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LATVIA'S SMART SPECIALISATION STRATEGY (RIS3)
SPECIALISATION AREA

Smart materials, technologies and engineering systems

RESEARCH ECOSYSTEM REPORT
(2014–2018)

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Ministry of Education and Science

THE NATIONAL DEVELOPMENT PLAN 2014-2020

EUROPEAN UNION
European Regional Development Fund

INVESTMENT IN YOUR FUTURE

Abbreviations

HEI – Higher Education Institutions

BMC – Latvian Biomedical Research and Study Centre

BBCE – Baltic Biomaterials Centre of Excellence

CAMART – The Centre of Advanced Material Research and Technology Transfer

CERN – European Organisation for Nuclear Research

CNCI – Category Normalised Citation Impact

CORDIS – Community Research and Development Information Service

DU – Daugavpils University

IH – Institute of Horticulture

IECS – Institute of Electronics and Computer Science

IPE – Institute of Physical Energetics

KET – Key-Enabling Technologies

LEIT – Leadership in Enabling and Industrial Technologies

LIET-ADVMANU – Advanced Manufacturing and Processing

LIET-ADVMAT – Advanced Materials LIET-BIOTECH – Biotechnology

LIET-NMP – Nanotechnologies

LMA – Latvian Maritime Academy

UL – University of Latvia

ISSP UL – Institute of Solid State Physics, University of Latvia

LSIWC – Latvian State Institute of Wood Chemistry

SME – Small and Medium-sized Enterprises

NSAIS – National Scientific Activity Information System

NIP – National Industrial Policy Guidelines 2014–2020

NRIS – National Research Information System

MTCO – Mechanics and Technology College of Olaine

IOS – Institute of Organic Synthesis R&I – research and innovations

RAI – Riga Aeronautical Institute RBC – Riga Building College

PSCUH – Pauls Stradins Clinical University Hospital

RTC – Riga Technical College

RIS3 – Smart Specialisation Strategy
RTA – Rezekne Academy of Technologies
RTU – Riga Technical University

SITC – Standard International Trade Classification

STEM – Science, Technology, Engineering and Mathematics

TTI – Transport and Telecommunication Institute

VUC – Ventspils University College

ViA – Vidzeme University of Applied Sciences

WoS – *Web of Science*

SI – scientific institutes

STDIG – Science, Technology Development and Innovation Guidelines

Content

Summary

The smart specialisation area "Smart materials, technologies and engineering systems" is the most extensive of all smart specialisation areas in Latvia and not only covers a wide range of fields of science, but also overlaps with other smart specialisation areas; therefore, in the 2014–2018 period the area had acquired the largest public sector research and innovation (hereinafter referred to as R&I) funding. The knowledge created in this area has high transversal potential and plays an important role in the development of other smart specialisation areas in Latvia. R&D capacity of the area is concentrated in internationally recognised centres of scientific excellence and universities. The niche of the area that attracted the largest amount of R&D funding between 2014 and 2018 is technology. The niche includes R&D projects focused on the introduction of new and advanced manufacturing and processing technologies in economic sectors such as metalworking, woodworking, chemical industry, and mechanical engineering. The funding acquired in this niche demonstrates that the R&D activity is currently taking place in areas of knowledge where Latvia already has a comparative advantage. A high share of fundamental and applied R&D projects is observed in the thematic niches of nanocomposites, ceramics and functional materials for light emitters.

The thematic niches of the area are related to the key enabling technologies defined by the European Commission. Within the framework of the Horizon 2020 Teaming Phase 2 programme, two major projects have been implemented – CAMART2 – Excellence Centre of Advanced Material Research and Technology Transfer and BBCE – Baltic Biomaterial Centre of Excellence. CAMART aims to modernise and upgrade an existing centre into a new, significantly more efficient centre of excellence that will not only stimulate research into the development of new advanced materials and technologies, but will also facilitate technology transfer and commercialisation. BBCE is a consortium of several national and international industry leaders that will enable sustainable and innovative biomaterial research for medical applications. CAMART2 and BBCE demonstrate the integrity, excellence and capacity of the Latvian Research Area and should serve as examples of scientific excellence and ambition for existing and emerging researchers.

Introduction

The smart specialisation strategy is an economic transformation strategy that focuses on creating higher value-added products and services to increase global competitiveness. The purpose of the Guidelines on Export Promotion of Latvian Goods and Services and Foreign Investment Attraction is to promote the growth of high- and medium high technology sectors output in Latvian export. The smart specialisation area "Smart Materials, Technologies and Engineering Systems" (hereinafter – the Area) plays a significant role in promoting the transformation of the national economy in order to advance the growth of high- and medium-high technologies in Latvian export. The analytical review of the area's research ecosystem provides insight into the niches of the area in which the R&D capacity has already developed, as well as those where this capacity could develop in the future, into the human capital, and scientific excellence. The review uses data from research projects and research results – publications, students, and research staff. Data sources used in the preparation of the review:

- National Research Information System;
- Scientific publications database/ repository *Web of Science* and analytical network tool InCites;
- Cohesion Policy Fund Management Information Systems for 2014–2020 (CP FMS);
- Latvian Council of Science data on Fundamental and Applied Research Programme;
- European Commission CORDIS database on "Horizon 2020" projects;
- National Scientific Activity Information System.

1 Global and national context of smart specialisation area R&D

Key Enabling Technologies (*KETs*) are a key element of innovation and provide all the necessary technological cornerstones that open up a wide range of product applications across a wide range of industries, from innovative technological solutions to improve energy efficiency and low carbon technologies, promoting the modernisation of the European industrial space, and ending with technological solutions for medical applications. *KETs* give an opportunity for the development of new, hitherto unexplored industrial sectors and play a crucial role in shaping European industrial policy.

Based on current global trends, emerging research directions, and societal challenges, the European Commission (hereafter – the Commission) has identified six *KETs* that have the highest market potential and relevance to global solutions to problems. "A European strategy for Key Enabling Technologies – A bridge to growth and jobs" has identified the following six *KETs*: micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies. *KETs* embrace a wealth of knowledge and are characterised by intensive R&D, rapid innovation cycles, high capital expenditures, and the need for a highly qualified workforce. *KETs* are multidisciplinary and transversal technologies with a significant contribution and application in other industrial sectors.[1] *KETs* make part of the European Union's development strategy "Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth" and are included in two flagship initiatives, "Innovation Union" and "Industrial Policy for the Globalisation Era".[2] The horizontal nature and high transformative potential of *KETs are essential components of the Smart Specialisation Strategy. The Smart Specialisation Strategy (hereinafter – the Strategy) is an economic transformation strategy that focuses on creating higher value-added products. The strategy aims to channel the R&D resources into those areas of knowledge that have the R&D capacity, or those, where this capacity may be developed. The Strategy in the national development planning system is part of the Science, Technology Development and Innovation Guidelines 2014–2020 (hereinafter referred to as "STDIG").*

The Strategy and NIP are mutually coordinated parts of the national economic development plan and ensure that the common goal of the transformation of the economy towards the creation of products and services with higher added value and greater competitiveness in the global market is achieved. The smart specialisation Area is part of Latvia's smart specialisation strategy. This is one of the five areas of knowledge where the creation of new product, technology and complementary research competency is vital to transforming the economy and promoting global competitiveness and visibility.

[1] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0341:FIN:EN:PDF
[2] https://ec.europa.eu/eu2020/pdf/1_LV_ACT_part1_v1.pdf

2 Scope of RIS3

The R&D capacity of the Area is concentrated in important internationally recognised centres of scientific excellence and universities. High scientific performance is seen in solid state physics, optics, photonics and chemical physics. One of the leading research institutes in the field is the Institute of Solid State Physics of the University of Latvia (hereinafter – ISSP UL), which is an efficient centre of scientific excellence with rich traditions and international recognition. The main research areas of the Institute are functional materials for photonics and electronics, nanotechnologies, nanocomposites and ceramics, thin-film and coating technologies, and theoretical and experimental studies on the materials structure and properties.[3] The industry collaboration platform "Materize" operates under the patronage of the Institute. The platform has been created with the aim to promote cooperation between the ISSP UL scientists and Latvian and foreign entrepreneurs. ISSP UL scientists are developing technologies for innovative materials that can be used in the high-tech industry, and such a platform is a springboard between knowledge creators and industry, facilitating successful testing and technology transfer. ISSP UL is one of the leading research institutes in the Area in attracting public funding and leading in the amount of funding in the "Horizon 2020" framework programme (hereinafter – Horizon 2020). It should be noted, however, that a large part of the funding is associated with the Centre of Advanced Material Research and Technology Transfer CAMART (hereinafter – CAMART). The activities of CAMART are aimed at raising scientific excellence, international cooperation, and industry involvement to promote technology transfer and market the introduction of new products. The second largest applicant for Horizon 2020 funding is Riga Technical University (hereinafter – RTU). Here too it should be noted that a large part of the funding is related to the Centre of Excellence – the Baltic Biomaterial Centre of Excellence BBCE (hereinafter – BBCE). The Centre of Excellence brings together a number of outstanding foreign and local scientific institutions: AO Research Institute (Switzerland), Fridrich-Alexander University of Erlangen – Nuremberg (Germany), Rudolfs Cimdins Riga Biomaterials Innovation and Development Centre (RTU), Latvian Institute of Organic Synthesis (hereinafter – IOS), and Riga Stradiņš University (hereinafter – RSU). RTU is one of the leading institutions of higher education in the Area, specialising in the synthesis of nanomaterials and their application in the manufacture of advanced materials and other specific products, materials for electronics, photonics and optoelectronics, information technologies, optimisation of technological processes of materials and constructions production from the point of view of saving energy and resources[4].

[3] https://www.cfi.lu.lv/fileadmin/user_upload/lu_portal/projekti/cfi/Citi_dokumenti/LU_CFI_Strategija_2017-2026.pdf
[4] https://www.rtu.lv/lv/universitate/strategija/ilgtspejiga-attistiba/rtu-prioritarie-merki

The ecosystem of the Area comprises not only the public sector, i.e. universities and research institutes, but also the private sector, that is, merchants that make the final decision on the introduction of innovation and new technologies into production and increase export potential. Among the leading companies in Latvia with the highest R&I capacity, which successfully attract public sector funding and are innovative, investing into R&D, are SIA "EuroLCDs", SIA "Schaeffler Baltic", SIA "Sidrabe", SIA "GroGlass", "Primekss", "ElGooTech", "MB Betons", etc. SIA "EuroLCDs", SIA "Sidrabe", and SIA "GroGlass" are partners of the technology transfer platform "Materize" and cooperate with the ISSP UL.[5] SIA "EuroLCDs" R&D activities focus on nanomaterials and advanced coatings.

[5] https://www.materize.com/

3 Latvian R&D competencies

The technologies niche includes the R&D projects focused on the introduction of new and advanced manufacturing and processing technologies in economic sectors such as metalworking, woodworking, chemical industry, and mechanical engineering. This is the niche of the Area that acquired the largest amount of funding – ~ EUR 21 million, which represents 41% of the total funding of the Area (~ 52 million) (see **Figure 3.1 A**). Funding of the Area is most extensive compared to other RIS3 areas, but it should be noted here that the Area also overlaps with other RIS3 areas. The second largest niche in terms of the acquired R&I funding is composite materials. This niche encompasses R&I projects on structural composite materials, polymer composite materials, nanomaterials and nanostructures, nanoceramics, and polymer nanocomposites. The niche devices, equipment and systems include R&I projects in the field of microelectronics and nanoelectronic devices, devices and systems, while functional materials include R&I projects in the field of materials for electronics and photonics. The highest levels of private sector funding are in the following niches: thin-films and coatings, devices, equipment and systems, and technologies (see **Figure 3.1 B**). Within these niches, projects supported by competence centres (Advanced Materials and Technology Competence Centre, Mechanical Engineering Competence Centre, and Advanced Engineering Systems, Transport and Energy Competence Centre) have the highest proportion of R&I projects. The leading users of thin-film and coating niche public funding are SIA "Sidrabe" and SIA "GroGlass". It should be mentioned that SIA "Sidrabe" and also "GroGlass" are actively cooperating with ISSF UL, and not only in the competence centre supported R&I projects. They are also part of the "Materize" platform partners in the field of advanced coatings. The niches of the Area that are covered in the nearly full TRL cycle (see **Table 3.1**) are Materials Development and Manufacturing Technologies, Nanocomposites and Ceramics, Functional Materials for Light Emitters, etc. The niches for R&I projects have both a national priority and an EU dimension. A high share of fundamental and applied R&D projects is observed in the thematic niches of nanocomposites, ceramics and functional materials for light emitters. The thematic niches of the Area are in line with EC-defined *KETs* and have the greatest potential in the global market. Given that these niches have a high global market potential and Latvia already has R&I capacity, it is necessary to promote industry attraction and private sector investment to stimulate technology transfer.

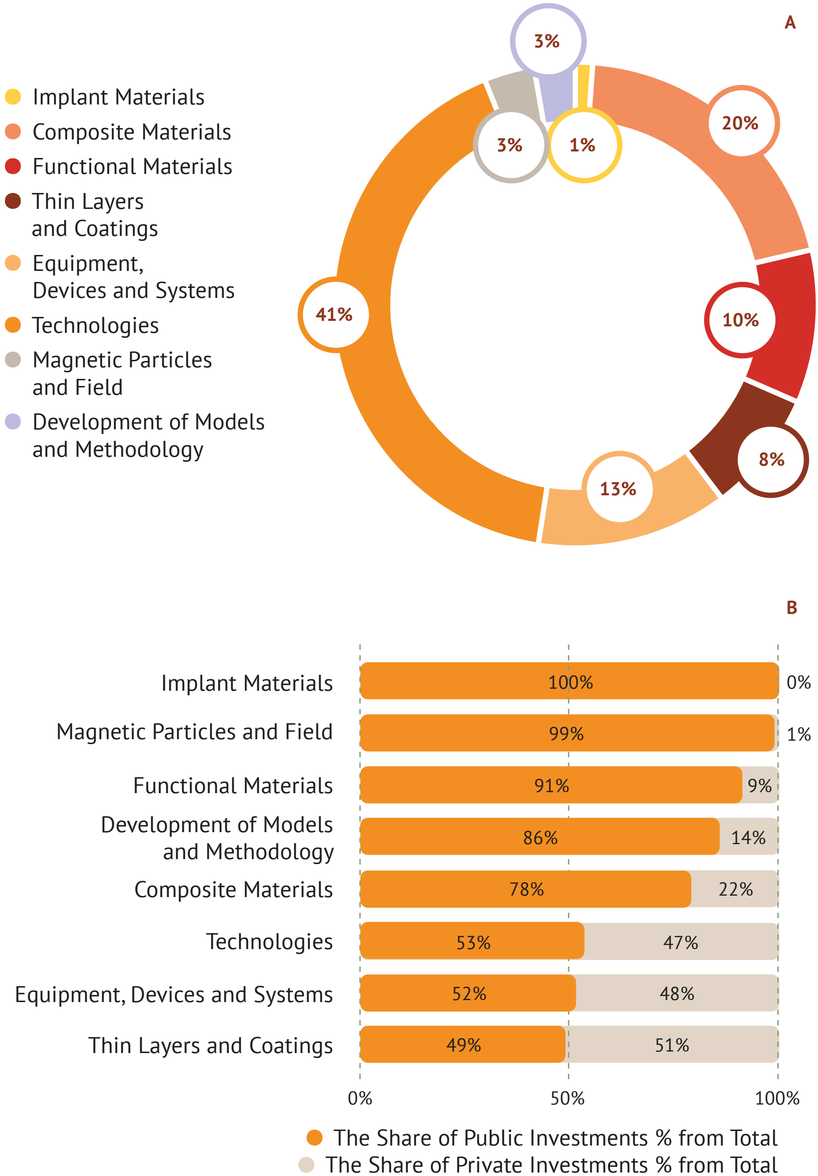


Figure 3.1. Investment into R&I projects in the Area by thematic niches 2014-2018
A – Investment (%). **B** – Public and private sector investment % into R&I in the Area by thematic niches

Table 3.1. R&I acquired projects by thematic niches and financial instruments 2014–2018

Research Niche	Research Sub-niche	TRL 1-2 FLPP	TRL 1-2 1.1.1.2.	TRL 2-3 1.1.1.1.	TRL 4-8 H2020	TRL 3-5 1.2.1.2.	TRL 4-6 1.2.1.1.
Implant Materials	Implant Materials	7.49%					
Composite Materials	Composite Materials and Polymers	9.73%	10.00%	16.41%		8.89%	9.86%
	Nano-composites and Ceramics	17.29%	20.00%	10.91%	16.67%	0.67%	
Functional Materials	For Light Emitters	13.70%	2.50%	4.12%		8.97%	2.01%
	Sensors	3.74%	5.00%	8.24%			
	For Photonics and Microelectronic Devices		5.00%	4.19%			
Thin Layers and Coatings	Thin Layers and Coatings	2.50%	7.50%	8.59%			13.96%
Equipment, Devices and Systems	Electronic			11.58%		35.00%	2.81%
	Electric					8.83%	4.77%
	Automatic Control Systems						12.02%
Technologies	Nanotechnologies	7.49%	5.00%	4.12%	11.94%		
	Transport Technologies			12.05%			17.05%
	Manufacturing Technologies for Automated Engineering Systems						15.12%
	Materials Development and Production Technologies	2.44%	2.50%	11.90%	7.44%	35.54%	14.46%
	Development and Production of Chemicals	8.74%	12.50%			2.09%	0.49%
	Advanced Manufacturing and Processing Technologies	7.49%	5.00%		60.63%		0.55%
	Medical Engineering	3.74%					0.24%
	Biotechnologies	6.93%	5.00%				5.62%
Magnetic Particles and Field	Magnetic Particles and Field	3.74%	15.00%	4.10%			
Development of Models and Methodology	Development of Models and Methodology	4.99%	5.00%	3.78%			1.03%

FARP – Fundamental and Applied Research Projects.
1.1.1.2. – Post-doctoral Research Aid.
1.1.1.1. – Applied Research.
H2020 – Horizon 2020 Framework Programme.
1.2.1.2. – Support for the Development of Technology Transfer System.
1.2.1.1. – Support for the Development of New Products and Technologies within Centers of Excellence.

4 Scientific capacity

4.1. Students

Sufficient and highly qualified human capital for R&I creation is one of the key prerequisites for efficient and sustainable investment in research. In 2014–2018, significant changes in the dynamics of the number of students in the Area-related Bachelor's and Master's study programmes are observed starting from 2017. The rapid increase in the number of students in the Area-related study programmes can be explained by the redistribution of places with the priority given to STEM study programmes. In the academic year 2018/19 the number of students is returning to the previous level. The highest number of students is observed in the field group of engineering sciences and technologies, with the highest number of students in the programmes of electronics (2328), heat, gas, and water technologies (1772), and engineering technology, mechanics, and mechanical engineering, whereas in the field group of naturals sciences – chemistry (1738) and physics (842).

Thanks to the EU Fund sub-activity "Support to the Implementation of Doctoral Programmes", the number of doctoral graduates in the Area-related programmes significantly increased in 2015, and decreased significantly at the end of this programme. New incentives and equivalent programmes are needed to increase the number of graduates.

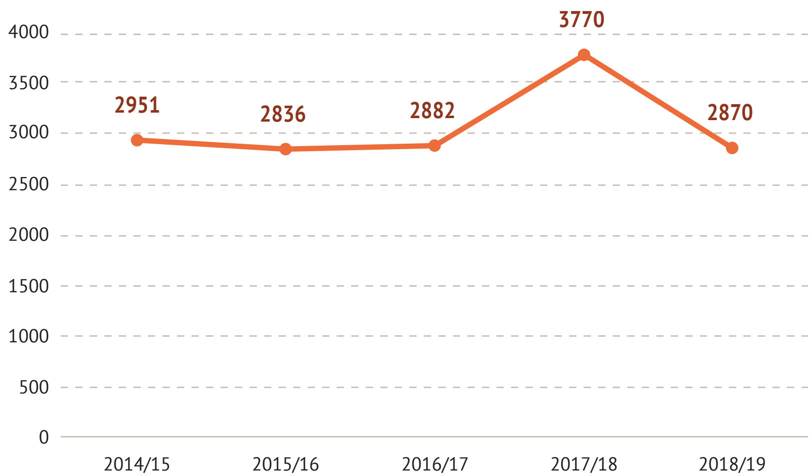


Figure 4.1.1. Student Dynamics in Field-related Study Programme

4.2. Scientific staff

There are ~ 2000 scientists (research assistants, researchers, and leading researchers) working in science fields and sub-fields related to the Area; more than half – 58% are men and 42% – women. The largest number of scientific staff in the Area is made up of leading researchers – 40% and researchers – 35%, while the number of research assistants is almost half as many as leading researchers – 24%. Almost the same number of scientific staff can be found in the areas of natural sciences and engineering and technology. The leading sub-fields of natural sciences in terms of scientific staff are Physics and Astronomy, Chemistry and Biology, while the leading sub-fields of engineering and technology are Electrical Engineering, Electronics, Information and Communication Technologies, which is also in a leading position, and Chemical Engineering (**Figure 4.2.1**). Most of the scientific staff in engineering and technology is provided by RTU, while in natural sciences – by UL, accounting for 35% and 23% respectively of the total number in the Area (**Figure 4.2.2**). RTU and UL also have the highest number of leading researchers and researchers from the total number of scientific staff at the respective university (**Figure 4.2.3**). Both universities are the largest educational institutions in Latvia.

The leading scientific institutes in the Area in terms of the number of scientific staff are IOS and ISSP UL, accounting for 9% and 6% of the total scientific staff respectively. IOS has a larger number of research assistants than leading researchers and researchers, whereas the ISSP UL has a significantly higher number of leading researchers (**Figure 4.2.3**) The Share of Scientific Personnel by Subfields.

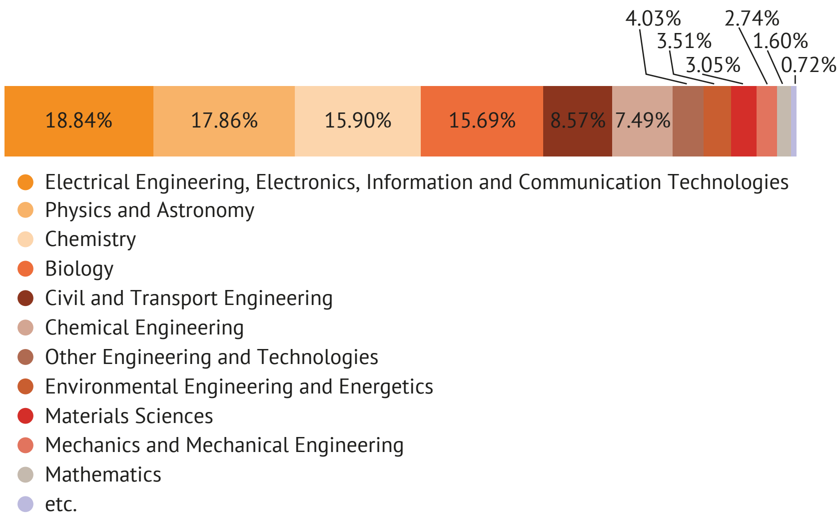


Figure 4.2.1. The distribution of scientific personnel by sub-fields

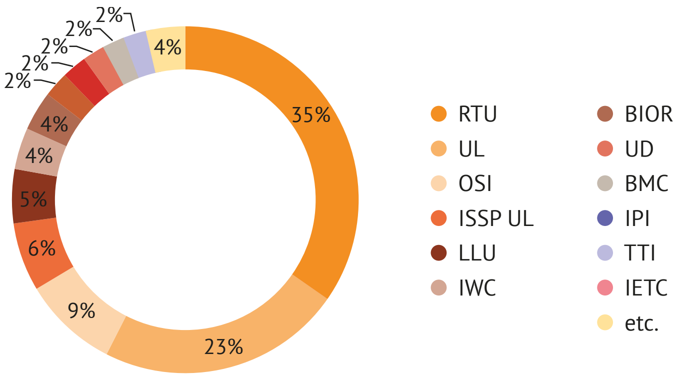


Figure 4.2.2. The Share of Scientific Personnel by Higher Education and Research Institutions

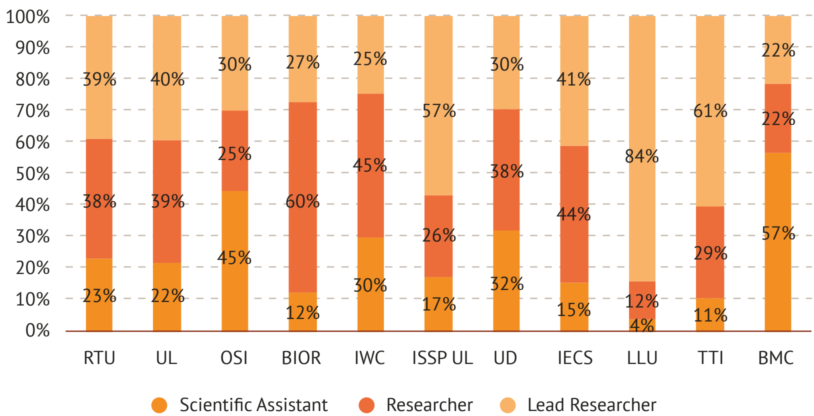


Figure 4.2.3. Distribution of Scientific Personnel by Scientific Position in Higher Education and Research Institutions

Latvia is the leading EU-28 country with the highest proportion of women in science, accounting for more than half (55%) of the country's scientific staff (**Figure 4.2.4**). Although the proportion of female scientists in Latvia is relatively high, it is field-specific. The sub-fields of science related to the Area with the highest proportion of women are Biology, Materials Sciences, Chemical Engineering, and Chemistry (**Figure 4.2.5**). One of the lowest rates of female scientists is in physics and astronomy. The highest numbers of scientific staff in the Area are in the age group of 25–34 (33%) and 35–44 (23%) (**Figure 4.2.6**).

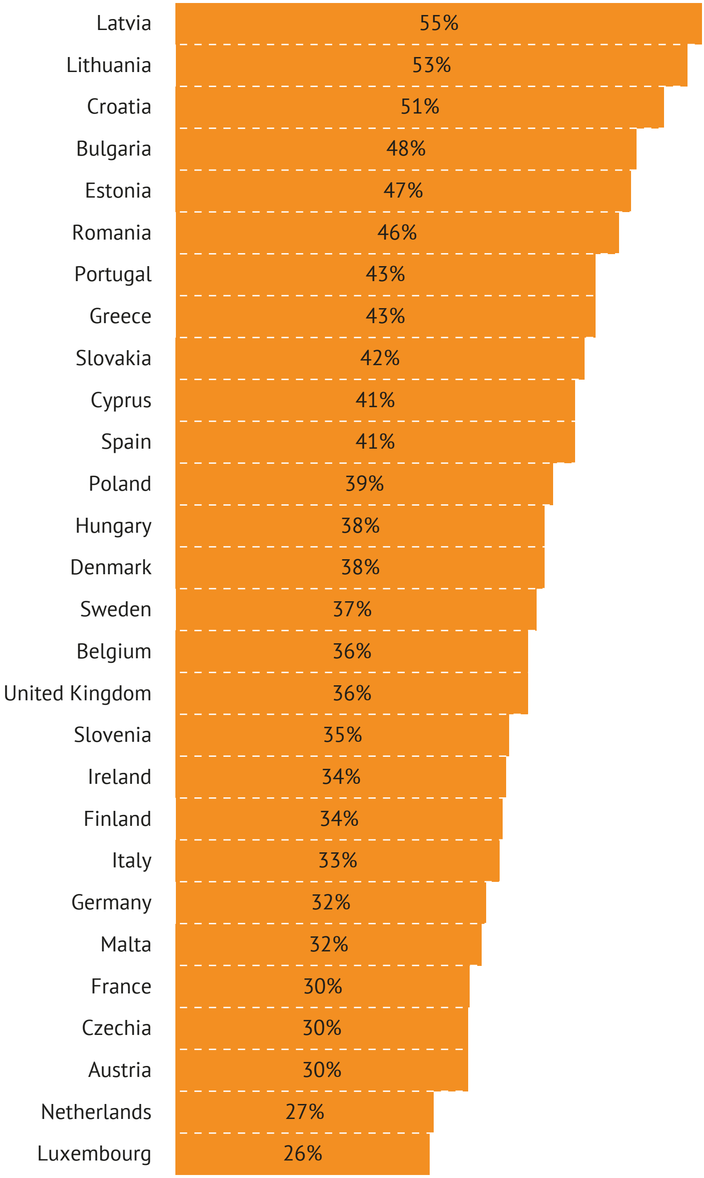


Figure 4.2.4. The Share of Female Researchers in EU-28

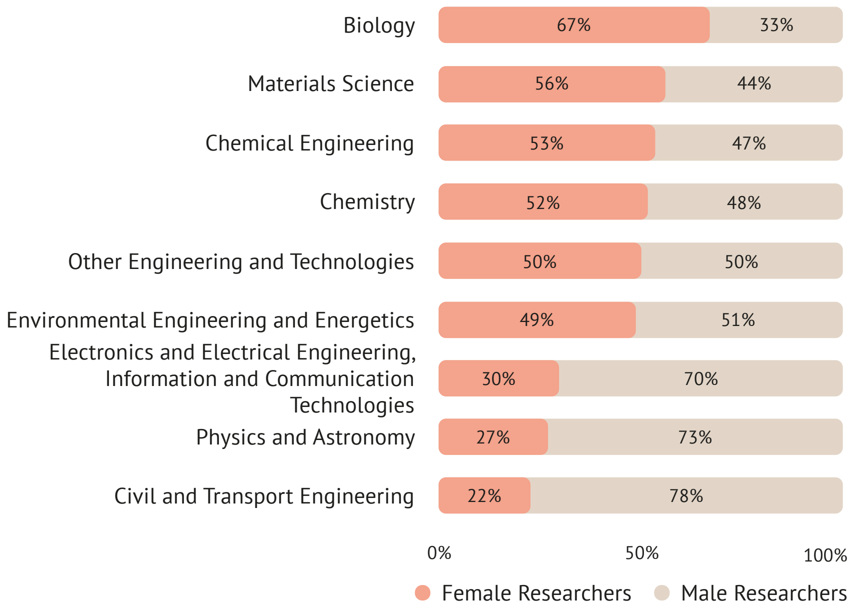


Figure 4.2.5. Proportion of scientists in Latvia by gender, 2008 (NZDIS)

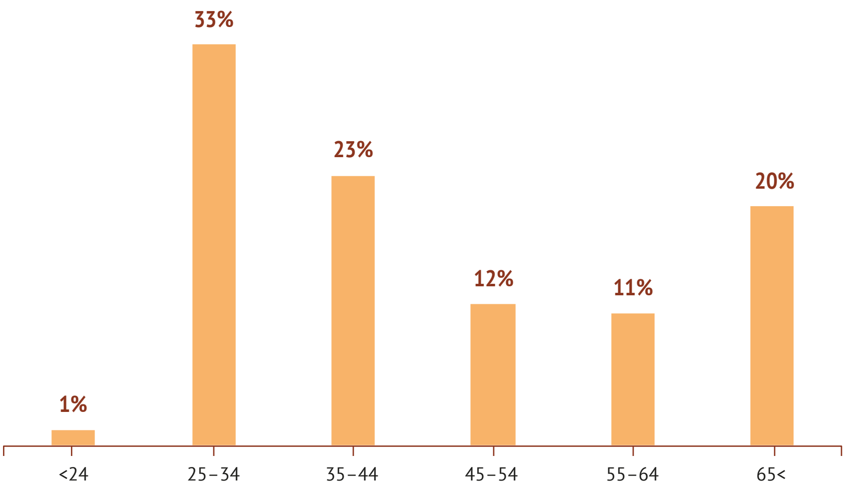


Figure 4.2.6. Proportion of scientific staff by age in the Area, 2018 (NZDIS)

5 Research excellence

Research excellence in the Area can be observed in certain fields and sub-fields of science, where scientific excellence is above or very close to the European average. Although the Area-related publications make up ~ 0.3% of the total number of publications in the EU-28, it should be noted that, compared to the rest of the EU-28, the number of people employed in science in full-time equivalent (FLE) % of total employed in the country, is one of the lowest in Europe. Comparing the collaboration and productivity of Latvian scientific publications with the EU-28, it can be seen (**Figure 5.1**) that % Industry Collaboration and Documents in the Top 10% of Latvia are above or very close to the EU-28 average, which characterise the high quality, novelty, and excellence of scientific publications in the Area (**Figure 5.1**). The leading research fields of the Area by the number of publications are Physical Sciences and Astronomy (**Figure 5.2**), where Physics, Applied, Optics, Physics, Particles & Fields, Physics, Condensed Matter, Physics, Nuclear, Physics, Fluids & Plasma, and Physics, Atomic, Molecular & Chemical have 352, 269, 246, 160, 82, 77, and 68 publications, respectively (**Table 5.1**). The second highest number of publications in this period is Materials Engineering (**Figure 5.2**), where Materials Science, Multidisciplinary, Materials Science, Composites, Materials Science, Ceramics, Metallurgy & Metallurgical Engineering, Materials Science, Coatings & Films, Materials Science, Paper & Wood, Materials Science, Textile, and Materials Science, Characterisation have 651, 79, 67, 37, 35, 32, 28, and 9 publications, respectively (**Table 5.1**). The third highest number of publications in this period is Chemical Sciences, with 630 publications, where Chemistry, Organic, Chemistry, Physical, Polymer Science, Crystallography, Chemistry, Applied, Chemistry, Analytical, Electrochemistry, and Chemistry, Inorganic & Nuclear have 162, 135, 118, 61, 60, 55, 23, and 16 publications, respectively.

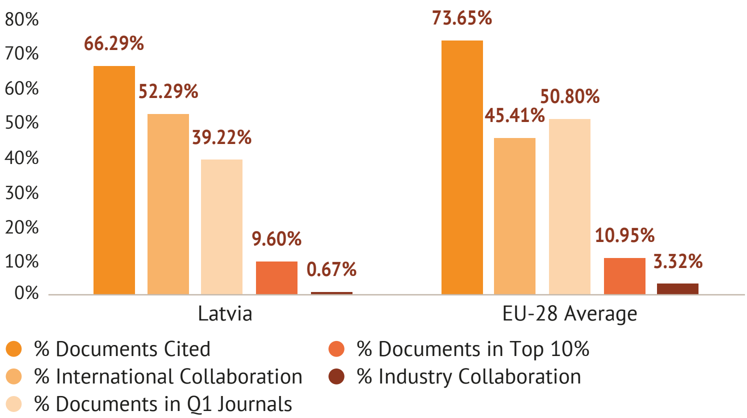


Figure 5.1. Productivity and Collaboration Metrics of Latvia and EU-28 Countries. Source: *Web of Science*; 2014–2018

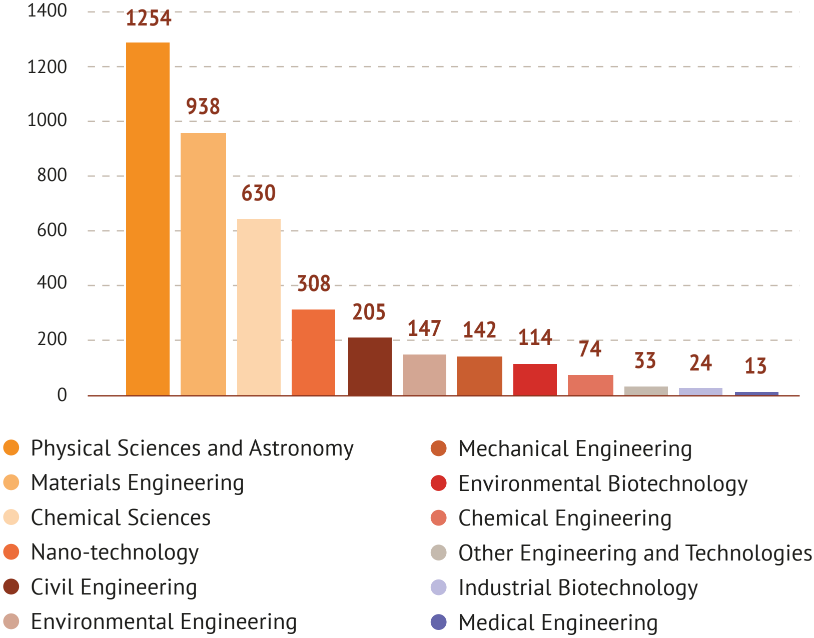


Figure 5.2. Publication Count by WoS field. Source: *Web of Science*; 2014–2018

Table 5.1. Number of publications in the research fields and sub-fields defined by the *Web of Science*, 2014–2018

WoS Field	WoS Subfield	Publications
Physical Sciences and Astronomy	Physics, Applied	352
	Optics	269
	Physics, Particle & Fields	246
	Physics, Condensed Matter	160
	Physics, Nuclear	82
	Physics, Fluids & Plasma	77
	Physics, Atomic, Molecular & Chemical	68
Materials Engineering	Materials Science, Multidisciplinary	651
	Materials Science, Composites	79
	Materials Science, Ceramics	67
	Metallurgy & Metallurgical Engineering	37
	Materials Science, Coatings & Films	35
	Materials Science, Paper & Wood	32
	Materials Science, Textile	28
	Materials Science, Characterization	9
Chemical Sciences	Chemistry, Organic	162
	Chemistry, Physical	135
	Polymer Science	118
	Crystallography	61
	Chemistry, Applied	60
	Chemistry, Analytical	55
	Electrochemistry	23
	Chemistry, Inorganic & Nuclear	16
Mechanical Engineering	Mechanics	118
	Engineering, Mechanical	117
	Nuclear Science & Technology	65
	Engineering, Aerospace	8
Civil Engineering	Engineering, Civil	120
	Construction & Building Technology	85
Environmental Engineering	Engineering, Environmental	147
Nano-technology	Nanoscience & Nanotechnology	142
Environmental Biotechnology	Biotechnology & Applied Microbiology	114
Chemical Engineering	Engineering, Chemical	74
Industrial biotechnology	Materials Science, Biomaterials	24
Other Engineering and Technologies	Engineering, Industrial	17
	Engineering, Manufacturing	16
Medical Engineering	Cell& Tissue Engineering	13

If Latvia's leading fields of science are viewed in the context of the EU-28 countries, then in terms of the quantity and quality of the scientific publications the field Physical Sciences & Astronomy is ranked just above the EU-28 average, while Materials Engineering is well below the EU-28 average in both metrics (**Figure**

5.3). Physical Sciences and Astronomy plays an important role in fostering Scientific excellence and international collaboration of the Area, not only in Europe but also worldwide, while the high number of publications in the Materials Engineering field demonstrates the capacity and potential of the field; therefore, this field needs incentives to promote scientific excellence not only at the European level, but also globally. On the other hand, in engineering areas, such as Environmental Engineering, Civil Engineering, the scientific excellence in terms of quantity and quality is well above the EU-28 average, reflecting the high quality of scientific publications in these fields.

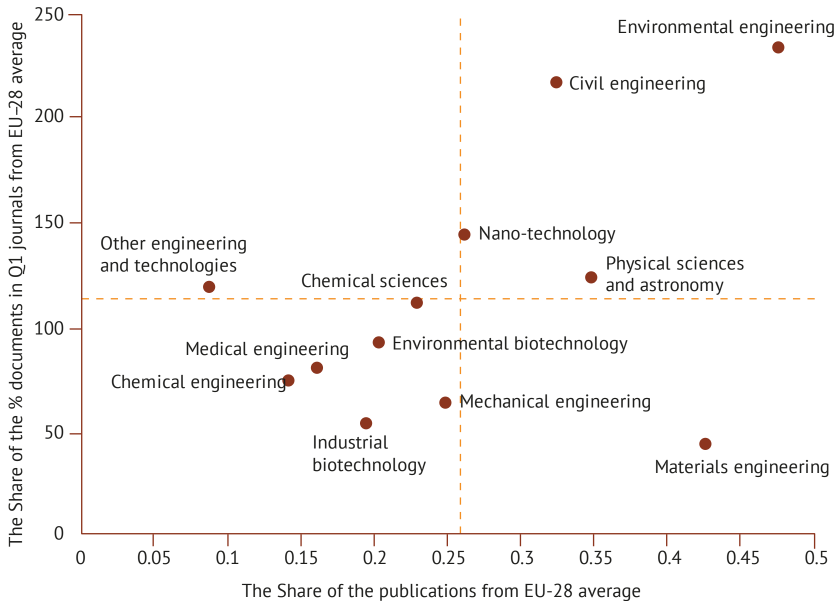


Figure 5.3. Quantity and quality (%) of Latvian scientific publications relative to EU-28 by research fields defined by *Web of Science*, 2014–2018

The leading HEIs in Latvia with the highest number of publications in the period 2014–2018 in the field of research Physics and Astronomy are UL and RTU with 720 and 528 publications, respectively (see **Table 5.2**). The three most developed research fields with the highest number of publications during this period at UL are Applied Physics, Optics and Physics, and Condensed Matter, with 236, 187, and 131 publications, respectively. The leading UL scientific institutes working in the above mentioned research subfields are ISSP UL, UL Institute of Chemical Physics (UL ICP), UL Institute of Atomic Physics and Spectroscopy (UL IAS) etc. Leading HEIs and SIs in the Area that operate in the field of Materials and the field of Engineering are UL, RTU, and LSIWC (see **Table 5.2**). In both UL and RTU the leading sub-field of research in the Area is Materials Science, Multidisciplinary, with 357 and 305 publications, respectively, whereas in LSIWC the leading sub-field of research in the Area is Polymer Science (39) and only then Materials Science, Paper & Wood, with 26 publications. In Chemical Sciences, the leading HEIs and SIs by the number of publication in 2014–2018 are UL, RTU, and IOS, where in UL the leading research sub-fields in the Area are Chemistry, Physical (92), Crystallography (48), and Polymer Science (42). In RTU, on the other hand, the leading research sub-fields in the Area are Polymers Science (61), Chemistry, Organic (38), and Chemistry, Physical (34). At the same time, in IOS the leading research sub-fields in the Area are Chemistry, Organics (128), Crystallography (11), and Chemistry, Inorganic & Nuclear (10). Although the leading research sub-fields of HEIs / SIs appear to overlap, it should be noted that each of these HEIs / SIs is leading in its area of specialisation and can therefore be considered that their main activities do not overlap.

Table 5.2. Breakdown of the number of HEIs / SIs publications by research fields defined by the *Web of Science*, 2014–2018

WoS Fields	RTU	UL	OSI	LSIWC	RSU	LULST	BMC	DU
Physical Sciences and Astronomy	528	720	5	10	3	2	5	22
Chemical Sciences	177	269	171	50	8	9	20	9
Civil Engineering	160	22	0	1	0	8	0	0
Mechanical Engineering	145	137	3	7	2	2	0	4
Chemical Engineering	35	24	4	10	5	3	1	0
Materials Engineering	445	479	12	71	11	10	2	13
Medical Engineering	7	1	0	0	8	0	2	0
Environmental Engineering	95	26	0	8	3	19	1	0
Environmental Biotechnology	19	54	4	7	53	5	15	1
Industrial Biotechnology	17	5	0	0	7	0	0	0
Nano-technology	43	109	1	2	2	2	1	4
Other Engineering and Technologies	11	2	0	0	2	0	0	0

This is also reflected in the breakdown of scientific publications. Chemical Sciences is the only field of the Area in which there are almost equal numbers of writers of both genders (first author), while Mechanical Engineering and Physical Sciences and Astronomy are overwhelmingly male-dominated (**Figure 5.4**). Although in Physics and Astronomy the first authors are predominantly male, the average number of publications relative to the number of writers of both sexes is almost equal, with men averaging 4.43 and women averaging 4.06 publications, indicating higher female productivity in this field of science (**Figure 5.5**). A similar situation can be observed in the Mechanical Engineering field, where the average number of publications for women is higher than for men, 2.92 and 3.21, respectively, despite the low (29%) number of female authors.

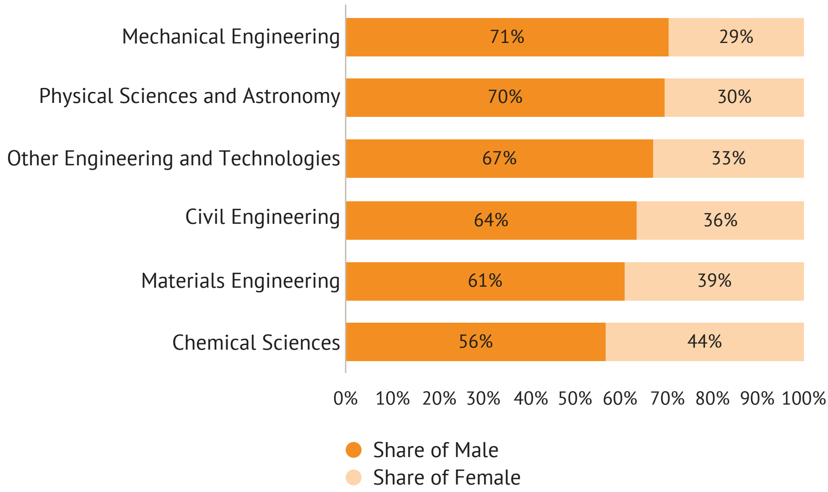


Figure 5.4. The Share of First Authors by Gender, 2014–2018 (*Web of Science*)

In the field of science Civil Engineering female scientists have a higher average CNCI than male scientists, while in Other Engineering and Technologies the average CNCI is higher for male scientists (**Figure 5.6**). CNCI is the number of citations of publications relative to the expected number of citations of the same type, year, and field publications, and it is a qualitative indicator.

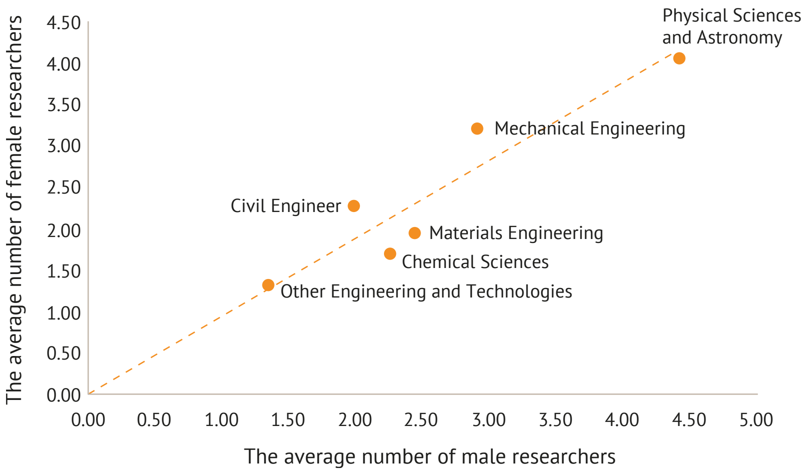


Figure 5.5. The average number of publications by gender in the Area, 2014–2018 (*Web of Science*)

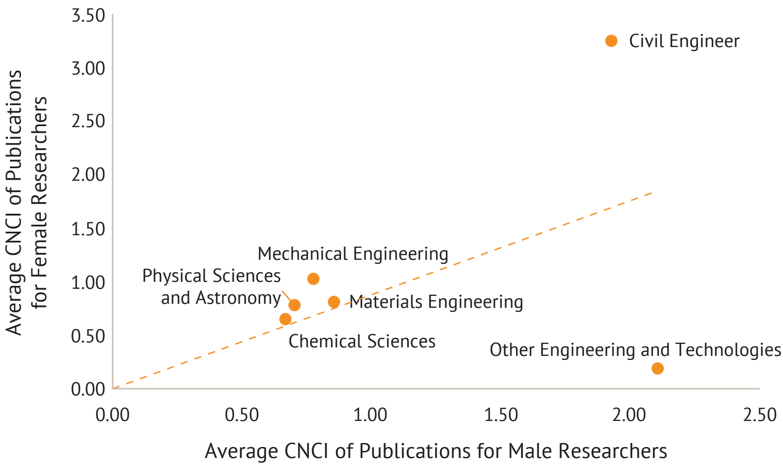
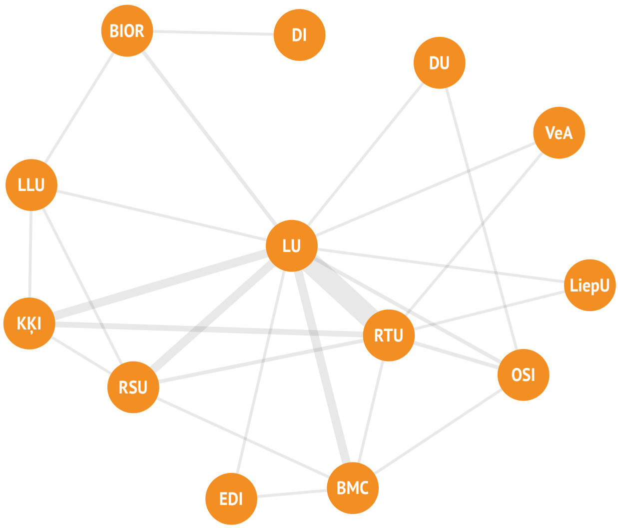


Figure 5.6. The average CNCI of publications by gender in the Area, 2014–2108 (*Web of Science*)

6 Cooperation

6.1. National cooperation

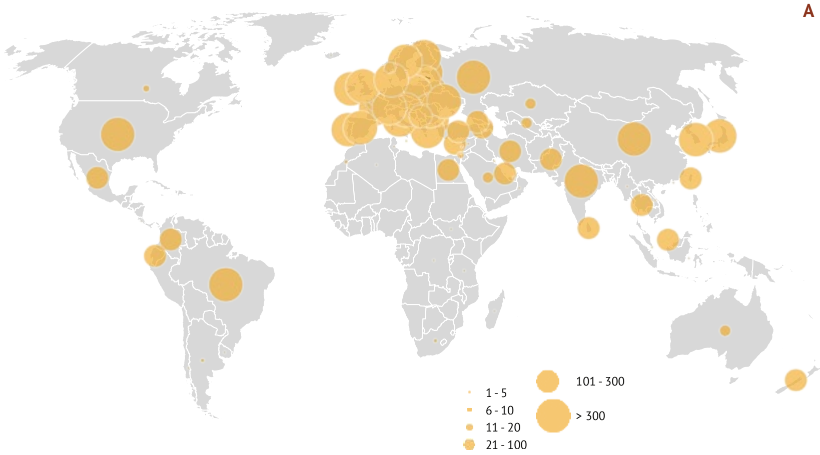
Among higher education and research institutions, the leading collaboration partnership developers in the Area at the national level are the UL and RTU (see **Figure 6.1.1**). UL cooperates with RTU, IOS, LSIWC, BIOR, DU, BMC, VUC, PSCUH, IECS, and LUA, whereas RTU collaborates with LSIWC, IOS, RSU, VUC, BMC, DU, PSCUH, LUA, and LiepU. The highest number of co-publications in the Area is between the UL and RTU (134 publications), UL in cooperation with the RSU (46) and IOS (25).



6.1.1. Figure. Collaboration between Area universities and scientific institutes from 2014 to 2018 (*Web of Science*). **Link** – Co-publications

6.2. International cooperation

In terms of publications, the leading global and European cooperation countries are Germany, France, Poland, Lithuania, Ukraine, Russia, and the United States (see **Figure 6.2.1 A** and **B**). As Germany, France and Poland are *CERN* Member States and Lithuania and Ukraine are Associate Member States, a large part of these co-publications are *CERN* consortium publications related to high-energy particle physics and related physics fields.[15] Russia and the US, on the other hand, are international partners of *CERN*. If Latvia's international partners are considered with the exclusion of the *CERN*-related fields of science, the number of cooperation partners decreases significantly, not only on a global and European scale. The total number of publications also decreases by more than half (see **Figure 6.2.2 A** and **B**). These data clearly illustrate the importance of Latvia's participation in international consortia to promote the development of the industry, international cooperation and visibility.



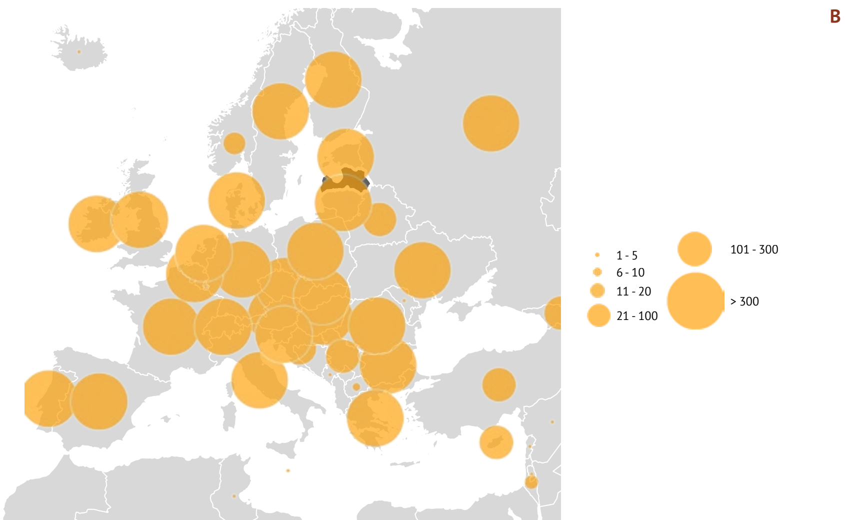
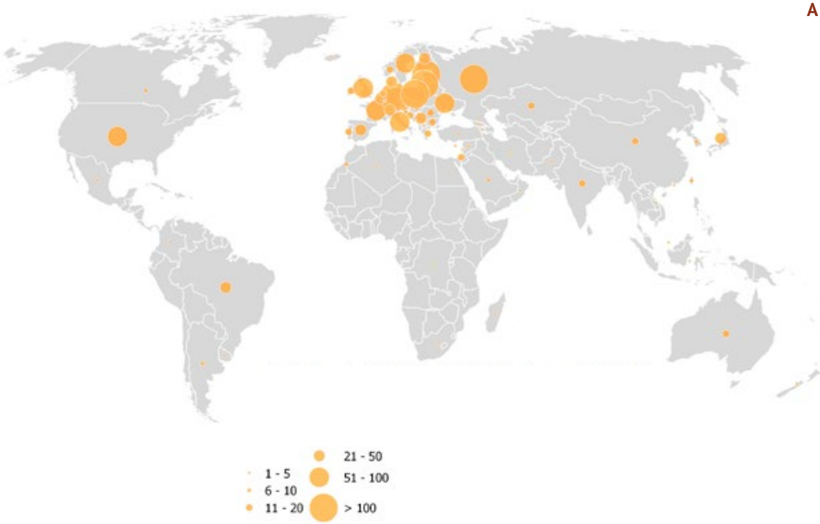


Figure. 6.2.1. International co-operation of Latvia in the Area by the number of co-publications in the world (A) and Europe (B), including high-energy particle physics fields, 2014–2018 (*Web of Science*)

A



B

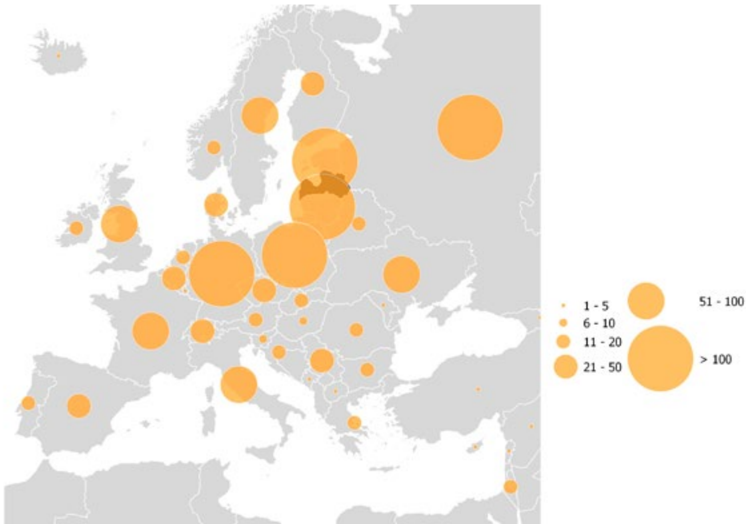


Figure. 6.2.2. International co-operation of Latvia in the Area by the number of co-publications in the world (A) and Europe (B), excluding high-energy particle physics fields, 2014–2018 (*Web of Science*)

The key institutional partners at an international level for leading Area's HEIs and SIs are shown in the figure The leading HEIs (top 5) in the Area that form the widest network of cooperation, are: RTU, UL, LSWIC, IOS, and RSU. RTU has the largest number of co-publications with various international institutions; the publications are in the fields of high-energy particle physics, namely particle physics and nuclear physics. The dominance of RTU in this area is explained by the fact that in 2012 RTU signed a memorandum of cooperation with *CERN* and a Centre of High Energy Physics and Accelerator Technologies has been established in RTU, responsible for Latvia's cooperation with *CERN*. The Centre ensures and coordinates the participation of Latvian scientific institutions in the consortium's R&I activities. 16 Some of the international cooperation partners of RTU also cooperate with the UL, namely Vilnius University, the Russian Academy of Sciences, and French National Centre for Scientific Research (CNRS).

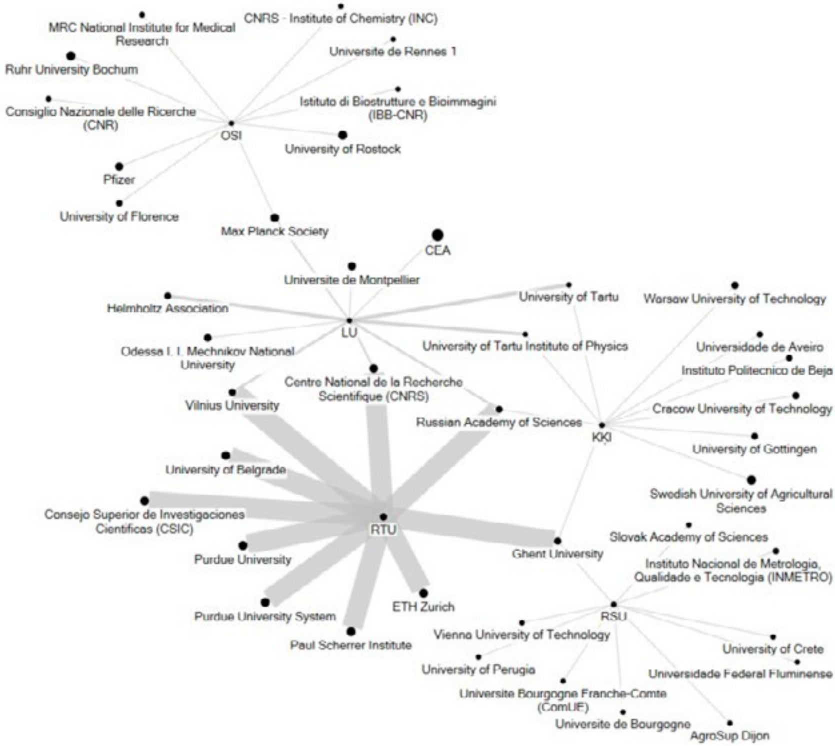


Figure 6.2.3. International cooperation partners of leading HEIs and SIs of the Area.
Link – Co-publications. **Dot** – quality by *CNCI* parameter (the larger the dot, the higher the quality)

6.3. Activities within the "Horizon2020" framework programme

The thematic niche of the EU framework programme "Horizon 2020" corresponding to the Area is "Leadership in Enabling and Industrial Technologies – LEIT". The "Leadership in Enabling and Industrial Technologies – LEIT" focuses on R&I to boost the capacity of European industry, entrepreneurship, and SMEs, and to foster cooperation between the private and public sectors and the transversal role of *KETs* in different sectors of industry. 17 The number of projects submitted by Latvian participants in the thematic sub-niches is as follows: Nanotechnologies – LIET-NMP – 70 project applications; Advanced Manufacturing and Processing LIET-ADVMANU – 28 project applications; Advanced Materials – LIET-ADVMAT – 25 project applications, and also Biotechnology – LIET-BIOTECH – 18 project applications (see **Figure 6.3.1**). The number of projects evaluated at the upper threshold is 11, 9, 5, and 4 for LIET-NMP, LIET-ADVMANU, LIET-ADVMAT, and LIET-BIOTECH, respectively, while 4, 7, 3, and 2 project applications, respectively, have been funded (see **Figure 6.3.1**). The amount of funding received by Latvian participants in the thematic niches LIET-NMP, LIET-ADVMANU, LIET-ADVMAT, and LIET-BIOTECH amounts to EUR 1 003 596, EUR 1 466 648, EUR 745 983, and EUR 168 309, respectively (see **Figure 6.3.2**).

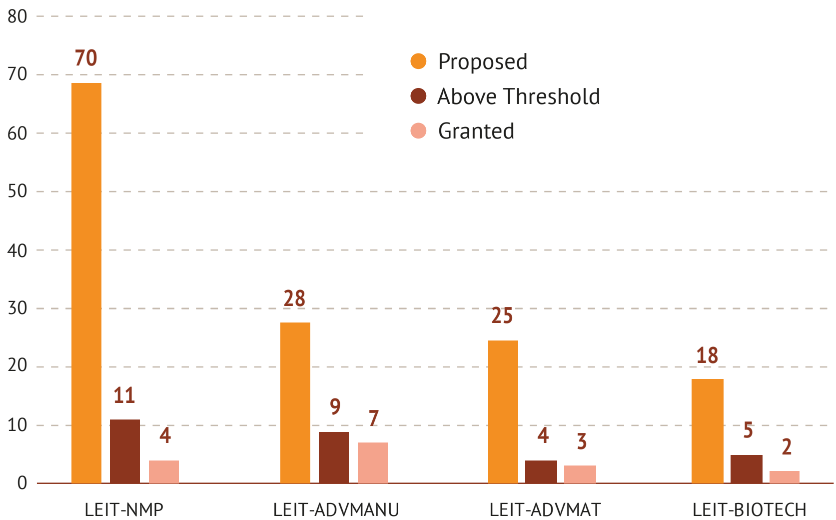


Figure 6.3.1. The success of Latvian participants in "Horizon 2020" framework programme by themes

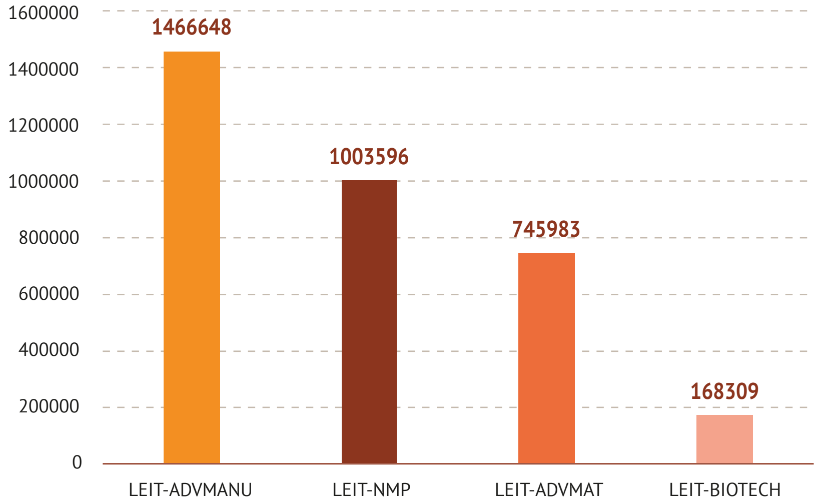


Figure 6.3.2. Acquired EC funding by Latvian participants in “Horizon 2020” framework programme by themes

7 Challenges of the area

The Area is characterised by relatively high performance in some fields of knowledge, which are concentrated in HEIs and SIs that have already proven themselves. The highest R&I capacity is concentrated in Riga. In some fields of science, it is necessary to increase scientific capacity and rejuvenation.

It is necessary to increase the number of graduates in STEM study programmes.

It is necessary to promote cooperation between the business sector and science.

The successful implementation of the innovation system requires close cooperation between all actors in the Area, namely scientists and entrepreneurs, to promote innovation and the transfer of new technologies to production. To reach the EU-28 average, increased investment in research and innovation is needed.

Conclusions

1. The RIS3 Area is characterised by a relatively high level of R&I performance in selected scientific fields concentrated in major centres of excellence.
2. There is a need to increase the number of STEM students and PhDs in order to promote rejuvenation and capacity building.
3. There is a need to promote knowledge and technology transfer.
4. There is a need to increase investment in R&I and to encourage private sector investment in R&I.

RTU is one of the leading engineering higher education institutions in the Baltic states and one of the leading HEIs in Latvia working in the field of materials science. Materials, processes, and technologies is one of the priority directions of scientific research in RTU. The Faculty of Materials Science and Applied Chemistry is the most active in this field, the main activities of which are in the field of innovative and advanced multifunctional materials, namely, production and research of **nanofibres**, **nanomaterials**, **composite materials**, and **biomaterials** used in medicine, electronics, photonics, and alternative energy. In parallel, the technological processes of material research are optimised and improved. **RTU Rudolfs Cimdins Riga Biomaterials Innovation and Development Centre**, the largest and most advanced biomaterial research centre in the Baltics, should be especially noted. With the involvement of interdisciplinary teams of researchers, the Centre is developing a line of research in the field of implant materials for medical applications. Co-operation takes place not only within RTU and nationally, but also internationally – by implementing interdisciplinary research projects. An example is the international collaboration project of the RTU Rudolfs Cimdins Riga Biomaterials Innovation and Development Centre, the Latvian Institute of Organic Synthesis, and Riga Stradiņš University with the AO Davos Science Institute and the Biomaterial Centre of Fridrich-Alexander University of Erlangen-Nuremberg on the Baltic Biomaterial Centre of Excellence (**BBCE**) creation.

The project is being implemented within the framework of the Horizon 2020 programme and provides for research into new biomaterials, bone tissue, facial, oral, jaw surgery, orthopaedic and other applications and will ensure a full lifecycle of biomaterials, from research to commercialisation.

The **Centre of High Energy Physics and Accelerator Technologies** operates under the patronage of RTU. The Centre is responsible for Latvia's international cooperation with **CERN** and its main tasks are promoting the development of the high-energy particle physics field in Latvia, participation in research on high-energy particle physics and accelerator technologies, and development of international Master's and doctoral programmes within the Baltic *CERN* group.

Facts:

- **Number of scientific staff** in the Area – **689**;
- Publications in the Area in 2014–2018 – **1227** (*Web of Science*);
- **Articles in top 25%** most cited journals – **57.79%**;
- **H-index – 34**;
- **Cooperation with industry – 0.33%**;
- **International cooperation – 47.51%**;
- **www.rtu.lv/eng**

The Baltic Biomaterials Centre of Excellence (BBCE) is a project implemented within the Horizon 2020 framework programme Teaming Phase 2 that will enable sustainable and innovative biomaterial research for medical applications. Increasing life expectancy, ageing of the population accompanied by health problems and reduced quality of life are global challenges.

The project will not only allow researching, developing, and commercialising new biomaterials for bone regeneration, facial, oral, jaw surgery, orthopaedics, etc., but will also enhance scientific capacity, excellence and develop interdisciplinarity. The Baltic Biomaterials Centre of Excellence will participate in the full biomaterial development cycle – from the idea to a ready product in the market.

Leading research institutions from Latvia and abroad have joined forces to implement the project. **RTU Rudolfs Cimdins Riga Biomaterials Innovation and Development Centre** is the leading research institute in the Baltic states working in the field of biomaterials and conducting research on implant materials for medical applications.

Riga Stradiņš University and Riga Stradiņš University Institute of Dentistry, are the leading scientific institutions in the field.

The Institute of Organic Synthesis is an internationally recognised research institution that conducts research in organic and medical chemistry, pharmacology, bioanalytics and biophysics.

International partners of the are AO Davos Science Institute and the Biomaterial Centre of Fridrich-Alexander University of Erlangen – Nuremberg.

UL is the most recognisable Latvian higher education institution in the national and international context that provides significant input in the research and innovation development of the Area through a wide range of study programmes in STEM fields, high-quality research-based higher education, etc. The UL has identified the following priority research fields:

- **atomic physics, optical technology, and medical physics**;
- **nano- and quantum technologies, innovative materials**.

One of the institutes working in the priority research fields defined by the University is the **UL Institute of Atomic Physics and Spectroscopy (UL IAS). UL IAS** is an international standard scientific institute that carries out both fundamental and applied research in atomic physics, spectroscopy, photonics, quantum physics, etc. The Institute has been recognised by the European Commission as a centre of excellence in fundamental and applied research. In turn, the **UL Institute for Mechanics of Materials (UL IMM)** carries out scientific research in the following fields of mechanics of materials and materials science:

- **studies on the mechanical integrity of materials**;
- **applications of modern materials in mechanical engineering and construction**;
- **composite material construction calculations**;
- **research on composite and nanomaterial technologies**;
- **influence of external environmental factors on the material incl. mechanical properties of nanomaterials, etc**.

UL IMM is conducting research in the field of carbon, Kevlar, and fibreglass composite materials that could be used in the aviation industry.

In order to improve the quality of studies and research and to ensure the efficient use of infrastructure and human resources, the UL has created an **Academic Centre**, whose function is to ensure synergy between the study process and research fields and to promote the international competitiveness of the University.

Facts:

- **Number of scientific staff** in the Area – **453**;
- **Publications** in the Area in 2014–2018 – **1394** (*Web of Science*);
- Articles in the top 25% most cited journals – 42.61%;
- **H-index – 33**;
- **Cooperation with industry – 21.47%**;
- **International cooperation – 65.78%**;
- **www.lu.lv/eng**

ISSP UL is an internationally recognised scientific institute, rich in tradition, whose main field of scientific research is material science. The Institute not only conducts internationally competitive research, but also trains students in advanced technology and materials science, and provides innovative solutions for industry needs. The Institute is developing 4 main research fields:

Functional materials for photonics and electronics:

- materials for light emitters
- materials for sensors
- materials for photonics devices in information and communication technologies
- prototyping of photonics and microelectronic devices

Nanotechnologies, nanocomposites, and ceramics:

- nanomaterials and nanostructures
- nanoceramics and polymer nanocomposites
- segnetoelectric ceramic materials
- materials for batteries
- materials for the production and storage of hydrogen
- materials for thermoelectric devices

Thin-film and coating technologies:

- PVD, HIPMS, CVD, and PLD thin-film coating technologies
- Organic and inorganic wet spray technologies

Theoretical and experimental studies of material structure and properties:

- theoretical material science
- X-ray absorption spectrometry
- optical spectrometry
- microscopy and structural methods
- metal testing laboratory

Facts:

- **Number of scientific staff** in the Area – **127**;
- **Publications** in the Area in 2014–2018 – **596** (Scopus);
- **www.cfi.lu.lv/eng/**

Starting from 2016, the Institute's project "Centre of Advanced Material Research and Technology Transfer" – **CAMART2**, has been approved and implemented through the Horizon 2020 Framework Programme.

The aim of the project is to modernise and upgrade the existing centre into a new, significantly more efficient centre of excellence that will not only stimulate research into the development of new advanced materials and technologies, but also technology transfer and commercialisation. The project is being implemented in collaboration with – KTH Royal Institute of Technology and Acreo Swedish ICT, a world-renowned leader in research and innovation that has implemented several successful commercialisation projects, and is part of the Stockholm (Kista) innovation system.

The technology transfer platform **Materize** (**https://www.materize.com/**) operates under the patronage of the Institute.

Materize is an industry cooperation and innovation platform for transferring and integrating research knowledge into business. Materize has built a strong ecosystem and, as a KET Centre and Digital Innovation Hub (DIH), helps SMEs and large companies tackle digitalisation and cross the bridge from lab to market to develop and produce new KET-based products. The main Materize cooperation partners are **GroGlass, SIA Sidrabe, EuroLCDs, LightGuideOptics, CeramOptec**.

LSIWC develops its research activities in areas consistent with bioeconomy-relevant research fields, namely:

- **biodegradation and protection of wood**;
- **polymers**;
- **biorefining**;
- **cellulose**;
- **lignin chemistry**;
- **bioengineering**.

Although LSIWC focuses its research on the bioeconomy, it has to be noted that it also overlaps with advanced materials to a certain extent through the development of new research on wood-derived biomaterials and composites. LSIWC cooperates with the **ISSP UL**, **UL**, and **RTU** in developing interdisciplinary research projects on materials for batteries etc.

Facts:

- **Number of scientific staff** in the Area – **77**;
- **Publications** in the Area in 2014–2018 – **114** (*Web of Science*);
- **Articles in top 25%** most cited journals – **41.38%**;
- **H-index – 13**;
- **International cooperation – 42.98%**;
- **www.kki.lv/en**

IOS is the leading medical chemistry and pharmaceutical research centre in the Baltics. IOS is the most export-capable scientific institute in Latvia, which performs both fundamental and applied research in organic, physical, and medical chemistry.

Facts:

- **Number of scientific staff** in the Area – **177**;
- **Publications** in the Area in 2014–2018 – **173** (*Web of Science*);
- **Articles in the top 25%** most cited journals – **19.19%**;
- **H-index – 14**;
- **Cooperation with industry – 1.16%**;
- **International cooperation – 30.64%**;
- **http://www.osi.lv/en**

This report was prepared as a part of the ERDF project No. 1.1.1.5/17/I/002
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representation for research and development of Latvia as part of European Research Area"

Ministry of
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