrepreneurial and innovation ecosystem conditions	-.034	.072	.210	.553
B5_11 Procurement of services and materials	.068	-.061	-.028	.491
B5_15 Inconsistencies between local and international management of ELI-NP	.239	-.006	-.020	.400

Extraction Method: Maximum Likelihood. Goodness of fit text: chi square = 43.18, df - 51, *p*=.773

Rotation Method: OBlimin with Kaiser Normalization. KMO = 0,841, N = 170. Missing values replaced with

Appendix 4: Roads to Solutions Suggested by Interviewed Experts

Table 67. Diagnosis and Possible Solutions for a Performant ELI-N

Source: RIFR 2017.

B6b Key proposed solutions or comments on generationg solutions
"Attracting top researchers from abroad, as well as better training of local researchers."
"Close interaction with the academic environment and intensive dedicated education / training programmes."
"Long, long road of rebuilding university education in Romania!"
"There is no short-term solution (2-3 years). For medium term (4-7 years) and long term (8-15 years), a significant improvement of the technical and scientific education in ROmania, to become competitive with the quality (not the mediocre) higher education in the advanced western countries (USA, Germany). Moreover, introduction of an incentive remuneration system for good researchers (young or old) who will work in ELI-NP or in smaller CDI projects with laser, in Romania."
"Improvement of the level of the Schools of Physics of the technical universities and courses dedicated to ELI-NP, coupling with master and doctoral studies. Preparing future researchers for ELI-NP."
"Ensuring the specific technical training in specialised centres abroad"
"Establishment of a technical college dedicated to train the technicians needed in various specialities involving the good operation of the facility; something after high-school with the duration of one year at the most."
"Solid, transparent and lasting partnerships with the technical universities in the country and the companies in the field."
"Import of research organisation and management experise (including data!) from Helmholz, Fraunhofer institutes, etc."
"The model of other countries having similar research centres should be studies."
"As some jkey-competences do not exist here in Romania (e.g. accelerator development), ELI should hire experts in these fields. ELI cannot rely totally on the support of foreign institutes, it must gain experience (excellence) in the technologies used inhouse"
"Multi-annual funding of the national research and development institutes and increase of the funds allocated for research."
"Well targeted marketing."
"I don't know of local industrial partners able to take over the results of the Romanian research in order to develop services and producs."
"The solution: establishing an industrial centre."
"A legislation which no longer allows appeals needing years until a decision is made."
"Taking the infrastructure from under the public procurement law, because the main activity of the infrastructure is research and development, and the equipment and materials used in this activity are usually state-of-the-art and not currently available on the market."
"Involvement of Romanian specialists from abroad."
"Provision of living and remuneration conditions consistent with the conditions in the West."
"Funding at European level."
"In Romania is an ordeal to carry out top research! Research is a creative work requiring effort, energy, and enthusiasm. How to get them when all the energy and enthusiasm are consumed from home to work and from work to home, on crowded and bumpy and muddy roads, or in a public transport system which is highly inefficient? In addition, there is the mockery of the authorities towards the time of the citizen. I have worked abroad for many years and therefore I can say that here is an ordeal and a mockery! Fortunately, the researcher community tries to cope with the situation, and at least you don't feel alone fighting the system which seems to be against you."
"This can be solved only over time, if ELI-NP demonstrates excellence in research and innovation."
"Predictable funding in the research system in Romania, which was absent for 27 years!"
"Finding alternative funding sources: European projects, companies."
"Launching programmes dedicated to ELI-NP experiments."
"Orientation of ELI-NP towards international / european funding."
"Modernisation of local management."
"The funding system of the Romanian national research and development institutes is different from that of the similar institutes abroad, being based on projects and therefore not always rhythmical. For instance, in applications to international project competitions it is hard to explain the need to cover the wages of the permanent staff as well as the structure of indirect expenses."
"Willingness to think for a few times a protocol/work framework/regulation before writing it down. Imagining scenarios where the concerned documents will be filled in/followed by the RESEARCHERS and seeking to eliminate all the redundant information and simplify the concerned process."

Table 68. The Most Competent Agent to Apply the Solution for the ELI-NP Case

Source: RIFR 2017. Absolute number of respondents answering the crossed questions.

B6a Which one of the following do you expect to be the main problem ELI-NP will be confronted with?	B6c Who do you think is the most competent to apply the solution you suggested?				Total
	National Government	Research institution	Other	No answer	
Access to local research funding	21	2	4	4	31
Procurement of services and materials	13	2	0	1	16
Access to competent local researchers in Romania	11	5	3	4	23
Attracting human resources from abroad to live and work in Romania	7	3	6	2	18
Access to competent local technical staff (vocational fields)	6	5	1	1	13
Access to competent research management staff	6	6	1	1	14
Inconsistencies between local and international management organizations	5	2	2	1	10
Availability of relevant local industries / supplieres in applications	4	2	5	3	14
Local entrepreneurial and innovation ecosystem conditions	3	1	0	0	4
Other	5	5	1	2	13
Total	81	33	23	19	156

Appendix 4: Descriptive for Dependent and Independent Variables in Multiple Regression Models

A. Dummy or continous independent variables	Mean	Standard Deviation
Manager	.40	.49
Top professional position	.56	.50
Studied abroad	.45	.50
Worked abroad	.57	.50
Lived abroad	.70	.46
Men	.65	.48
Working in Măgurele	.59	.49
years working in organization	15.56	.50
age	48.38	12.32
IFIN	.15	.36
LASER National Institute for Laser, Plasma & Radiation	.15	.36
MATERIALS National Institute of Materials Physics	.08	.28
Universities from Romania	.13	.34

B. Nominal independent variables		%
Type of institution	Directly involved in ELI-NP activities	35
	Close to ELI-NP activities	38
	Universities	18
	Other, far from ELI-NP	9
Type of R&D activities	Research and experimental development	18
	Fundamental and applied research	30
	Fundamental research	14
	Applied research	19
	Applied research and experimental development	13
	Other	5

A. Dummy or continous dependent variables		Mean	Standard Deviation	Minimum	Maximum
Equipment in organization is...	Up to international standards	.77	.42	0.00	1.00
	Not old	.65	.48	0.00	1.00
	Operable	.85	.36	0.00	1.00
	Accesible	.87	.34	0.00	1.00
	Positively perceived by all the four dimensions (factor score converted in Hull score)	50.00	14.00	9.96	60.13
Own organization is able to (A15)	Attract top researchers	.40	.49	0.00	1.00
	Maintain top researchers	.44	.50	0.00	1.00
	Attract high-skilled technicians	.50	.50	0.00	1.00
	Maintain high-skilled techinicans	.42	.49	0.00	1.00
	Support careers for young researchers	.28	.45	0.00	1.00
Index of efficacy in management of human resources in organization		50.00	14.00	17.13	80.54
Difficulties in cooperation with SMEs (A21)	Absence of interaction between RDIs and firms	.42	.49	0.00	1.00
	Finance and costs	.55	.50	0.00	1.00
	Absence of interest from industry	.58	.49	0.00	1.00
Proactive orientation of researchers for reaching funds (factor score of A13.3, A13.5)		.00	100.00	-273.31	212.65
Adequacy of institutional supply of funding (factor score of A13)		.00	100.00	-238.25	265.54
Perceived positive effects of ELI-NP on... (B3)	Scientific progress in general	.35	.48	0.00	1.00
	Advancing fundamental research in Romania	.43	.50	0.00	1.00
	Enhancing scientific cooperation	.46	.50	0.00	1.00
	Economic development of Măgurele	.35	.48	0.00	1.00
		.41	.49	0.00	1.00