Application Questionnaire

for the accession of the Republic of Latvia
to CERN as an Associate Member State

CERN, Geneva
February 24th, 2020

Contents

List of Abbreviations

CERN	– European Organisation for Nuclear Research
CMS	– Compact Muon Solenoid
RTU	– Riga Technical University
UL	– University of Latvia
HPC	– High Performance Computing
EU	– European Union
MoES	– Ministry of Education and Science of Latvia
ICA	– International Cooperation Agreement
R&D	– Research and Development
ISSP	– Institute of Solid-State Physics
CCC	– Crystal Clear Collaboration
IP	– Institute of Physics
CBG	– CERN Baltic Group
FCC	– Future Circular Collider
CFA	– Collaboration Framework Agreement
MoU	– Memorandum of Understanding
HEP&AT	– High-Energy Physics and Accelerator Technologies
HEP	– High-Energy Physics
LHC	– Large Hadron Collider
HGCal	– High-Granularity Calorimeter
DAQ	– Data Acquisition
WLCG	– CERN Worldwide LHC Computing Grid
NICPB	– National Institute of Chemical Physics and Biophysics (Estonia)
IT	– Information Technologies
LIEBE	– Liquid Lead Bismuth target for EURISOL
ARIES	– Accelerator Research and Innovation for the European Science and Society
QuantHEP	– Quantum Computing Solutions for High-Energy Physics
HERTIS	– Hybrid Exhaust-gas-cleaning Retrofit Technology for International Shipping
I-FAST	– Innovation Fostering in Accelerator Science and Technology
PRISMAS-MAP	– Production of High Purity Isotopes by Mass Separation for Medical Application
COST	– Cooperation in Science and Technology
CA	– COST Action
ESA	– European Space Agency
ESS	– European Spallation Source
ITER	– International Thermonuclear Experimental Reactor
LC	– Laser Centre
VIRAC	– Ventspils International Radio Astronomy Centre
VUAS	– Ventspils University of Applied Sciences
GDP	– Gross Domestic Product
SMEs	– economically active and commercial companies
SOEs	– State owned Enterprises
ESIF	– European Structural and Investment Funds
SJC	– Scimago Journal & Country Rank
FTE	– Full-time Equivalent
MoF	– Ministry of Finance
MoE	– Ministry of Economy
STEM	– Science Technology Engineering and Mathematics
H2020	– Horizon 2020
RTU	– Riga Technical University
UL	– University of Latvia

Executive summary

This document is the *Application Questionnaire* created to support and provide the relevant information for the accession of the Republic of Latvia to the status of Associated Member state of the European Organisation for Nuclear Research (CERN).

Multiple Latvian institutes have collaborated with various CERN-based experiments since 1996, when an Institute of Electronics and Computer Science contributed to the development of software algorithms for the hadronic calorimeter of the Compact Muon Solenoid (CMS) experiment. Since then, the collaboration between Latvia and CERN has grown considerably, both in breadth and in depth. In 2012, a collaboration framework agreement was signed between Riga Technical University (RTU) and CERN, paving the way for further involvement of Latvian research institutes in CERN-based and CERN-related projects.

The relevant political decisions have been made by the Government of the Republic of Latvia in recent years in order to facilitate the development of the field of high-energy particle physics, as well as the research into particle accelerator and detector technologies via the provision of the required governmental funding and relevant policy actions. In 2018, the Government made the decision to apply to institute Latvia as an Associate Member state of CERN. In 2019, the Government passed a legislation designating appropriate funding for maintaining Latvian cooperation with CERN and the development of the high-energy physics research capacity in Latvia in the medium term. The task of the coordination of the accession procedures and the development of the national study and research programs in high-energy physics was given to the RTU Centre for High-Energy Physics and Accelerator Technology, founded in 2017. This centre was also assigned to act as a national contact point between Latvia and CERN in all relevant matters.

The centre is involved in various projects and activities to promote and solidify the cooperation with CERN and to boost the experimental high-energy physics research community in Latvia. In 2017, RTU deployed the first two researchers to be based at CERN full-time. Since the beginning of 2020, a further three researchers have joined the group and work on the CMS experiment. Two of these are high-energy physics researchers working on top quark physics, while the third is an engineer involved in contributing to a smooth operation of the experiment. The Latvian research team is expected to be boosted by a few high-energy physics doctoral students by late 2020. Furthermore, work on a federated Tier2 High Performance Computing (HPC) site is currently on-going in Latvia, with the aim of contributing to the CERN computing needs in due course by joining its world-wide computing grid.

The activities relating to cooperation between Latvia and CERN, including the accession of the Republic of Latvia as a CERN Associate Member state, are fully endorsed and encouraged by Latvian industry. Latvian businesses and engineering and technology companies are keen and excited about the prospect of the availability of future collaboration with CERN. Some are already involved in R&D activities at CERN.

Latvia has an established and high-quality research community, comprised of a multitude of research-led universities and institutes. There is a strong and long-standing research activity at University of Latvia (UL), and RTU is performing cutting-edge research in engineering and other technology-driven fields. The latter is already successfully contributing to the number of CERN led accelerator technology projects.

The research community in Latvia is eager to see the country become an Associate Member state of CERN in order to invigorate the fields of high-energy physics and particle accelerator and detector technologies in the country, and has the full backing of policy makers and industrial partners.

1. Introduction

The following document has been prepared in order to support the application of the Republic of Latvia (in further text – Latvia) to Associate Membership of the European Organisation for Nuclear Research (CERN). First, a comprehensive overview of the past and on-going cooperation between Latvia and CERN is presented in section 2. Then, sections 3 to 5 provide a summary of the relevant political, economic and scientific aspects of Latvia, as well as an overview of the structure of the educational system in the country.

Latvia has been a member state of the European Union (EU) since 2004 and is a valued member of the European scientific research community. Latvia is a modern, transparent and dynamic European democracy with a solid economic and scientific output. Through the above, Latvia readily fulfils the most fundamental criteria for accession to the status of an Associate member state of CERN, possessing:

- A well-established and varied scientific community with advanced technological capabilities;
- A strong industrial capacity, capable of successful engagement in the CERN procurement processes;
- A clear political support for the Latvian accession to the status of an Associate Member state of CERN;
- A growing high-energy physics community.

Latvia considers Associate Membership of CERN to be of great strategic importance for further scientific and technological development in the country in the medium-to-long term. A more substantial association with CERN will allow Latvian scientific institutions to enhance their research output in the fields of high-energy physics and particle accelerator and detector technologies. Moreover, it will allow the Latvian scientific community, as well as its industry, to contribute more broadly to the scientific output of CERN.

Regarding the above, the Prime Minister of Latvia, in a letter addressed to the CERN Council on 19th of May 2018, *stated* that:

"Latvia is looking forward to bring its cooperation with CERN to a higher stage in order to enjoy the partnership to the full, by considering the application to the membership status at CERN, initially as an Associate Member, followed by the full membership."

Subsequently, on 27th of June, 2018, the director-General of CERN sent the following correspondence to the Minister of education and Science of Latvia:

"the matter was discussed by the CERN Council in a Closed Session on 14th of June 2018. The Council is pleased to note Latvia's wish to intensify its institutional links with CERN. At the same time, the Council considers that the ***foundations of particle physics in Latvia require further strengthening*** *before an application for Membership can be envisaged. The CERN Management, with the full support of the Council, looks forward to continuing to help Latvia consolidate and expand the actions taken in the context of the International Cooperation Agreement with a view to build up the particle physics community and paving the way for an application in the medium-term."*

Following the above exchange, the Government of Latvia, in particular, the Ministry of Education and Science (MoES) in close cooperation with the management and the International Relations Directorate of CERN, took a series of policy actions aimed at considerably strengthening the foundations of high-

energy physics in the country. Furthermore, decisions to implement tangible measures to ensure the longevity and development of the field of high-energy physics were also taken. These measures are outlined in this document.

The relevant scientific institutions and the Government of Latvia have been making all of the necessary institutional, financial and policy steps to allow for the creation of a solid and successful research community in high-energy physics and related technologies in Latvia and the Baltic States. The continued participation of Latvia at the forefront of research in fundamental physics at CERN is at the centre of its bid to become an Associate Member state of CERN. With the support of the CERN Council and management, Latvia is aiming to have fulfilled all the necessary procedures to complete its accession to the status of an Associate Member state of CERN in the year 2021.

1.1. Benefits of Latvia's Associate Membership to CERN

From Latvia's Associate Membership, CERN stands to gain a reliable European partner that shares and respects the values outlined in CERN's Constitution and embedded in its principles of governance. The Latvian scientific community will be rapidly integrated into on-going scientific and technological research projects at CERN, and will immediately engage with the development of future projects as well. *Inter alia*, CERN, and the high-energy physics community as a whole, will gain the following:

- An Associate Member state, which is also a member state of the EU and has a voice in overall EU policy making, including the scientific agenda;
- Direct access to the dynamic, innovative and versatile scientific community in Latvia;
- The experience, technological solutions and know-how of the Latvian research institutes;
- A pool of talented and motivated students in multiple fields of interest, from theoretical physics to mechanical engineering;
- Access to new industrial suppliers and the accompanying unique and novel technologies and products;
- Direct and indirect financial contributions from Latvia;
- An additional direct link to the Baltic scientific community at large.

1.2. Benefits of the CERN Associate Membership to Latvia

CERN is a unique project of scientific collaboration on a global scale. Apart from the well-known physics discoveries benefiting the advancement of fundamental science, there have been numerous technological breakthroughs and landmark engineering achievements that have emerged from this organisation. Although difficult to quantify directly, these have undoubtedly provided great benefit not only to CERN and its member states, but also to society as a whole. Such benefits, however, take some time to evolve, thus these gains must always be viewed in the medium-to-long term, instead of focusing purely on the immediate metrics, such as the instantaneous industrial return.

The potential overall benefits of Latvia's accession to the status of an Associate Member state to CERN are in accordance with the goals of the national development plan of Latvia[1]. Additionally, it will

[1] https://www.pkc.gov.lv/en/node/427

contribute immensely to the development of the science and technology base and the research and innovation potential of Latvia at a national scale through the following:

- Associate Membership will significantly enhance the capacity of the domestic scientific institutions and will strengthen the fundamental science framework, in particular with regards to the fields of high-energy physics and particle accelerator and detector technologies;
- Latvia will gain access to an unparalleled scientific and technological excellence;
- Latvian scientists and students will gain direct and long-term access to CERN's infrastructure and its scientific and technical personnel;
- Latvia will benefit from a variety of programmes and capacity-building measures available through CERN (doctoral students, fellows, associated staff, etc.);
- Local industry will directly benefit from the knowledge, technology transfer and R&D and will gain access to the CERN procurement process;
- Membership to CERN will facilitate scientific collaboration among the domestic scientific institutions and with local industry.

1.3. Political commitment

The Government of Latvia has repeatedly demonstrated a strong political commitment regarding the country's membership to CERN. Two successive Governments have been directly engaged and have demonstrated a clear support for the accession of Latvia to the status of an Associate Member state of CERN – a notable indication of the stability of the relevant policy strategy. This has also been illustrated by the following long-term policy and financial decisions made at the highest level of policy making in Latvia – the Cabinet of Ministers:

- September 2016 – the decision to sign the *International Cooperation Agreement* (ICA) with CERN is made; a mandate to engage with CERN in this regard is given to the Minister of Education and Science[2];
- February 2018 – the decision to apply for the Associate Membership of CERN is taken; the relevant financial framework is outlined; a mandate to engage with CERN in this regard is given to the MoES[3];
- July 2019 – the decision to proceed with the Associate Membership to CERN is taken; this mandates the MoES to prepare and submit to CERN Council the *Application Questionnaire*; the decision includes the creation of the *state research programme in high-energy physics and accelerator technologies*, as well as outlining a legally binding medium-term financial framework for the potential membership, the said research programme and the CERN national contact point in Latvia[4];
- December 2019 – the decision to sign the *Protocol to the ICA* is taken; a mandate to act on the behalf of the Government in this regard is given to the Minister of Education and Science[5]; this protocol establishes the operational framework for mutual collaboration between Latvia and CERN.

[2] http://tap.mk.gov.lv/lv/mk/tap/?pid=40389544&mode=mk&date=2016-09-27
[3] http://tap.mk.gov.lv/lv/mk/tap/?pid=40447205&mode=mk&date=2018-02-06
[4] http://tap.mk.gov.lv/mk/tap/?pid=40475304
[5] http://tap.mk.gov.lv/lv/mk/tap/?pid=40473887&mode=mk&date=2019-12-17

The above policy decisions and the long-term commitment of the Government have been strongly supported by the relevant scientific and industrial stakeholders, as well as the social partners and associations. The keen interest in Latvia's collaboration with CERN has been further demonstrated by a series of high-level official visits to CERN:

- October 2016 – Minister of Education and Science, Prof. Kārlis ŠADURSKIS;
- February 2017 – **Minister of Foreign Affairs, Edgars RINKĒVIČS;**
- June 2017 – Minister of Welfare, Jānis REIRS (accompanied by the major social partners);
- September 2017– **Prime Minister, H.E. Māris KUČINSKIS** (accompanied by scientific stakeholders);
- January 2018 – Parliamentary Secretary of the Ministry of Economy, Jānis UPENIEKS (accompanied by a delegation of Latvian industry and social partners);
- April 2018 – State Secretary the MoES, Līga LEJIŅA;
- October 2019 – Parliamentary Secretary of the Ministry Education and Science, Anita MUIŽNIECE;
- January 2020 – **President of the Republic of Latvia, H.E. Egils LEVITS;**
- February 2020 – Parliamentary Secretary of the Ministry Education and Science, Reinis ZNOTIŅŠ.

In addition to the ones listed above, regular visits of representatives and researchers of a number of Latvian scientific institutions to CERN have been taking place since 2012, with the aim of expanding and solidifying the mutual collaboration. These have resulted in a broader participation of Latvian researchers in the CERN-based experiments and the relevant EU co-funded scientific projects. Likewise, the directors and the management representatives of CERN have been welcomed in Latvia on several occasions, as was the CERN travelling exhibition, which was greeted in Riga in April 2018 and was inaugurated by the Prime Minister of Latvia.

Finally, the Minister of Foreign Affairs has designated an advisor directly responsible for the relations and scientific collaboration between CERN and Latvia. The Permanent Representative of Latvia to the United Nations office and other international organisations situated in Geneva, is directly engaged with the facilitation of the continuous cooperation between CERN and Latvia.

2. Historic and on-going cooperation between Latvia and CERN and other relevant physics research activity in the country

The collaborative relationship between Latvia and CERN has developed gradually and in several fields of research in parallel. Historically, besides high-energy physics, the collaboration has covered a wide range of topics, including the accelerator and detector research and development (R&D), mechanical and electrical engineering, robotics, computing and data processing.

2.1. History of Latvia's relations with CERN and the participation in CERN programs

Latvia has had a long-standing tradition of cooperation with CERN and its experiments, as shown in Figure 2.1. Since Latvia regained its independence in 1990, there have been several scientific cooperation projects between Latvian research institutes and a variety of CERN-based collaborations, experiments and projects. For instance, in the early stages of the **CMS experiment** in 1996, the Institute of Electronics and Computer Science[6] – at that time as a part of the Latvian Academy of Sciences – contributed to the development of the **software algorithms for its Hadron Calorimeter tracker**[7]. In 2000, the Institute of Solid-State Physics[8] (ISSP), of the University of Latvia[9] (UL), joined the **Crystal Clear Collaboration** (CCC)[10] and participated in the development of **scintillation detectors** made of BGO and PbWO4. These were later chosen as the sensing materials in the CMS detector systems. The ISSP re-established its active participation in the CCC in 2018 and today is providing a valuable contribution to its work. Since 2005, the Institute of Physics (IP)[11] of UL, with its expertise in liquid-metal pumps used for the ISOLDE targets, is an active member of the **ISOLDE-based LIEBE Collaboration**[12]. From 2005 to 2008, Riga Technical University[13] (RTU) and the Institute of Mathematics and Computer Science[14] of UL, were members of the **BalticGrid**[15] and directly contributed to the **CERN computing**.

[6] http://www.edi.lv/en/about-edi/
[7] http://inspirehep.net/record/1614056/files/LHCC-97-032.pdf
[8] https://www.cfi.lu.lv/en/
[9] https://www.lu.lv/en/
[10] https://crystalclear.web.cern.ch/crystalclear/Default.html
[11] http://ipul.lv/main/
[12] https://indico.cern.ch/event/805955/
[13] https://www.rtu.lv/en
[14] http://www.lumii.lv/?lang=en
[15] https://cordis.europa.eu/project/id/026715

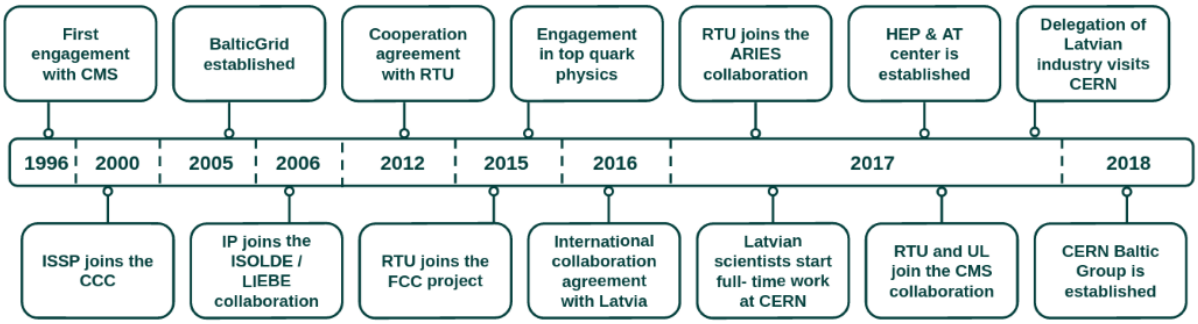

Figure 2.1: Milestones of the cooperation between Latvia and CERN.

In 2012, CERN signed the collaboration framework agreement with a key research and technology institution of Latvia – RTU. This provided a fresh impetus and opened new avenues for Latvian engagement with CERN. For example, in 2015, RTU joined the **Future Circular Collider** (FCC) study and, in 2017, the CERN coordinated **ARIES project**[16]. Furthermore, based on this agreement, in 2015, an RTU PhD student of high-energy physics joined the **CERN Experimental Physics Department** and the CMS Physics, Software & Computing Group, and successfully developed and defended his research thesis in the field of **top quark physics**. Continuing its fruitful collaboration with CERN, in 2017, RTU started to deploy its scientific staff to full-time work at CERN. In 2017, Latvian Consortium of RTU and UL joined CMS experiment, and in 2018 the CERN Baltic Group (CBG) was established.

2.2. International and institutional agreements between Latvia and CERN

Several international and institutional agreements are currently in place between CERN and Latvia, as well as between CERN-based experiments and collaborations and Latvian scientific institutions. The most relevant are:

- The **Collaboration Framework Agreement** (CFA) and the accompanying Addenda, between CERN and RTU; in force since 12th of October, 2012;
- Memorandum of Understanding (MoU) for the FCC study (hosted by CERN) between CERN and RTU; in force since 27th of November, 2015;
- The **International Collaboration Agreement**; in force since 31st of October, 2016;
- MoU for the CMS detector; in force since 14th of May, 2018;
- Protocol to the ICA; in force since 7th of January, 2020.

2.3. Historic and current investment in CERN-related research

Historically, most of the investment covering CERN-related research activities both in Latvia and at CERN was provided by RTU. This involved covering the various travel and accommodation expenses and, since 2017, the expense of researchers based at CERN. Until 2019, RTU was also the chief sponsor of the Latvian participation in the CERN summer student and physics teacher programs. The

[16] https://aries.web.cern.ch/

participation in the research project listed in the previous section was financed by either the specific institutions involved, including CERN, or via the relevant EU co-funding mechanisms.

Since 2019, **designated CERN-related funding from the state budget** has been made available via the aforementioned decisions made by the Government. This was supported by the appropriate scientific policy actions made by the MoES. As a result, at the end of 2019, the following state budget funds were assigned:

- **322 000 EUR** – for the participation in the **CMS experiment**, including travel and the subsistence allowances for the researchers based at CERN;
- **70 000 EUR** in 2019 and **100 000 EUR** in 2020 – for the **national capacity building measures**, including the CERN national contact point in Latvia;
- **300 000 EUR** – **annual** funding for the **state research programme in high-energy physics and accelerator technologies**;
- **75 000 EUR** – for the **annual** participation in the **summer student, doctoral student and physics teacher programs**, and for scientists' visits to CERN;
- **40 000 EUR** – for the **annual** participation in the **CERN MEDICIS** project;
- **100 000 EUR** – **annual** financing of the national contact point's **representative at CERN**.

Additionally, substantial resources from the EU structural fund programmes where allocated by the MoES for the national capacity building measures:

- **100 000 EUR** – for a three-year cover of the development of a multi-disciplinary doctoral level **study programme in high-energy physics and accelerator technologies**;
- **100 000 EUR** – for a three-year cover of the **national capacity building measures** and the CERN national contact point in Latvia;

The financial resources listed above are directly linked with the Latvia's CERN national contact point's plan and the relevant high-energy physics capacity building measures. Potential annual membership payments to CERN of **1M CHF** (circa **860 000 EUR**), with respective indexation, where also dully considered within the framework of the multi-annual state budget planning.

2.4. The current state of high-energy physics and other CERN-related experimental physics research in Latvia

After the decommissioning of the IP's nuclear research reactor in Salaspils in 1998, the experimental nuclear and high-energy physics scientific communities in Latvia were absorbed by other research domains, and research output in these fields began a slow decay. Nevertheless, certain activities where maintained in the Laboratory of Radiation Physics[17]. Concurrently, the Faculty of Physics and Mathematics[18] of UL remained an established and internationally recognised actor in the theoretical and mathematical aspects of particle and nuclear physics. Furthermore, important high-energy physics expertise was maintained and further-developed within the industry – for instance by *Baltic Scientific Instruments*[19].

[17] https://www.cfi.lu.lv/en/about-us/research-units/laboratory-of-radiation-physics/
[18] https://www.lu.lv/en/studies/faculties/faculty-of-physics-mathematics-and-optometry/
[19] http://bsi.lv/en/

2.4.1. Centre of High Energy Physics and Accelerator Technologies

The Centre of High-Energy Physics and Accelerator Technologies[20] (HEP&AT centre) was established in 2017, under the auspices of RTU. The main objectives of this centre are to **facilitate the development of the fields of high-energy physics and particle accelerator and detector technologies** in Latvia and to **encourage the inter-disciplinary collaboration** between said areas of scientific research. In more detail, the principal tasks of the centre are:

- To facilitate the development of the high-energy physics community in Latvia;
- To promote and facilitate the migration of the interested potential personnel to the field of high-energy physics from suitable related fields of research, such as nuclear physics, in Latvia;
- To facilitate improvement in the understanding of the goals, tools, methods and outcomes of high-energy physics research in the general public, in particular, to facilitate the increase in the understanding and competence, in said field, in the pedagogical, academic and scientific communities in Latvia;
- To facilitate capacity building in Latvia in the field of high-energy physics research;
- To coordinate and enable the use of foreign academic and teaching staff in Latvian institutions relating to the field of high-energy physics, as deemed necessary;
- To coordinate and support the R&D activities for technologies relevant to high-energy physics and particle accelerator and detector research in the country;
- To coordinate and support knowledge exchange between the pedagogical and scientific personnel, as well as between academia and industry, with respect to high-energy physics and particle accelerator and detector technologies, in the country;
- To participate, alongside partner institutions in Latvia and in cooperation with CERN, in the establishment of a high-energy particle physics study programme in Latvia at both the masters' and doctoral levels;
- To carry-out the "Action Plan of the National Contact Point at CERN";
- To coordinate the participation of Latvian scientists and institutions in the CMS experiment;
- To coordinate RTU's participation in the FCC project.

The HEP&AT centre has a leading role in the high-energy physics capacity building activities in Latvia, as well as on a regional level, acting as the secretariat for the CERN Baltic Group (CBG), discussed in more detail further in text. The centre leads the participation of the Latvian consortium of UL and RTU in the CMS experiment. In addition, the centre is coordinating the development of the Latvian Tier2 data centre, discussed further in text. Finally, the scientific research activities of the centre are directly supported by the national science policy via its engagement in the newly established the state research programme in high-energy physics and accelerator technologies.

[20] https://www.rtu.lv/en/hep/about-us-hep

2.4.2. The CMS experiment

In order to contribute to the CMS experiment in the most efficient way and to foster institutional cooperation in the country, Latvia joined CMS as a consortium of two major universities - RTU and UL. It was done under the auspices of the MoES - the funding agency for the Latvian contributions to CMS. The MoU for CMS was signed by the Minister of Education and Science, in the presence of the Prime Minister, in Latvia at the inauguration of the CERN traveling exhibition at the National Library of Latvia. This occasion served as a demonstration of the strategic importance of the participation in the CMS experiment to the national scientific research policy of Latvia.

In physics research, Latvia and RTU is currently represented by two researchers, based full-time at CERN and working within the CMS collaboration. The main focus of Latvia's research team is t**op quark physics** at the Large Hadron Collider (LHC). As a part of the top quark analysis group of the CMS experiment, Latvian researchers are involved in studies of colour flow reconnection in top quark decays and in exploring the potential mass difference between the top quark and anti-top quark masses using the Run 2 data of the CMS experiment.

In the absence of the observation of New Physics at the tera-electron-volt (TeV) scale, precision physics is becoming an especially important topic at the LHC experiments. Looking for minuscule enhancements in particle production rates via the loop level Feynman diagrams allows to search for potential New Physics at a higher energy regime. Analyses regarding the top quark are particularly interesting, given the high mass of the top quark, indicating the strongest known coupling to the Higgs boson, which might extend to unknown new particles as well. Therefore, the Latvian CMS physics team will look to join and give valuable input into top quark production analyses using the Run 2 and, later, Run 3 data collected by the CMS experiment.

Furthermore, as described in the recently circulated CERN yellow report on the physics prospects at the HL-LHC and HE-LHC[21], top quark physics will become an even more interesting topic in the future (Run 4 and beyond). First, the increased statistics and, in the latter case, the higher energy reach, will provide the opportunity to further constrain the top quark mass and production mechanisms, which are key for searching for New Physics at the precision frontier. Latvia's CMS group will look to become an integral member of the top quark physics group, both at the CMS experiment and LHC-wide, in order to contribute to these exciting physics prospects.

In addition to the physics analyses, the aim is to deeply involve the group in CMS upgrade projects in the near future, with joining the **HGCal project** being one of the areas being explored at this stage. Another option of contribution to the upgrade in the short term is to join the **data acquisition (DAQ)** readout board production and validation efforts. To explore the most beneficial avenues of joining the upgrade efforts, Latvia's CMS group has been boosted by a senior full-time engineer embedded in the CMS Technical Coordination group.

We aim to expand our CMS group by employing a minimum of two PhD students in the latter half of 2020, with the goal of repeating with the same or enlarged cohort in 2021 and beyond. These students are to spend part of their doctoral studies based in Latvia and part based at CERN.

The Latvian consortium at CMS is currently represented by 5 scientists[22]: 3 physicists and 2 engineers, of whom: 2 are on the list of CMS authors and 4 are 100% present at CERN and are fully integrated

[21] http://dx.doi.org/10.23731/CYRM-2019-007
[22] http://cms.cern.ch/iCMS/admin/prjlist?instcode=RIGA-RTU

within the above-mentioned groups. Registration of other 7 scientific and technical CMS users is under way.

2.4.3. Development of a Tier2 centre in Latvia

One of Latvia's strategic projects regarding its CERN-related activities, is to seek to contribute to the CERN Worldwide LHC Computing Grid (WLCG) via the establishment of a new Tier2 data centre in the country.

During 2019, RTU and UL began a collaborative effort of uniting their respective HPC resources into a single network, with the aim of using the unified HPC as a single Tier2 site. A state-financed pilot project is underway to validate the feasibility of the overall scheme and is showing positive results. The above project is viewed as a natural continuation of the aforementioned BalticGrid and is open to further institutes in Latvia, in possession of substantial HPC resources, joining in the future.

The development of the Tier2 project in Latvia is supported by experts from the Estonian Tier2 site hosted by the National Institute of Chemical Physics and Biophysics (NICPB) and from CERN and CMS. The fast-paced development if further aided by the strength of the information technology (IT) industry in the country.

The benefit of the ground-up development of a new Tier2 site is the freedom to incorporate the most up-to-date technologies available in the field. The Tier2 expert's group in Latvia are in the position of using a state-of-the-art system architecture. The flexibility of this architecture allows the flexible scale-up of the computing capabilities of the new Tier2 site by adding HPC resources of new *federation members* form other institutes in Latvia. The management system is based on the *OpenStack* cloud-server platform and *CEPH* software-defined storage solutions. A single compute-element management system has been implemented. This is to receive tasks from CERN and serve as the single point of contact. Then, the tasks are distributed throughout the available HPC resources on the *federation* partners, where *Slurm* resource management system is used to automatically distribute and execute the tasks on the available CPUs. These tools are recommended by CERN and will allow for success in both the pilot-project and the following development of a fully functional Tier2 site.

A series of technical upgrades of the management system have been carried out to meet the performance requirements and a unique domain – *t2cms.hpc-net.lv* – has been registered. This is to be followed by the linking of the computing resources of the *federation* partners and by the registration of the Latvia's Tier2 date centre with CERN. The subsequent tests and the full-scale implementation will be performed in due course.

2.4.4. The ISOLDE - LIEBE collaboration

Institute of Physics of the UL is a core member of the LIEBE project – "Liquid Lead Bismuth target for EURISOL[23]". It builds upon the long-standing tradition of molten metal targets usage at ISOLDE. The main goals of the project are to adapt the design of a molten Pb/Bi loop into the operating environment of CERN-ISOLDE; to perform the offline tests for the development and licensing of the

[23] http://ipnwww.in2p3.fr/The-EURISOL-project?lang=en

target loop; to obtain a meaningful set of data during its operation using state-of-the-art strategies. LIEBE target offers improved isotope-release efficiencies for short-lived isotopes, alongside the capability of operating at a high primary-beam power. The design of the 100kW molten target for EURISOL must, therefore, evolve towards a circulating molten metal loop, accommodating a diffusion chamber and a heat exchanger. At a moderate flow rate of 0.2 l/s, 30 kW of the deposited heat must be evacuated and the pump technologies handling pressures in excess of about 1 Bar are required in the proposed design of the molten Pb target.

The LIEBE collaboration was established in May 2012 and resulted in an ISOLDE-environment offline experiment in 2019. The IP, based on its expertise, have created an electromagnetic permanent-magnet pump for the Pb/Bi circulation and have carried out offline experiments using a special mock-up loop to qualify the hydraulic parameters for LIEBE loop at ISOLDE.

The project is currently at the stage of qualifying the LIEBE loop and the target at the ISOLDE-environment for safe operation and is soon to carry out an online test.

2.4.5. Crystal Clear Collaboration

The ISSP has a long-standing cooperation with the CCC, which began in 2000. This institute re-established its membership to the CCC in 2018 and is now engaged in a project entitled "Radiation damage studies in scintillator materials for high-energy physics and medical applications". It is important to underline that this research activity is state-financed, via the national grant system[24].

The project is devoted to systematic **studies of the radiation damage** kinetics and basic processes in **scintillating materials** currently used in particle physics experiments, neutron research and medical imaging. The main goal is a prediction of **long-time radiation stability** of strongly irradiated scintillator materials based on a careful analysis of the defect annealing kinetics. This research activity covers the following:

- Demonstration of the Meyer–Neldel rule for the thermal annealing of radiation defects in ZnO, BaF_2, CaF_2, $Y_3Al_5O_{12}$, $Gd_3Ga_5O_{12}$ and other scintillator materials; a relation of the defect migration-recombination properties and radiation fluence;
- Acquistion of new data on oxygen interstitial diffusion parameters (activation energy), derived from the thermal annealing kinetics;
- Search for defect-induced Raman modes in heavily-irradiated scintillators, where optical methods fail; theoretical *ab-initio* modelling;
- Analysis of the EPR spectra of radiation-induced defects in heavily-irradiated scintillators;
- *Ab-initio* calculation of the atomic and electronic structure of pure and doped luminescent materials, e.g. CeO_2:Tb^{3+} and $NaYF_4$:Ce^{3+};
- Time-resolved luminescence spectroscopy, including the use of synchrotron radiation (MAX-IV), of the perspective new scintillator materials, as well as for the study of the mechanisms of their radiation degradation.

[24] https://www.cfi.lu.lv/en/research/projects/lcsgrants/radiation-damage-studies-in-scintillator-materials-for-high-energy-physics-and-medical-applications-2018-2021/

2.4.6. CERN-MEDICIS project

A consortium of two Latvian universities (RTU & UL) is on its way to join the MEDICIS[25] collaboration, under the auspices of the MoES. The relevant MoU has been prepared, however, at the time of writing, it is yet to be signed. It is envisaged that this consortium, composed of the Institute of Biomedical Engineering and Nanotechnologies of RTU and the Faculty of Medicine of UL, both in a partnership with the Nuclear Medicine Centre[26], will contribute to MEDICIS with its expertise in **medical physics, clinical radiology and rare nuclear isotope production**.

2.5. Other CERN related activities

Latvian scientific institutions are participating in a wide range of CERN coordinated projects. Several of these projects have been co-funded by the EU Horizon 2020 (H2020) programme and/or directly co-financed by the Latvian scientific institutions participating in these unique scientific collaborations.

2.5.1. The Future Circular Collider study

RTU joined the FCC in the crucial stage of its development in 2015. Since then the university has had an active involvement in the project and has made important contributions to the overall study, namely, in the **development of new concepts for the maintenance, repair and surveillance** using robotic platforms with an integrated laser-cladding equipment[27]. Furthermore, RTU has contributed to the final **FCC conceptual design** reports (Parts I, II, III and IV), which have been published in the European Physical Journal[28]. The FCC project, with the involvement of Latvian experts, is providing valuable inputs to the upcoming European particle physics strategy update.

2.5.2. The ARIES project

Accelerator Research and Innovation for the European Science and Society[29] (ARIES), is a CERN coordinated H2020 integrating activity project, dedicated to the **research, development and innovation** of European **particle accelerators** and the related **infrastructure and technology**.

RTU is participating in the overall management of the project and is contributing to several important activities of the collaboration, such as the study of intense **RF modulated E-Beams** by the Institute of Industrial Electronics and Electrical Engineering; the research in **Thin Film for Superconducting RF Cavities SRF** by the Institute Technical Physics; the training, communication and outreach for the accelerator science in Europe; and promoting innovation. The HEP&AT centre is leading the ARIES

[25] https://kt.cern/success-stories/cern-medicis-novel-isotopes-medical-research
[26] http://www.rnmc.lv/en/
[27] https://indico.cern.ch/event/556692/contributions/2592726/
https://indico.cern.ch/event/656491/contributions/2938828/
[28] https://fcc-cdr.web.cern.ch/#
[29] https://aries.web.cern.ch/

Proof-of-Concept project entitled: "**Development of hybrid electron accelerator system for the treatment of marine diesel exhaust gases**".[30]

In 2018, RTU successfully hosted the ARIES Annual meeting in Riga[31].

2.5.3. QuantHEP project

The **Quantum Computing Solutions for High-Energy Physics**[32] (QuantHEP) project aims to develop quantum algorithms as a solution to the increasingly challenging problem of analysing and simulating the collision events for the large particle physics experiments. QuantHEP is developing **quantum algorithms for the event selection and reconstruction**, and will use these algorithms to perform a proof-of-principle analysis using real data from CERN. It will be exploiting a combination of classical and freely-available quantum processors and benchmark the potential advantage of this novel quantum-enhanced processing.

UL is a core member of this collaboration and is in charge of the development of the q**uantum algorithms** and looking for the **quantum computational complexity** solutions.

2.5.4. Robotics at CERN

With the direct support of CERN, RTU has a project associate (PJAS) embedded in the **CERN survey, mechatronics and measurements group**. One of the main projects of this group is the research in human-robot collaboration and autonomous person detection, localization and non-contact vital parameter monitoring in harsh environments. The goal of the project is to develop an approach for an autonomous victim detection, localization and non-contact vital parameter assessment (e.g. heartbeat and respiration frequency) in search and rescue scenarios using a set of on-board sensors to classify the casualties according to their need for medical attention.

2.5.5. The HERTIS project

At the time of writing, the **Hybrid Exhaust-gas-cleaning Retrofit Technology for International Shipping**[33] (HERTIS) project is in the application stage. This project will develop a novel, hybrid-technology based on the concept of combining two methods to clean up the exhaust gases: irradiation by an electron beam accelerator and the subsequent purification by an improved wet-scrubbing technology. This innovative, hybrid exhaust-gas cleaning retrofit technology will provide a solution for the SOx, NOx and PM emissions challenge in a single technological system, which will cost less than operating on a low-sulphur fuel or deploying a conventional scrubber.

Under the leadership of RTU, HERTIS will bring together two parties that have never combined their expertise before – the **maritime transport and particle accelerator communities**. The HERTIS project was formed and is operated as a consortium. The 12 partners from 8 countries, including CERN,

[30] https://acceleratingnews.web.cern.ch/article/bringing-particle-accelerators-ships
[31] https://acceleratingnews.web.cern.ch/article/aries-first-annual-meeting-riga
[32] https://www.quantera.eu/calls-for-proposals/funded-projects-call-2019/96-quanthep
[33] https://www.rtu.lv/en/hep/accelerator-technologies/international-projects/hertis

represent universities, technology institutes and industry. HERTIS will drive the development of this technology to TRL 6. This process will be accompanied by a series of on-board tests related to the environmental and safety requirements. The lifetime cost-effectiveness, market potential and the environmental impact of this novel emission clean-up technology will be evaluated and the results presented and disseminated to the relevant stakeholders and to the general public.

2.5.6. The I-FAST project

The **Innovation Fostering in Accelerator Science and Technology (I-FAST) project** is a CERN coordinated H2020 project in the pre-submission stage. This is a new instrument for particle accelerator R&D in Europe. It is unique due to the direct engagement of the project with industry as a co-innovation partner. The aim of it is to improve the sustainability of future accelerators via lower cost of technologies, lower power consumption and environmental impact. The project also aims to support the transition of the accelerator technologies developed within its framework towards industrial and medical applications and a status of an applied science in general. This is a major undertaking by the accelerator community, comprised of around 50 established and well-known scientific and industrial partners in Europe. In I-FAST, RTU contributes to the overall project management and leads Innovative accelerator technologies work package, as well as contributing to several other tasks within the project.

2.5.7. The PRISMAS-MAP project

The **Production of High Purity Isotopes by Mass Separation for Medical Application** (PRISMAS-MAP) project is a CERN coordinated H2020 project proposal in the pre-submission stage. This integrating activity will mobilize a consortium of key research infrastructures in Europe. PRISMAS-MAP proposes to exploit the newly available mass separation technique at MEDICIS with other large European production infrastructures to foster a new research era based on **emerging medical isotopes**. The aim is to provide an improved access to new medical isotopes at a very high purity grade thanks to the close coordination and networking offered in the project.

UL and RTU, with their expertise in clinical radiology, medical physics and nano-dosimetry, are contributing to this project in several work packages.

2.5.8. EU or other international grants related to research at CERN

Latvia is a member state of the European Cooperation in Science and Technology - **COST**, a pan-European funding organisation aimed at cultivating research and innovation networks through four-year long COST Actions (CAs). Since 2018 Latvia is participating in and is represented in the management committee of the CA16201 – "**Unravelling new physics at the LHC through the precision frontier**"[34]. Through the participation in this CA Latvia aims to build and enhance its high-energy physics capacity by participating in and organising **training and networking events** funded or part-funded by this CA. One such event is the **Baltic School of High Energy Particle Physics and Accelerator**

[34] https://particleface.eu/

Technologies, organised in the framework of CERN Baltic Group partners, with the inaugural event planned for August 2020. This COST action was initiated in 2017 and will run until the latter half of 2021, upon when the continuation of its operation will be reviewed. During the remainder of the current round of this CA, we aim to utilise the vast network of connections and the monetary support it provides to increase Latvia's capacity in high-energy physics through further training events in Latvia and traineeship opportunities of Latvian students at CERN.

In addition, the administrative and scientific staff of the RTU's HEP&AT centre have recently participated in the **ERASMUS+** staff mobility training at CERN. The staff were introduced to and educated in the use of CERN-specific and other management tools and services, such as the indico system. The centre personnel liaised with the CERN staff responsible for the CERN visits by students, teachers, scientists and other visitors, and were introduced to various student, intern and teacher programs available at CERN.

2.6. Relevant physics activities and projects outside the cooperation with CERN

There are several scientific institutions and laboratories in Latvia, which are conducting world-class research, in both fundamental and applied science, in fields closely related to the portfolio of research activity of CERN. For the most part, these research activities are state funded. Their excellence is demonstrated through their participation in important international scientific collaborations and EU-funded projects. These scientific institutions are directly engaged in, for example, the research and technology development activities at the **European Space Agency (ESA),** the **European Spallation Source (ESS) and** the **International Thermonuclear Experimental Reactor (ITER)**. It is important to note that Latvia is well on its way to become an Associate Member state of ESA.

2.6.1. Atomic and Molecular Physics, Astrospectroscopy

Faculty of Physics, Mathematics and Optometry of the UL is the home of the Laser Centre (LC) - a unique experimental infrastructure centre at a national and regional level. LC was established as an open facility, with the goal of providing access to all the interested external researchers. LC's own researchers actively work in the areas of atomic, molecular and chemical physics and astrophysics, as well as various applications of laser technology. Research in the LC is structured topically in one of its three laboratories: the Atomic and Molecular Physics Laboratory, the Molecule Optical Polarization Laboratory, and the Laboratory of Astrospectroscopy.

Several research groups at the LC and the Institute of Atomic Physics and Spectroscopy at the UL study laser-light interaction with atoms and small molecules. Namely, the creation of coherent atomic states upon the interaction of the radiation from the laser with the atoms, as well as the manipulation and the destruction of these states by external fields and the environment[35].

[35] Auzinsh, M. Ferber R. Optical Polarization of Molecules, Cambridge University Press, 1995, 2005; 324 pages, ISBN-13: 978-1107609259; ISBN-10: 1107609259;

Auzinsh M., et al. Optically Polarized Atoms. Understanding Light Atom Interaction, Oxford University Press, 2010, 2014.; 400 pages, ISBN-13: 978-0198705024

In the context of the research activities carried out at CERN, these investigations can be related to the tests of the Standard Model. Namely, the coherent atomic states in collinear/anti-collinear electric and magnetic fields can be used for the detection of permanent electric dipole moment of atoms (EDM experiments)[36]. The EDM enhancement effects in heavy atoms and molecules can be instrumental for that. This, however, should be done carefully, as several other sources can mimic the effects similar to those associated with permanent electric dipole moment of electrons[37].

These coherent processes in atoms are used at the UL to device practical magnetometers for the magnetic field and, possibly, the electric field measurements with high sensitivity and in broad dynamic range of field intensities[38].

There also exists a not yet fully resolved puzzle regarding the possible time variation of the fine structure constant, alpha, which implies that, at least one of such physics constants as the electron charge or the Planck's constant, could be time dependent. Coherent effects in some heavy atoms, like dysprosium, can be used to determine these variations or to set an upper limit for them[39].

Finally, the atomic physicists at the UL have gained invaluable experience in previous collaboration with the Theodor W. Hänsch group at the Max Planck Institute for quantum optics in Germany. This collaboration brought remarkable and record-breaking precision measurements of some atomic constants, such as the Rydberg constant - the preferred constant to be used for the comparison studies of the properties of matter and anti-matter[40].

Furthermore, the Laboratory of Atomic and Molecular Physics possesses great experience in the field of **high-energy cosmic-ray physics**. Its researchers are involved in the activities of the General Antiparticle Spectrometer (GAPS), more specifically, in the dark matter search using cosmic-ray antideuterons.

The Laboratory of Astrospectroscopy focuses on the applications of high-resolution spectroscopy for space research, performing the abundance analysis of stellar atmospheres, nucleosynthesis and the chemical evolution of a Galaxy, including neutron-capture nucleosynthesis (s-/r-process). This research laboratory has led or coordinated a number of major national and international research projects including the FP7 – "Evolved stars: clues to the chemical evolution of galaxies".

[36] M. Auzinsh, et al., A new experiment to measure the muon electric dipole moment, AIP Conference Proceedings, issue 698, pp 196 – 199 (2003).

[37] Auzinsh M, et al, Electric Field Induced Symmetry Breaking of Angular Momentum Distribution in Atoms, Physical Review Letters, 97, 043002(4), 2006, arXiv.org, physics/0603194

[38] European Space Agency funded project: Feasibility study of spacecraft magnetometers based on nitrogen-vacancy centres in diamond (2020 - 2021), Laser Centre of the University of Latvia, project leader prof. Marcis Auzinsh

[39] M. Auzinsh, et al. Can a quantum nondemolition measurement improve the sensitivity of an atomic magnetometer? Phys. Rev. Lett. 93 (17) 173002, 2004, arXiv: physics/0403097

[40] Christian G. Parthey, Arthur Matveev, Janis Alnis, Randolf Pohl, Thomas Udem, Ulrich D. Jentschura, Nikolai Kolachevsky, and Theodor W. Hänsch Precision Measurement of the Hydrogen-Deuterium 1S−2SIsotope Shift Phys. Rev. Lett. 104, 233001, June 2010

2.6.2. Astroparticle Physics

Astroparticle physics in Latvia is mainly conducted at the Ventspils International Radio Astronomy Centre (VIRAC) at the Ventspils University of Applied Sciences (VUAS). It operates the key radio-telescopes in Latvian and the Baltic States: RT-16 (16m with 4.5-8.8 GHz receiver); RT-32 (32m 4.5-8.8 GHz receiver) and LOFAR (HBA antenna at 110-250MHz and LBA antenna at 10-90MHz). VIRAC operates as an observatory member of the European VLBI (Very Large Base Interferometry) network (EVN). Since 2016, it is a member of the JIVE (Joint institute for VLBI, a European Research Infrastructure Consortium) network. Since 2019, it is also a member of the International LOFAR (Low Frequency Array) telescope network (ILT). With its radio telescopes, VIRAC carries out the methanol maser observations and performs the studies of interstellar dust and solar activity. VIRAC also houses an advanced HPC facility, used for its research in engineering physics, radio astronomical data processing and the near-space object tracking.

The Institute of Astronomy of the UL conducts **fundamental and applied research in astronomy** and related areas. The institute runs two observatories in Latvia – the Astrophysical Observatory and the Geodynamical Fundamental Station. These observatories are equipped with modern equipment and are comprised of modern facilities, and successfully participate in the implementation of international projects such as the international laser-ranging service. Several asteroids discovered at the Baldone Astrophysical Observatory have been given names with Latvian connections.

2.6.3. Solid State Physics and Technical Physics

ISSP is an internationally recognised leader in the materials sciences and cross-disciplinary topics in the Baltic States. It is also the coordinating entity of the EUROfusion programme in Latvia, ISSP is conducting research in the following main areas:

- Theoretical and experimental studies the structure and properties of materials. Fundamentals and technology of multifunctional materials; computational modelling of materials and devices; quantum chemistry and molecular dynamics study of fine structural effects relevant to nanomaterial structural, electronic, magnetic and optical properties. The experimental tools include high-power computing, x-ray absorption and optical spectroscopies, as well as scanning/electron/optical microscopy;
- Nanotechnology, thin films, nanomaterials and ceramics. Nanomaterials and nanostructures, crystals, glasses, nanoceramics and hybrid structures. The R&D activities address the so-called Green Thin Film Nanotechnologies based on vacuum technologies such as the physical and chemical vapour deposition and pulsed laser deposition as well as the organic and inorganic spray wet technologies and novel High-Power Impulse Magnetron Sputtering technology;
- Functional materials for photonics, sensorics and electronics. Organic materials for light emitters, lasers and OLEDs, waveguides and IR sensors, transparent nanocomposite oxyfluoride materials for optical applications, materials for photonic applications in ICT, large area nano-coatings for application in transparent and flexible electronics. Additional application areas: dosimeters and sensors using thermos-luminescence and optically stimulated luminescence in nitrides and oxides, scintillators for high-energy physics and biomarkers for medical applications;
- Materials for energy harvesting and storage: fuel cells, photovoltaics, thin film batteries, lithium ion and lithium coating batteries, supercapacitors, piezoelectric energy harvesters,

lead free ferroelectric perovskites for electromechanical actuators and energy harvesting. Hydrogen generation, hydrogen and sustainable energy storage, thermoelectric, advanced functional and constructive materials for thermonuclear fusion reactors.

ISSP is a member of the CCC and will host the 2020 Spring meeting in Riga. CCC indirectly contributes to the CMS experiment.

Complementary to ISSP, the Institute of Technical Physics[41] in Faculty of Materials Science and Applied Chemistry of RTU is conducting scientific and research activities in the areas of Solid-State Physics; Radiation Engineering Physics; Engineering Physics of Condensed Matter and Semiconductor Physics. Research Laboratory of Semiconductor Physics of this institute is engaged in the aforementioned ARIES project and performs research on Thin Film for Superconducting RF Cavities SRF, as well as research in the fields of:

- nanostructured materials for sensing;
- modification of materials at the nano-level by laser radiation;
- dynamical optical holography;
- energy harvesting from ambient and human motion.

2.6.4. Extremely-precise event timing measurements

The Institute of Electronics and Computer Science and its Space Technology Laboratory have an established expertise for the extreme precision Event Timing measurements in the ps range. Alongside other research activities, this institute is participating in Jiangmen Underground Neutrino Observatory (JUNO) collaboration and has developed the special timing system for monitoring the White Rabbit[42] (WR) network, providing time synchronization in JUNO. This timing system includes a Multifunctional True Event Timer (MTET), providing 1PPS signal measurement from different WR nodes and the external control and access to the measurement results using Experimental Physics and Industrial Control System (EPICS).

2.7. The status and the future of scientific computing in Latvia

Latvia has one of the fastest telecommunications infrastructures in the world[43], providing companies with seamless connection with customers and partners abroad. According to the World Broadband Speed League data, in 2018 Latvia had the 13th fastest internet speed in the world (28.63 mb/s), not only outperforming Estonia and Lithuania, but also such locations as Hong Kong, United States, France, Spain and other technologically advanced countries.

Academic Data Centre (owned by the MoES) is located in the RTU campus. The Academic Data Centre is a national-level computing hub, which has the direct connectivity to the largest internet providers as well as to the European e-infrastructures through GEANT. The connection speed to the GEANT network is 10Gbps.

[41] http://www2.ktf.rtu.lv/TFI/index.html
[42] http://white-rabbit.web.cern.ch/
[43] http://www.liaa.gov.lv/en/invest-latvia/why-latvia/developed-infrastructure

There are two state designated entities dedicated to the fundamental and applied research in computer science, information, communication and electronic technologies: the **RTU High Performance Computing[44] Centre** and the **Institute of Mathematics and Computer Science (IECS)** of the UL. They are aiming to provide support in the application of the e-science technology. Other scientific institutions in Latvia also operate high-capacity and high-performance data storage and data processing infrastructure, such has the aforementioned ISSP and VUAS.

The MoES is representing Latvia in the EuroHPC[45] initiative and, jointly with RTU and UL, is developing the National Competence Centres. Total computation capacity in scientific sector was estimated to be on the order of 300 Tflops, with the storage capacity of 2-3 PB. Taking into account the strength and importance of its IT sector[46], Latvia has a significant role in the European Cloud Computing Strategy[47]. This could be of significant interest to CERN and its computing activities.

2.8. Technological impact of high-energy physics and the prospective industrial engagement with CERN

Prospects of the industrial collaboration with CERN are of high importance to Latvia and its economy. Positive technological impact from the industrial engagement and the access to CERN R&D developments, as well as potential invitations to CERN tenders, are very attractive to the national business. This applies to a range of Latvian hi-tech, IT, electronics, manufacturing engineering and other companies that are very interested in the collaboration with CERN. Such collaboration has not only a clear commercial and knowledge-transfer benefit, but also a prestige boost from the association with CERN. Ministry of Economy fully endorses Latvia's associate membership to CERN and sees clear opportunities of a well-balanced industrial return[48]. Furthermore, all major industrial stakeholders and social partners in Latvia (the Confederation of Employers of Latvia - LDDK[49], Latvian Chamber of Commerce and Industry[50], Latvian Electrical Engineering and Electronics Industry Association – LETERA[51], Investment and Development Agency of Latvia - LIAA[52], The Association of Mechanical Engineering and Metalworking Industries of Latvia - MASOC[53]) are fully engaged in the preparatory process of Latvia's accession to the status of an Associate Member state of CERN, and give their unanimous support and direct encouragement to the relevant policy decisions.

Several industrial-related events have already been organised for the business in Latvia, where the cooperation and technological opportunities have been discussed in detail. Furthermore, representatives of CERN have on numerous occasions visited Latvian companies and witnessed their technological capacity.

[44] https://hpc.rtu.lv/hpc/?lang=en
[45] https://eurohpc-ju.europa.eu/
[46] https://www.itbaltic.com/
[47] https://ec.europa.eu/digital-single-market/en/european-cloud-computing-strategy
[48] https://cds.cern.ch/record/2703434
[49] http://en.lddk.lv/
[50] https://www.chamber.lv/en
[51] http://www.letera.lv/en/about-us/
[52] http://www.liaa.gov.lv/en/about/about-liaa
[53] https://www.masoc.lv/en

In May 2017, during the "CERN Science Week in Latvia" a "CERN Roundtable on Industrial Partnerships[54]" was organised. It included high-level representatives from CERN and was moderated by the ex-minister of Economics. The event was well attended by business and other major stakeholders.

The industrial visit to CERN was organised for a high-level industry and business delegation in January 2018. A wide range of Latvia's' companies took part and the delegation was led by the Parliamentary Secretary to the Ministry of Economy. During this visit, their collaboration potential was discussed and affirmed by the involved parties.

Even now, before the accession, there are companies that are engaged with CERN via the CMS experiment. These are:

- **Primekss Group**[55] - consultancy services for the assessment of the quality of the CMS cavern floor and R&D project for the gas-tight, radiation-safe concrete development together with CERN, RTU and ISSP;
- **Dati Group**[56] - contributing significantly to the development of the Tier2 centre of Latvia;
- The **Nuclear Medicine Centre**[57] (NMC): engaged with the CERN-MEDICIS activities with its expertise in the medical isotopes production using the 18MeV cyclotron.

Other companies in Latvia, which would greatly benefit from the technological impact of HEP and could be excellent suppliers of their production to CERN and its experiments, have been identified. To name a few:

- **Baltic Scientific Instruments** (BSI)[58] - specialized in the development and fabrication of devices for spectrometric analysis based on semiconductor and scintillation radiation detectors. BSI products are applied in multiple industries: nuclear power; environmental monitoring; geophysics and the mining industry; medicine and healthcare; research, including space sciences; security systems and customs control, etc;
- **SAF Tehnika**[59] - in addition to an industry-standard portfolio containing a full range of modular split-mount and full outdoor Native Ethernet/IP microwave systems for licenced and licence-free frequencies, SAF Tehnika has several industry unique and market-shaping products such as the *Integra* and *Spectrum Compact*;
- **HanzaMatrix**[60] - major Nordic and Baltic electronic system development and manufacturing company serving the leading OEMs in their respective markets such as the transportation, telecom, renewable energy and medical industries. HansaMatrix has a great potential to engage with the CERN.

Latvian industry and relevant associations are integral part of the CERN Latvia Stakeholders Group.

[54] https://www.rtu.lv/writable/public_files/RTU_cern_nedelas_programma.pdf
[55] https://primekss.com
[56] https://datigroup.com/datigroup-en.html#par-mums
[57] http://rnmc.lv/en/
[58] http://bsi.lv/en/
[59] https://www.saftehnika.com/en/
[60] http://www.hansamatrix.com/complete-manufacturing-services-innovation.html

2.9. CERN-related education and outreaching activities

Recognising the value and significance of targeted educational and outreach initiatives, Latvia is greatly benefiting from the multitude of opportunities kindly provided by CERN. This includes activities both in Latvia and at CERN. In the future, Latvia is considering to also contribute to the CERN Science Gateway project.

2.9.1. Short-term student visits to CERN

Annually, since 2013, a group of around 20 **doctoral students**[61] from RTU and other Latvian universities have been coming to CERN for an educational and motivation study trip. Lately, master-classes on the topic of high-energy physics have been included in this programme as well. This provides an excellent opportunity for the best students of CERN-related engineering and fundamental sciences fields to learn directly about CERN and its groups and activities. On many occasions, direct synergies with the domestic research work have been identified and links made between the home institutions and the CERN-based experiments or research groups. Until now, these trips have been directly sponsored by RTU and graciously supported by CERN and its staff. Starting from 2020, targeted state funding shall be provided for these annual doctoral visits.

In the scope of the activities of the *Junior Achievement Latvia* organisation, annually over the last three years, a group of 5-6 pupils, so called **Shadows**[62] have visited CERN to follow the daily work of the Latvian scientists at CERN. The travel and the stay at CERN of the *shadows* are directly sponsored by Latvian businesses, keen to promote CERN ideas and to motivate the youth in Latvia to choose STEM-related paths in their future studies.

2.9.2. Participation in the CERN Summer Student Programme

Starting from 2013, talented UL[63] and RTU[64] students from Latvia are taking part in the CERN **Summer Student Programme**. Ordinarily, one or two students come to CERN and are integrated within a carefully chosen CERN Group. These are usually masters' students, studying in physics, engineering or computing sciences. Latvia and CERN reciprocally are covering their expenses. Selection of these students is entrusted to the national CERN contact point and is done jointly by the relevant representatives of the applicant universities. As from 2020, an annual support for two Latvian students is foreseen and shall be covered by the aforementioned capacity building measures.

[61] https://www.rtu.lv/en/hep/about-us-hep/hep-news/open/rtu-doctoral-students-at-the-worlds-physics-top-research-centre
[62] https://www.rtu.lv/en/hep/about-us-hep/hep-news/open/six-pupils-will-shadow-rtu-scientists-in-the-european-centre-for-nuclear-research-in-switzerland
[63] https://www.jf.lu.lv/en/par-mums/mediji/news/zina/t/51085/
[64] https://www.rtu.lv/en/hep/about-us-hep/hep-news/open/rtu-student-andris-logins-will-participate-in-cern-summer-school

2.9.3. Physics teachers programme

Latvian Physics Teachers programme has been up and running since 2016. Around 80 Latvian physics teachers have benefited for the experience of the CERN Physics Teachers programme. In recent years this has grown into the CERN Baltic Physics Teachers[65], which full alignment with the overall CBG objectives and philosophy of the development of the physics and high-energy physics community in the Baltic region. This activity has been co-sponsored by RTU and the MoES. Furthermore, several bright Latvian physics teachers also participated in the **International High School Teacher Programme** organised at CERN.

2.9.4. Schools, conferences and workshops

In April 2018 a 5th **CERN Spring Campus** was successfully organised and very well attended in Riga[66]. This CERN Campus was of a series of schools dedicated to Information Technology and Computing. Over 4 intensive days, event brought together experts from around CERN, to meet with future engineers and scientists in a program of scientific and technological dissemination and cultural exchange. Target audience was primarily final year BSc students and MSc students in the field of Computer Science or related, who wanted to know more about the latest technologies and industry trends in IT.

In May 2018 RTU hosted the 1st **ARIES project annual meeting**[67], which brought together more than 100 representatives of the accelerator community. Several workshops and specialist discussions where organised in the margins of that meeting.

In June 2019, with support of CERN, the **European Physics Olympiad**[68] was hosted by UL in Riga - it is a contest for high school students. In addition to the International Physics Olympiad, traditions of regional competitions such as Asian Physics Olympiad and Ibero-American Physics Olympiad are established. The concept of EuPhO is similar to real research situations, with brief problem description and plenty of space for creative solutions. Prominent physicists honoured this event by their presence and talks.

In the framework of the CERN Baltic Group, RTU is organising **Baltic School of High Energy Physics and Accelerator Technologies**[69] in August 2020. It was granted EU COST action funding and will host prominent lectures and will cover variety of the high-energy physics topics.

Naturally, Latvian students and young scientists are actively participating in various CERN and related schools, conferences and workshops.

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[65] https://indico.cern.ch/event/721827/

[66] https://www.rtu.lv/en/internationalization/international-events/summer-schools/cern-spring-campus-23-26-april-2018

[67] https://indico.cern.ch/event/699219/

[68] https://eupho2019.lv/

[69] https://indico.cern.ch/event/878009/contributions/3699476/attachments/1978339/3293408/Poster_CBG_Summer_School.pdf

2.9.5. Other activities

Commencing in 2012, series of well high-level **guest lectures**[70] of prominent physicists, scientists and experts from CERN, have been regularly organised in the universities of Latvia. Topics have included: high-energy physics, quantum physics, accelerator and beam technology, medical applications of the accelerators, etc. These were provided by Prof. Jonathan R. Ellis, Dr. Paul Collier, Dr. Tadeusz Kurtyka, Dr. Christoph Schaefer, Dr. Maurizio Vretenar, Dr. Manjit Dosanjh, Dr. Thierry Stora, Dr. Yuri Dokshitzer and others.

In May 2017 RTU in cooperation with CERN and the MoES will organized milestone event - **CERN Science Week**[71] in Latvia. During this week, CERN officials and scientists were meeting with the administration of RTU, the Minister of Education and Science, Minister of Foreign Affairs, as well as the members of the Parliament to discuss potential membership of Latvia in CERN. The events organized during this week where of relevance not only to researchers and students but also to a wide audience — students, teachers, science enthusiasts and basically anyone Latvian citizen. CERN scientists have delivered popular scientific lectures on CERN activities and research. It was complemented by interactive **exhibition of the LHC tunnel**. The Latvian entrepreneurs were actively participating in the roundtable discussion, together with CERN officials, on industrial collaboration possibilities within CERN.

One year later, in May 2018 landmark **traveling exhibition «CERN – Accelerating Science»**[72] was inaugurated at the National Library of Latvia by the Prime Minister Māris Kučinskis in the presence of the Minister of Education and Science Kārlis Šadurskis and the management of Latvian universities and CERN. Numerous visits of the school children, students and general public were organised. This exhibition was very well attended and received by the public and its very symbolic presence at the National Library of Latvia was a remarkable Latvia-CERN collaboration achievement. Importantly this CERN exhibition was part of the official Latvia's Centenary celebration programme[73].

Latvia was greatly benefiting from the opportunities of CERN **Virtual Visits**. These were organised on several occasion for different levels of audience in Latvia, including translations to the regional schools during the high-level visits to CERN. Interactive lectures from the CMS cavern were provided on several occasions covering hundreds of participants from the Latvian regional schools.

High-Energy Physics, scientific and engineering thematic of CERN over the years were covered by numerous **media of Latvia**. Latvian press and media representatives (e.g. State Radio, State Televisions and commercial media) were regularly coming to CERN. Interviews with the CERN management, scientist and Latvian researchers were recorded and broadcasted in Latvia by major media players. This was well received by the general public and today we can say that Latvian society is rather well informed about CERN work, its objectives and role of Latvia at CERN. Written press was also actively covering CERN related topics and several interviews of CERN and Latvian scientists were published in the journals, newspapers and web-based media.

[70] https://www.rtu.lv/en/hep/latvia-and-cern/cern-in-latvia/guest-lectures
[71] https://www.rtu.lv/en/university/for-mass-media/news/open/rtu-invites-to-the-CERN-scientific-week-in-Latvia
[72] https://www.rtu.lv/en/university/for-mass-media/events/open/the-exhibition-cern-accelerating-science
[73] https://www.lv100.lv/en/about/

3. Policy actions intended for strengthening the high-energy physics community in Latvia

In order to implement the aforementioned political commitment for Latvia to become a CERN Associate Member state, the Government of Latvia, and in particular the MoES, undertook tangible strategic decisions and policy actions supported by a number of financial instruments. This has been done in a close cooperation with the national scientific community, major stakeholders and the social partners. The coordination of all CERN-related activities was assigned to the HEP&AT centre. This allowed for a more efficient and focused communication between the representatives of CERN and Latvia. Furthermore, the creation of HEP&AT centre as a focal point of this communication allowed for the strategy of CERN-related activities to be coordinated on a regional level, via the position of the centre as the acting secretariat of the CBG.

3.1. The national contact point for CERN

The national contact point for CERN was established as a part of the Protocol to the ICA between Latvia and CERN. The duties of the national contact point form a crucial part of the portfolio of activities of the HEP&AT centre. The national contact point coordinates the following activities:

- Participation of Latvian students in CERN student programmes, including the summer school programme'
- Participation of Latvian teachers in the CERN teacher programme;
- Visits to CERN by Latvian students and the academic, scientific and teaching staff;
- Scientific and technical cooperation between Latvia and CERN in the development of high-energy physics and particle accelerator and detector technologies in the country;
- Academic, scientific and technical training of Latvian university staff by experts from CERN.

In addition, the national contact point is involved in the following national and international activities:

- The management of the CERN Latvia group, in which the HEP&AT centre is a stakeholder, and its engagement in CERN-related activities;
- Coordination and participation in the work of the CBG;
- Dissemination of information relating to CERN to Latvian partners, including industry;
- Exchange of information between CERN and the relevant governmental and policy making institutions;
- Coordination of the development of the national capacity in high-energy physics research;
- Support and facilitation of a variety of CERN and CERN-related outreach activities;
- Representation of Latvia vis-à-vis CERN and other relevant stakeholders.

3.2. The action plan for the national contact point

The National Action Plan was developed as a part of the broader strategic framework aimed at strengthening the research in high-energy physics and particle accelerator and detector technologies in the country, as well as to ensure the long-term benefits to the Latvian scientific and business

communities. The plan was formally approved by the MoES in October 2019; however, it has been *de facto* acted upon from early 2018. The action plan is linked to the *Road Map of Latvia' s Accession to CERN in the Capacity of Associate Member State*, which contains the following priority actions:

1. Coordination and further development of the participation of the Latvian consortium in the activities of the CMS experiment; this participation is further coordinated at the regional level by the CBG;
2. Assurance of the operation of the HEP&AT centre;
3. Creation of a study programme in high-energy physics and accelerator technologies at the doctoral and masters' level;
4. Participation in the MEDICIS collaboration, in particular with regards to *theranostic* research in oncology patients;
5. National capacity building in high-energy physics and accelerator technologies; Latvia's participation in CERN teacher and student programmes;
6. Widening scientific and research cooperation with CERN in particle physics and accelerator technologies; engagement of further scientific (SASS) and project (PJAS) associates and potential CERN fellows;
7. Maintenance and expansion of Latvia's research institution participation in CERN-based and CERN-coordinated projects, e.g. FCC, CCC, ISOLDE, ARIES.

3.3. CERN Latvia Stakeholders Group

The **CERN Latvia Stakeholders Group**[74] is composed of Latvian scientific, research, business and social partners who are engaged or are interested to take part in CERN-related activities. The group is guided and managed by the CERN national contact point and its main objective is to facilitate the collaboration between CERN and scientific and industrial partners in Latvia in areas such as:

- The fundamental and applied research in high-energy physics;
- The R&D of the particle accelerator and detector technologies;
- The industrial R&D projects;
- IT solutions and Big-Data projects.

Within the remit of this group, the national contact point is tasked with the following:

- Informing the stakeholders about the relevant CERN-based and CERN-related activities;
- Directly supporting the stakeholders' engagement with CERN;
- Managing the information exchange and collaboration vis-à-vis CERN and the stakeholders.

The activities of this group are, to a certain extent, a preparatory work for the activities of a future national Industrial Liaison Officer (ILO) at CERN.

It is crucial to identify and inform the partners interested in collaboration with CERN in order to consolidate the Latvian portfolio of activity relating the organisation. Establishing a united communication platform at this early stage will allow the partners to more readily benefit from Latvia's accession to the status of an Associate Member state of CERN.

The group is based on the fundamental ethos of collegiality, transparency and collaboration.

[74] https://indico.cern.ch/category/11669/

3.4. Study programme in particle physics and acceleration technologies

The overall objective of the creation of a **PhD study program, entitled "Particle physics and accelerator technologies"**[75], is to strengthen the particle physics and particle accelerator and detector technology research communities in Latvia. Currently RTU and UL, in close cooperation with the CBG and with the support of the MoES, are in the process of developing this study programme as a part of a larger EU co-funded programme. The creation of a complementary masters' level study programme is also envisaged. The following steps to be taken have been identified:

- Gathering and preparing an array of experts in order to boost the relevant knowledge-intensive industries in the country;
- Educating, training and preparing the relevant scientific staff in the field of high-energy particle physics to a globally competitive level;
- Continuing and assuring Latvia's accession to the status of an Associate Member state of CERN and providing continual support to the national capacity building programs in the relevant areas of research.

The CBG has a dedicated Working Group tasked with outlining the scope, content and the requirements of this study programme. This is being done in close consultation with external experts, including CERN representatives.

The overall concept of the structure of the study programme was agreed in the 4th CBG General Meeting[76] in October, 2019, and is shown in Figure 3.4. The current financial and human resource support of the CBG and CERN will allow the completion and the accreditation processes of the programme to be complete by 2021.

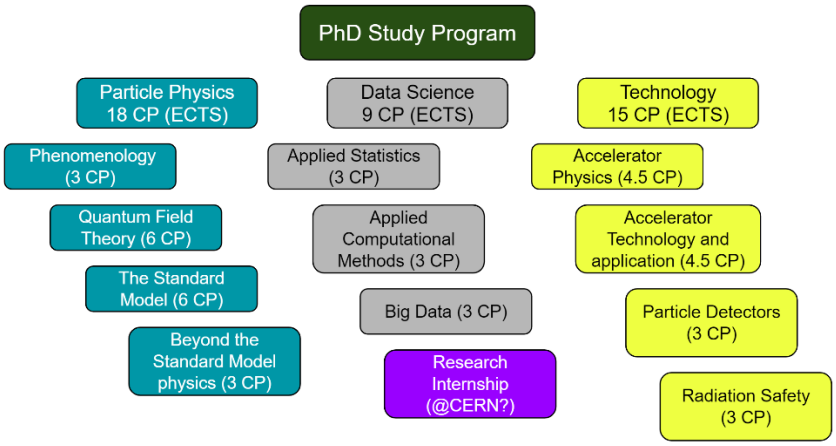

Figure 3.1: An outline of the PhD study programme of particle physics and accelerator technologies.

75 https://indico.cern.ch/event/781162/contributions/3251813/attachments/1784886/2905541/Particle_physics.pdf

76 https://indico.cern.ch/event/811370/contributions/3380991/attachments/1923400/3182542/2019_10_10_Current_progress_SP_creation.pdf

3.5. The state research programme in high-energy physics and accelerator technologies

The state research programme in high-energy physics and accelerator technologies is one of the corner stones of the measures taken by the Government of Latvia to reinforce the expertise in the relevant scientific research fields in the country. The programme is to be receive the annual state funding of 300 000 EUR and will provide the framework for the dedicated capacity building measures in the relevant areas of research.

In order to ensure the fulfilment of the overall objective of the state research programme – to strengthen the high-energy physics community in Latvia – a strategic committee for the programme was established under the auspices of the MoES. This committee, composed of established experts in the field:

- Jonathan Richard Ellis, Prof., Dr., King's Collage London, CERN;
- Andris Skuja, Prof., Dr., University of Maryland, CMS;
- Yuri Dokshitzer, Prof., Dr.,;
- Maurizio Vretenar, Dr., CERN;
- Mārcis Auziņš, Prof., Dr., University of Latvia;
- Christoph Schaefer, Prof., Dr., CERN;
- Vladimirs Gostillo, Dr., *Baltic Scientific Instruments* (industry);
- Toms Torims, Prof., Dr., Riga Techincal University, CERN;
- Anatolijs Sarakovskis, Dr., University of Latvia, Institute of Solid-State Physics;
- Dmitrijs Stepanovs, Dr., Deputy State Secretary for the Ministry of Education and Science;

which met in February 2020[77].

The state research programme is a part of a long-term strategy of priority sector development in Latvia. As such, the programme is to:

- Ensure long-term development of a sustainable knowledge base in the relevant fields of scientific research;
- Promote the participation of Latvian scientists in international science cooperation networks;
- Foster a coordinated academic involvement in scoping earlier phases of education in the country, to ensure continuous development of home-grown talent in the relevant fields of scientific research;
- Maintain public engagement and outreach efforts to promote the relevant fields of research to the general public.

3.6. The CERN Baltic Group

The CBG is a group of Estonian, Latvian and Lithuanian research institutions, which are involved, do a varying degree, in CERN-related activities. In order to organise the collaboration in CERN-related activities within the Baltic States, the group holds regular meetings[78] and operates following a signed MoU. The main objectives of the CBG are:

[77] https://indico.cern.ch/event/885425/
[78] https://indico.cern.ch/category/10023/

- Coordination of the activities relevant research institutions in the Baltic States and their cooperation with CERN and CERN-related collaborations and experiments;
- Strengthening the high-energy physics community in the Baltics States;
- Development of a regional masters' and doctoral level study programme in high-energy physics and accelerator technologies.

The CBG operates under the principles of transparency, honesty, knowledge-sharing and collaboration. It is, currently, comprised of the following institutions:

is meeting regularly to coordinate activities between Baltic countries and CERN. It collegially and in the spirit of true collaboration acts on the basis of the signed MoU. The main **objectives of the CBG** are:

- Coordination of the Baltic research institutions activities towards CERN and related Collaborations/experiments;
- Strengthening and development of Baltic High Energy Physics community;
- Development of the Baltic international multidisciplinary masters/doctoral lever study programme in High Energy Physics and Accelerator Technologies.

The main principles of the CERN Baltic Group are: transparency, honesty, sharing and collaboration. Members of CBG:

- Riga Technical University (RTU) - Latvia;
- University of Latvia (UL) - Latvia;
- Tallinn University of Technology (TalTech) - Estonia;
- National Institute of Chemical Physics and Biophysics (NICPB) - Estonia;
- Vilnius University (UV) - Lithuania;
- Riga Stradins University (RSU) - Latvia;
- University of Tartu (UT) - Estonia;
- Kaunas University of Technology (KTU) - Lithuania;

and is open CBG is open to other Baltic universities and research institutions.

The CBG was established in early 2018 and holds bi-annual general meetings, hosted by one of the Baltic States on a rotational basis. It aims to coordinate the scientific activities between the Baltic countries and CERN; develop a successful scientific collaboration, including joint scientific projects with CERN; boost the expertise in particle physics and accelerator technologies in the region. The general meeting is used to set the short-, mid-, and long-term objectives of the group and to coordinate said objectives of the individual member institutions.

The CBG secretariat hosted by the Latvian national contact point for CERN and is providing support for the group's day-to-day operational needs. The coordination team meets approximately every two months and is composed of the CBG Chairman and the secretariat and a designated representative of each partner institution. CBG has established the following Working Groups:

- CMS Working Group;
- Study Programme Working Group;
- Industry Working Group.

4. General economic situation in the country

In Latvia, the stable economic growth, exceeding the EU average, has resumed. From 2011-2018, the GDP, on average, increased by 3.5% annually.

In 2017-2018, the economic growth rate accelerated. The GDP grew by 3.8% and 4.6%, respectively. Accelerated economic growth was facilitated by improvements in the external environment, increased absorption of the EU structural funds, and rising employment and wages.

4.1. State of the economy

Starting from 2019, the economic growth has become more moderate. In the first half of 2019, GDP grew by 2.3%. The slight economic slowdown was driven by both internal factors (e.g. increased use of the EU investment funds, developments in the financial sector) and external factors (e.g. review of global trade tensions, Brexit, slower growth in other EU countries). It is anticipated that the aforementioned global factors will also affect Latvia's economic growth in 2020, negatively impacting Latvia's export capacity. At the same time, positive development trends are expected to be observed in the commercial services and other internal demand-oriented sectors of the economy.

According to the forecasts by the Ministry of Economics, GDP growth in 2019 could reach 2.5%.

	2012	2013	2014	2015	2016	2017	2018	2019f
GDP, at current prices, billion euro	21.9	22.8	23.7	24.4	25.1	26.8	29.2	30.7
	changes as per cent							
GDP	4.1	2.3	1.9	3.3	1.8	3.8	4.6	2.5
Private consumption	3.6	5.7	1.1	2.5	1.5	3.1	4.2	2.9
Public consumption	0.4	1.2	2.1	3.0	2.9	3.2	4.0	2.5
Gross fixed capital formation	16.1	-5.9	-0.3	-1.2	-8.2	11.3	15.8	4.6
Exports	9.8	1.1	6.5	2.9	4.0	6.4	4.0	0.6
Imports	5.4	0.4	3.0	1.7	3.8	8.4	6.4	3.8
Consumer prices	2.3	0.0	0.6	0.2	0.1	2.9	2.5	2.9
	as per cent							
Employment changes	1.6	2.1	-1.0*	1.3	-0.3	0.2	1.6	0.0
Employment rate	56.1	58.2	59.1	60.8	61.6	62.9	64.5	64.9
Unemployment rate	15.0	11.9	10.8	9.9	9.6	8.7	7.4	6.5
	as per cent of GDP							
General government budget balance	-1.2	-1.2	-1.4	-1.4	0.1	-0.5	-0.7	-0.5
General government debt	41.6	39.4	40.9	36.7	40.3	38.6	36.4	36.0
Net exports	-4.4	-3.5	-2.0	-0.9	1.0	0.2	-0.9	-0.2

Table 4.1: Latvia: Key Figures of Economic Development.
Source: Ministry of Economics of Latvia

Further economic development heavily relies on the situation in the external environment and the implementation of reforms. The development of Latvian economy will be closely linked to export opportunities. Thus, the largest risk to economic growth is related to the development trends in the global economy. The further development of the EU's common space is of vital significance. The economic advantages of Latvia in the medium term will mainly be based on the achieved

macroeconomic stability, which has resulted in improved credit ratings of Latvia, the efficient acquisition of EU structural fund programmes, and overall improvements in the business environment.

The accelerated growth scenario assumes that the growth in the largest Latvian export markets will be sustained, the competitiveness of Latvia's economy will mostly rely on technological factors, such as improved production efficiency and increased innovation; however, the reliance on cheap labour force and low resource prices will be subdued. In the medium term, Latvia's growth rates could reach 4-5% annually. However, in the weak growth scenario, Latvia's economic growth rates may be much slower as growth in the EU would weaken and geopolitical conditions would not significantly improve.

4.1.1. Exports

Export growth is one of the main drivers of economic development. It is closely linked to external demand and economic development of key partner countries.

In 2018, exports of goods and services increased steadily. The growth was mainly facilitated by economic development in Lithuania and Estonia, stable demand in the most important export markets (other EU countries), and the stabilization of economic situation in Russia and other CIS countries.

In the first half of 2019, export growth, in comparison with the corresponding period the previous year, was more moderate. The decline in growth was driven by weaker growth rates amongst major trading partners.

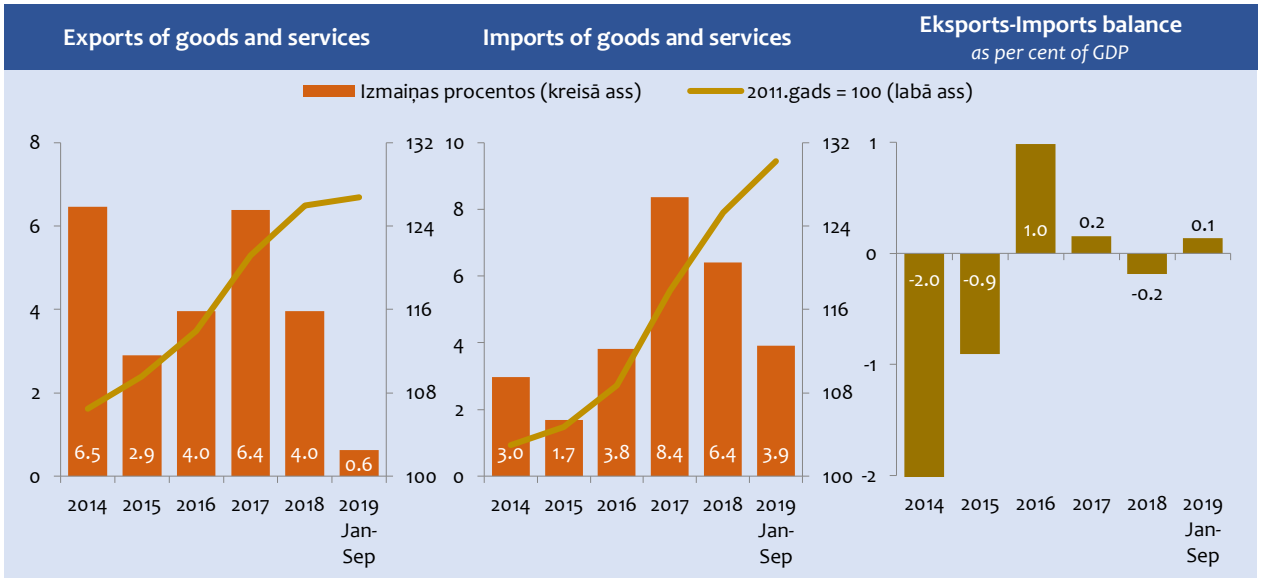

Figure 4.1: Import and Export of Latvia.
Source: Ministry of Economics of Latvia

4.1.2. Investments

In recent years, investment (gross fixed capital formation) has increased significantly. Since 2017, the period of weak investment growth has been overcome. In 2017 and 2018, investment grew by 11.3% and 15.8% (a growth rate significantly above the EU average), respectively. In 2019, investment

activities also remained relatively high. In the first half of 2019, investment in Latvia's economy was by 4.9% higher than the previous year. The increase was mainly driven by large investment volumes in construction assets.

Aggregate investment levels have also peaked, reaching 22.5% of GDP in 2018. However, it still remains lower than the pre-crisis level.

The relatively low level of investment can mainly be attributed to the lacklustre recovery of private investment. Private investment during the post-crisis period (2010-2018) on average constituted 17.6% of GDP (i.e. almost 11 percentage points lower than during the years of rapid economic development). Low level and moderate dynamics were mainly driven by weak lending, low demand, relatively high levels of private sector indebtedness, and economic and political uncertainty in the external environment. In recent years, the dynamics of private investment have improved. In 2018 and during the first quarter of 2019, private investment increased by 13.6% and 5.3%, respectively. Private investment growth was facilitated through co-financing of the EU structural funds.

In Latvia, public investment remains at a high level. In recent years, public investment constitutes 1/5 of total investment in the Latvian economy, and its dynamics largely rely on the cyclicality of the absorption of EU structural funds. Since 2017, along with the recovery of EU structural funds, public investment has increased on average by 33.5% annually. In the first quarter of 2019, public investment exceeded the previous year's level by 23%. In Latvia, the share of public investment is one of the highest amongst EU member states. According to Eurostat, public investment in EU-28 on average constituted 2.8% GDP in 2018. However, in Latvia it reached 5.4% of GDP.

Since 2007, the structure of investment assets has changed. During the economic recession, investment volumes declined in all asset classes. The largest downturn was observed in construction. However, the drop in investment in machinery and equipment was slightly more moderate. Investment in intellectual property remained essentially unchanged, constituting on average 1% of GDP (including investment in R&D of 0.6% of GDP) for several years.

4.1.3. Productivity

In recent years, productivity dynamics in Latvia on average have increased at a higher rate than the EU average. Between 2010 and 2018, the productivity gap with the EU has fallen by nearly 12%. In 2018, GDP per capita (productivity) in Latvia reached 49% (69.3% based on PPP) of the EU average.

Although Latvia ranks very high based on productivity growth amongst other EU member states, labour costs have risen at a higher rate than productivity, thus undermining the competitiveness of entrepreneurs in Latvia. Also, an increase in nominal unit labour costs (ULC) reflects the increased risks of declining cost competitiveness.

Over the last three years (2016-2018), productivity on average increased by 3%. At the same time, labour costs rose by 7.8% (at 2.5 times higher rate). The strong increase in labour costs is affected by both wage convergence processes in the integrated EU labour market and rising tension in the domestic labour market.

In recent years, a strong increase in nominal unit labour costs can be observed in Baltic countries. Between 2016 and 2018, nominal ULC in Latvia, Estonia, and Lithuania increased by 14.7%, 14.3%, and 16.5%, respectively (EU average – 0.6%). The indicator exceeds the threshold set by the EU Alert Mechanism.

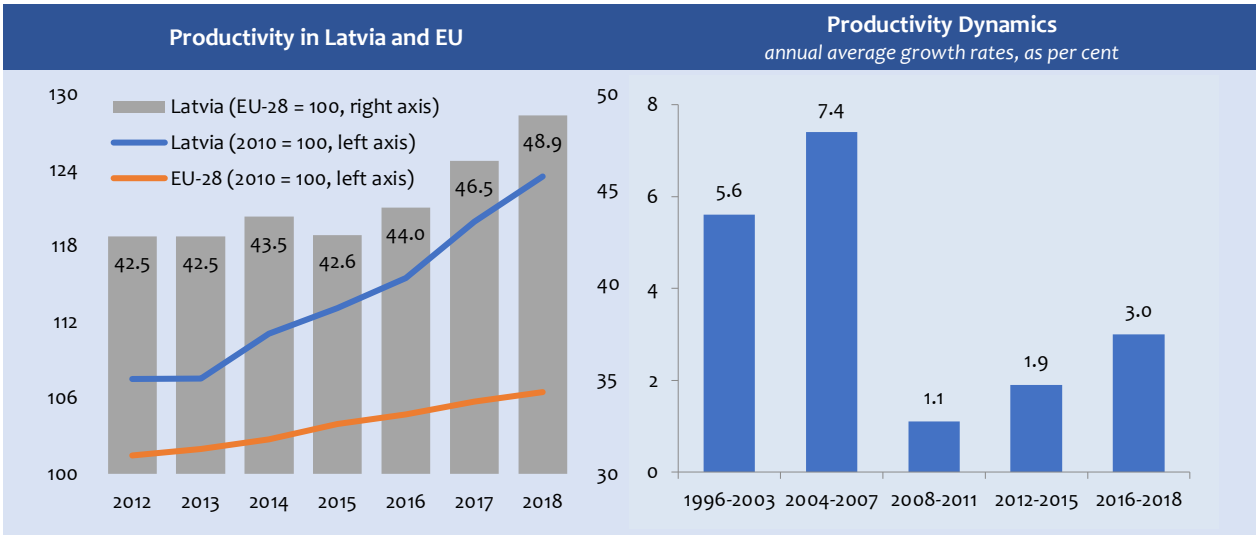

Figure 4.2: Productivity Dynamics in Latvia and EU.
Source: Ministry of Economics of Latvia

4.1.4. Labour market

Despite the economic slowdown, activity in the labour market remains high. In the first half of 2019, a major driver of economic growth was the development of domestic demand-oriented sectors. An increase in occupied posts was observed in construction and trade. At the same time, demographic processes are increasingly affecting developments in the labour market. The decline in working-age population reduces labour supply, thus adversely affecting free labour force reserves. In the first half of 2019, unemployment rate declined to 6.6% (the lowest rate in the last decade). At the end of August 2019, the number of registered vacancies in State Employment Agency were by 36% higher than a year ago.

In the next years employment will continue to increase and unemployment will decrease, which, in turn, will stimulate further increase of wages. Meanwhile, along with unemployment decrease, the labour shortage problem will become more visible, which will be aggravated by the unfavourable demographic trends. Employers must consider that it is becoming more difficult and more expensive to retain current employees and recruit new employees.

It is expected that the number of employed will increase by approximately 16 thousand in 2023, compared to 2018. Thus, the number of employed could reach 928 thousand in 2023, while the share of employed in the population aged 15-74 years could increase to almost 67 percent.

Until 2023, the most significant increase in the number of employed will be observed in the commercial services sector, in the manufacturing industry and construction. At the same time, a drop in the number of employed is expected in the primary sector – mainly in the agriculture and forestry, as well as the public services. Decrease in labour demand in the agricultural sector is mainly attributable to efficiency enhancement of the industry – formation of farmers' cooperatives and large farms, introduction of systematic production organisation, introduction of more complex technological solutions in the production process.

4.1.5. Development perspectives for 2020-2023

Slower and rapid growth scenarios are developed for the medium term until 2023. Basic assumptions of the scenarios are based on different trends of global economic developments in the medium term and the efficiency of structural policy implemented by Latvia. For Latvia, as a small open economy with a relatively high degree of market liberalisation, growth is significantly affected by the global economic development and maintenance of stable competitiveness.

Further development of the EU's economy is particularly important for Latvia. There is still big uncertainty associated with the UK's exit from the EU (Brexit), and there is no clarity about the future economic relations between the UK and the EU, and how it may affect economic development of the whole EU, including Latvia.

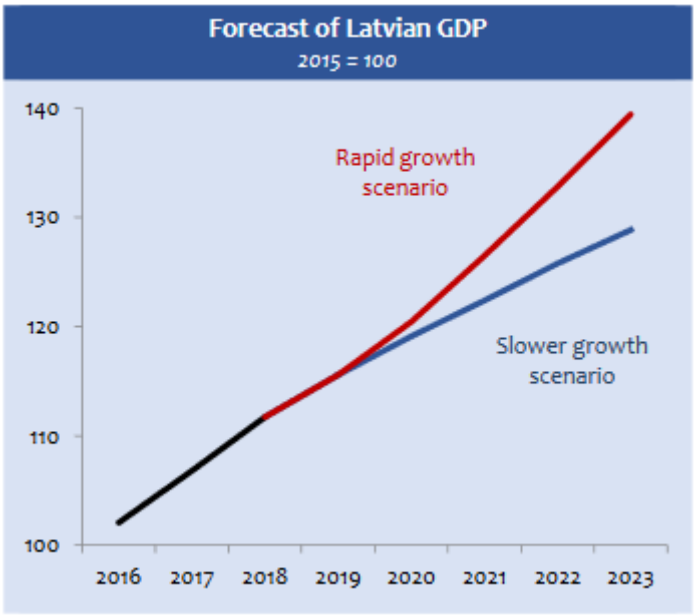

Figure 4.3: Forecast of Latvian GDP.
Source: Ministry of Economics

Income from exports, expansion of export possibilities, ability to integrate in the global value chains with higher value-added products, and ability to create more qualitative final products are the main drivers of economic growth. At the same time, in the medium term in open labour market conditions the increase in labour costs will remain comparatively fast and competitive advantages of labour costs will continue to decrease. In the medium and long-term, more rapid development is expected in the sectors, which can boost productivity through overcoming the technological lags, modernization of production, investments in human capital, research and innovation, and other supply-side factors. The slower growth scenario assumes that the global economic development is uneven, and convergence of wages with the Western European countries will continue in conditions of the open labour market in the medium term.

This will result in a negative effect on competitiveness of companies in low value-added segments. Furthermore, a transition to higher value-added economy will happen gradually. In the scenario of slower growth, the annual export growth rates during this period might be around 2.5%. Private consumption and investments will grow slowly. By contrast, annual GDP growth rates on average from 2020-2023 are estimated to be 2.7%.

Forecast of Latvian GDP by Sectors *changes as per cent*						
	Fact			Forecasts		
	2015	2016	2017	2018	2019	2020-2023 annual average
Gross domestic product	**3.0**	**2.1**	**4.6**	**4.6**	**3.5**	**2.7 ... 4.8**
Agriculture, forestry	12.5	-9.8	1.9	5.1	2.9	1.9 ... 3.2
Manufacturing	0.4	2.8	8.0	2.5	3.1	2.8 ... 5.3
Other industries	16.6	10.3	7.1	1.4	3.1	2.8 ... 4.3
Construction	-1.8	-14.7	19.4	17.7	7.1	3.6 ... 5.3
Trade, accommodation	7.2	2.6	5.2	2.5	4.0	3.1 ... 5.2
Transportation and storage	-7.7	6.1	7.5	4.5	3.3	2.7 ... 4.3
Other business services	2.9	2.0	1.6	4.2	3.6	2.6 ... 4.3
Public services	1.6	3.0	4.7	3.4	2.6	2.6 ... 3.6

Table 4.2: Forecast of Latvian GDP by Sectors.
Source: Ministry of Economics of Latvia

The rapid growth scenario for the future years assumes a continued stable growth in the main export markets of Latvia, and the benefits of the economic competitiveness are mainly based on technological factors, improvement of production efficiency, and innovation; to a lesser extent on cheap labour and low resource prices. Annual average GDP growth rates in the medium term may reach 4.8%. In this scenario, exports and manufacturing retain a relatively fast growth rate in the medium term, based on both the competitiveness of Latvian producers and growing external demand. At the same time, growth will not be linked to extensive material-intensive production, but with the use of the latest technological processes, digitalisation (Industry 4.0 concept), optimisation of processes, etc. Faster development due to the abovementioned factors is expected in high and medium-high technology sectors. In the medium term, exports should grow more rapidly than the rest of the economy. Investments should also increase rapidly; however, they should not exceed 25-30% of GDP.

4.2. Industry Characteristics

In Latvia, 99% of economically active and commercial companies (with some exceptions) are SMEs, and 90% of these SMEs are micro-enterprises.

At the same time in 2018 in the Latvian 'non-financial business economy', SMEs account for 70.0 % of value added and 79.0 % of employment, significantly higher than the respective EU averages of 56.8 % and 66.4 %. The annual productivity of Latvian SMEs is slightly less than EUR 17 200 per person, less than half the EU average of EUR 43 900. The majority of SMEs are represented in wholesale and retail trade and manufacturing, with a combined contribution of 44.9 % to total SME value added and 43.4 % to SME employment.

Class size	Number of enterprises			Number of persons employed			Value added		
	Latvia		EU-28	Latvia		EU-28	Latvia		EU-28
	Number	Share	Share	Number	Share	Share	Billion €	Share	Share
Micro	104 795	92.1 %	93.1 %	208 970	33.4 %	*29.4 %*	2.5	20.9 %	*20.7 %*
Small	7 344	6.5 %	5.8 %	146 547	23.4 %	*20.0 %*	2.8	23.0 %	*17.8 %*
Medium-sized	1 421	1.2 %	0.9 %	138 276	22.1 %	*17.0 %*	3.2	26.1 %	*18.3 %*
SMEs	**113 560**	**99.8 %**	**99.8 %**	**493 793**	**79.0 %**	***66.4 %***	**8.5**	**70.0 %**	***56.8 %***
Large	195	0.2 %	0.2 %	131 173	21.0 %	*33.6 %*	3.6	30.0 %	*43.2 %*
Total	**113 755**	**100.0 %**	**100.0 %**	**624 966**	**100.0 %**	***100.0 %***	**12.1**	**100.0 %**	***100.0 %***

Table 4.3: Main figures of Industry.
Source: European Commission

In 2013-2017, the value added of Latvian SMEs rose by 25.6 %, slightly less than the 27.5% growth of large businesses. SME value added growth accelerated in 2016-2017, with SMEs generating a two-digit increase of 11.5%, against the modest annual gains of 3.9% in 2014-2015 and 2.4% in 2015-2016. SME employment increased by 8.4% in 2013-2017, largely thanks to micro firms, which created 24.8 % more jobs, whereas small and medium firms reported a decrease of 1.2 % in employment in the same period.

Latvian manufacturing grew faster than the rest of the economy during the post-2008 crisis period. SMEs now generate 69.8 % of the value added in this sector, a much higher percentage than the EU average of 41.6%. This proportion increased by an additional 4.1 percentage points in 2013-2017, when SME value added rose by 30.3 % against the lower growth of 21.4 % achieved by large firms.

Employment growth in manufacturing is generated entirely by SMEs, in which employment increased by 3.5 % in 2013-2017. In contrast, large manufacturing firms lost a fifth of their labour force in the same period. Sector growth has been facilitated by an improvement in the international competitiveness of Latvian manufacturers, helped by various government support programmes which have increased the competitiveness and productivity of SMEs, improving their performance in foreign markets.

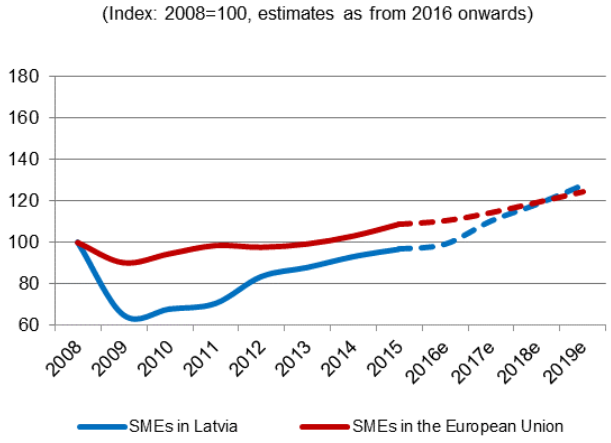

Figure 4.4: Value added of SMEs.
Source: Ministry of Economics of Latvia

Although these programmes were intended to support SMEs in almost all sectors of the economy, SMEs in manufacturing were the main beneficiaries since they are more export-oriented by nature.

Another factor in the growth of this sector was the positive demand dynamics in major export markets, mostly the growth in spending in the EU.

4.2.1. Manufacturing

The development of manufacturing is driven by improvements in the competitiveness of producers in Latvia and the favourable demand dynamics in major export markets. In 2017, a rapid growth in production volumes was observed. In 2018, the growth rate, however, slightly moderated. The growth was positively affected by the largest sub-sector – manufacture of wood and its products. At the same time, the second largest sub-sector (manufacture of food products) slightly declined.

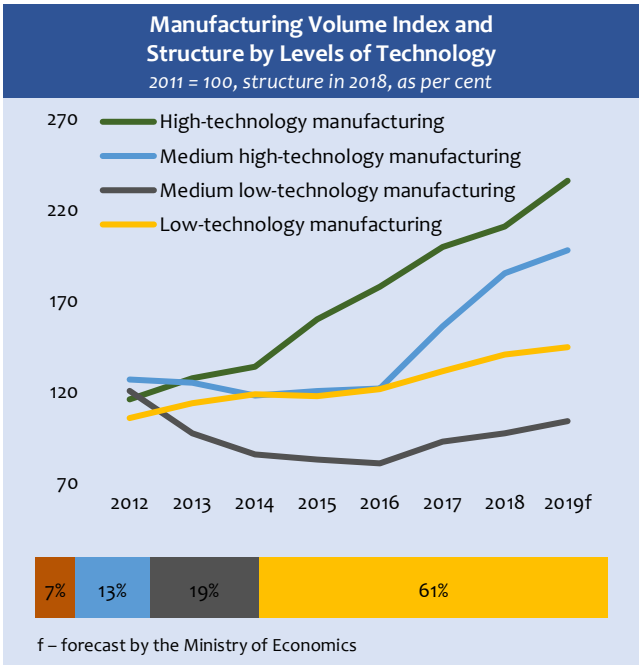

Figure 4.5: Manufacturing Volumes Index and Structure by Technology Levels.
Source: Ministry of Economics of Latvia

In 2019, a relatively moderate growth in manufacturing was observed. The growth was mainly driven by positive developments in the manufacture of basic metals and the manufacture of computer, electronic, and optical products. Similarly, production volumes increased in the manufacture of paper and paper products, machinery and equipment, and the manufacture of chemicals and chemical products. It is anticipated that similar growth in manufacturing will prevail. Accelerated growth in manufacturing will be constrained by uncertainties in the external environment, which will not provide significant export expansion opportunities.

	Structure in 2018			Changes in production volumes				
	Output	Occupied posts	Exports in total Sales	2015	2016	2017	2018	2019 Jan-Aug
Manufacturing	**100**	**100**	**65.4**	**4.3**	**5.6**	**8.0**	**2.7**	**2.3**
Manufacture of food products	21.5	19.6	35.0	-4.6	1.8	5.2	-2.9	-1.1
Light industry	3.5	10.0	84.1	-13.2	2.1	7.6	-0.8	-1.3
Manufacture of wood and of products of wood	28.2	20.2	71.3	7.1	8.0	2.1	4.5	0.2
Manufacture of paper and paper products	3.8	4.3	64.7	0.0	3.6	4.5	-3.7	5.2
Manufacture of chemicals and chemical products	8.3	7.2	76.8	-4.1	10.7	11.4	7.0	0.9
Manufacture of non-metallic mineral products	6.0	4.9	52.4	-9.8	11.6	11.1	1.3	-3.1
Manufacture of basic metals	8.5	10.1	68.5	34.8	5.4	12.0	3.6	14.5
Manufacture of computer, electronic, and optical products	8.2	4.7	90.5	16.7	12.6	15.8	12.1	14.2
Manufacture of machinery and equipment	2.7	3.5	88.4	7.9	8.5	21.5	7.0	3.2
Manufacture of motor vehicles	4.1	3.4	91.7	3.5	-2.9	22.8	7.3	-3.5
Other manufacturing	5.0	12.1	66.4	3.5	0.8	4.3	-1.8	2.6

Table 4.4: Structure of Manufacturing and Development Trends of Sectors
Source: Ministry of Economics of Latvia

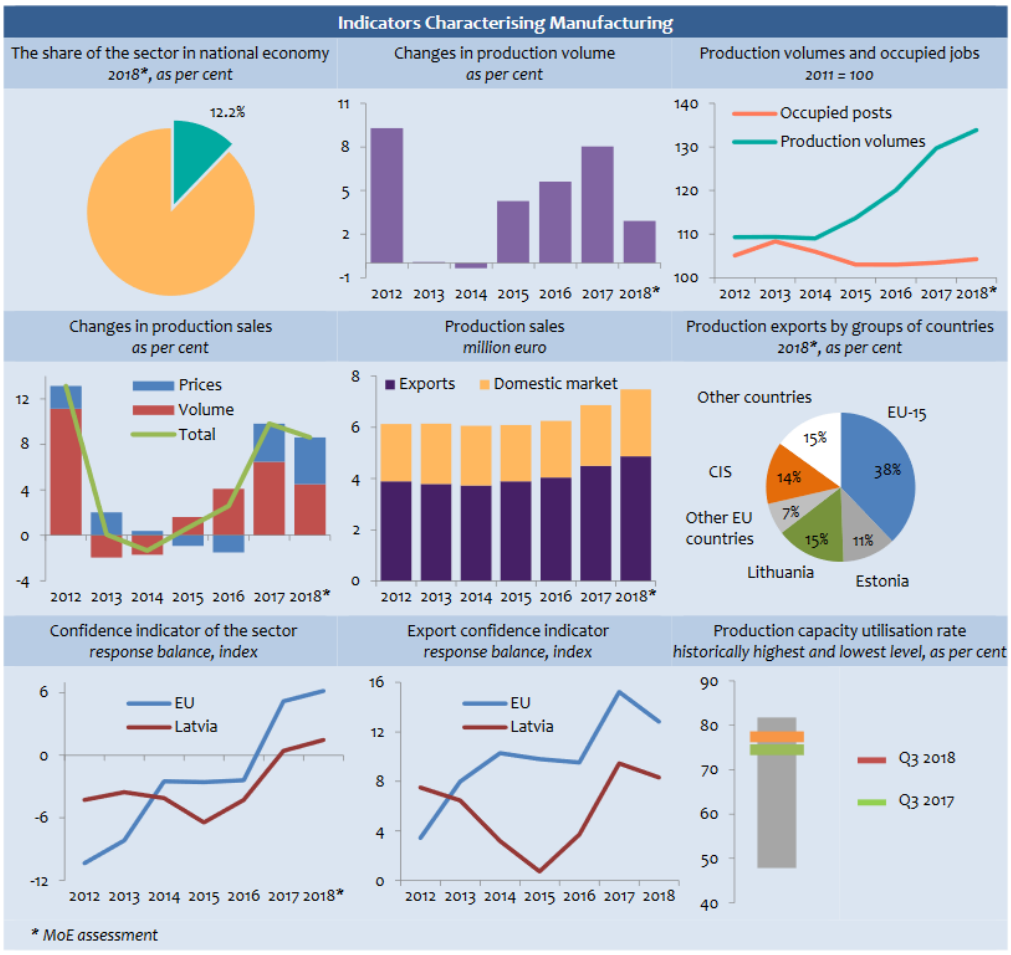

Figure 4.6: Indicators Characterising manufacturing.
Source: Ministry of Economics of Latvia

4.2.2. Small and Medium-sized enterprise profile

Latvia has a competitive Small Business Act (SBA) profile with five principles scoring above the EU average (entrepreneurship, 'responsive administration', state aid & public procurement, access to finance and single market). Latvia maintains strong financial and entrepreneurship framework conditions for SMEs. The remaining areas are on a par with the EU average, except for skills & innovation which is the only area that lags behind the other EU Member States.

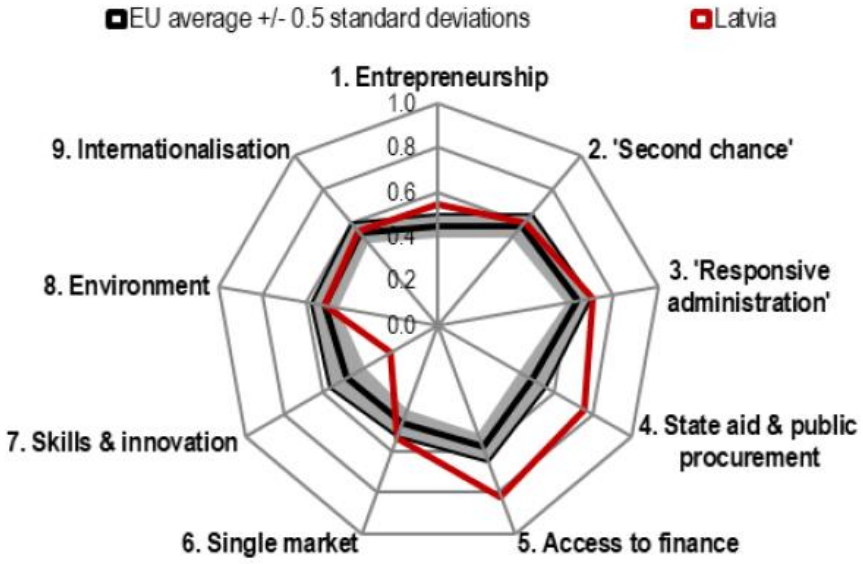

Figure 4.7: Small Business Act profile of Latvia
Source: European Commission

In 2015, 1051 firms in the 'business economy' with at least 10 employees could be classified as high-growth firms. This represented 12.2 % of all firms in Latvia, which is substantially higher than the EU average of 9.9 %. However, in contrast to the trend in the EU, this percentage has continued to fall for the third year in a row.

Growth in SME value added is predicted to slow down to one-digit rates of 7.4% and 7.9% annually between 2017 and 2019. However, it will still exceed the annual growth rates of large firms. SME employment is likely to rise by around 2% annually in 2017-2019, generating around 19 800 new jobs by 2019.

Since 2008, policy progress in implementing the SBA recommendations in Latvia has been moderate. The most significant progress has been achieved in implementing recommendations in the areas of skills & innovation and access to finance. SMEs can benefit from a variety of mechanisms to access funding for research and development of new products and services, and to increase their productivity and export capacity. Latvia has improved its policy towards SMEs' access to skilled workers — improving the vocational education and training system by introducing work-based learning and ensuring funding for companies to further train their employees. Over recent years, Latvia has implemented numerous measures to introduce the 'Think Small First' principle and address recommendations under such areas as responsive government — cutting administrative burden and developing accessible e-services, state aid & public procurement, 'second chance' and internationalisation.

Technological innovation, to the extent that new products (goods or services) and processes are introduced, which are an essential part of innovation in production. A larger share of technology innovators reflects overall higher levels of innovation activity. In 2016, 11.89% of SMEs have indicated that they have introduced product or process innovations.

At the same time many companies, particularly in the services sector, are developing innovation through other, non-technological forms of innovation, such as marketing and organizational innovations – in 2016 18.97% of SMEs have indicated that they have introduced marketing or organisational innovations.

4.3. Gross Domestic Expenditure on R&D

The target of the National Reform Plan of Latvia regarding investments in research and development (R&D) for 2020 is 1.5% of GDP.

The European Innovation Scoreboard 2018 places Latvia 24th among 28 EU Member States included in the research, allowing it to keep its position in the moderate investors group, where performance in the area of innovations is 50-90% of the EU average level.

At present there is clear that the target for investments in R&D by year 2020 will not be met. Latvia similarly to other EU member states formulated ambitious goals for investments in R&D to be reached by year 2020, that did not clearly match the real economic and policy capabilities. The amount of private sector investment in R&D is especially low and is one of the main challenges, that explains the low overall R&D expenditure. Meanwhile, it also must be noted that the current actual R&D expenditure is most likely higher than currently identified - the accounting principles and underreporting of R&D activities by enterprises could also partially explain the very low expenditure on R&D[79].

Nevertheless, alongside current innovation policy objectives and instruments to support R&D, multiple recent initiatives have been launched to increase the amount of R&D expenditure.

4.3.1. Value chain ecosystems

In order to ensure EU level industrial, innovation and R&D excellence in the fields related to industry and research strengths, the value chain ecosystem pilots have been started, led by Ministry of Economics. In practice it means development of collaboration platforms bringing together entrepreneurs, research/education institutions and public administration. Three value chain ecosystem pilot projects have been under the implementation: (1) Biomedicine; (2) Smart materials, and (3) Smart city.

[79] See also European Commission (2018) *Specific Support to Latvia: Final Report – the Latvian Research Funding System*. Available: https://rio.jrc.ec.europa.eu/en/library/specific-support-latvia-final-report-%E2%80%93-latvian-research-funding-system

4.3.2. Innovation in State Owned Enterprises (SOEs)

SOEs (LMT, TET, Latvijas valsts meži, Latvenergo, Latvijas Dzelceļš, Latvijas pasts etc.) have started proactive activities to encourage innovation as well as cross-sectoral cooperation to define and implement new innovation-oriented projects, incl. aimed at development and integration of digital technologies and solutions. These include, for example, project ideas for drone-based forest monitoring, smart houses, 5G solutions, autonomous cars, biorefining etc.

4.3.3. Increase of the demand for innovation through public procurement for innovation

One of initiatives for increasing the demand for innovation is through public procurement - Latvia currently is not active enough in using public procurement to support innovation. Nevertheless, innovation procurement is performed within both innovation partnership and other procurement procedures. The legislation system allows to perform innovation procurement, however there is a lack of practical information on the use of such.

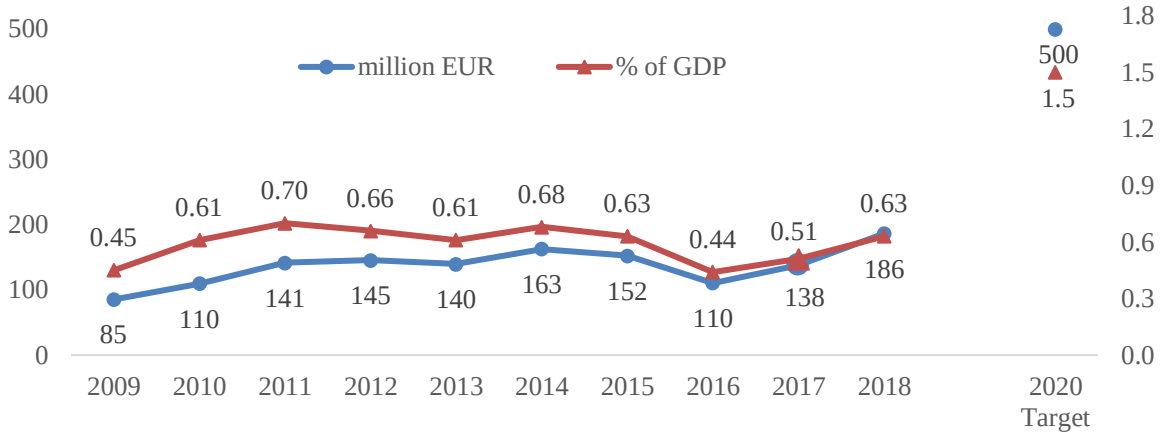

Figure 4.8: Target for investments in R&D.
Source: Ministry of Economics of Latvia

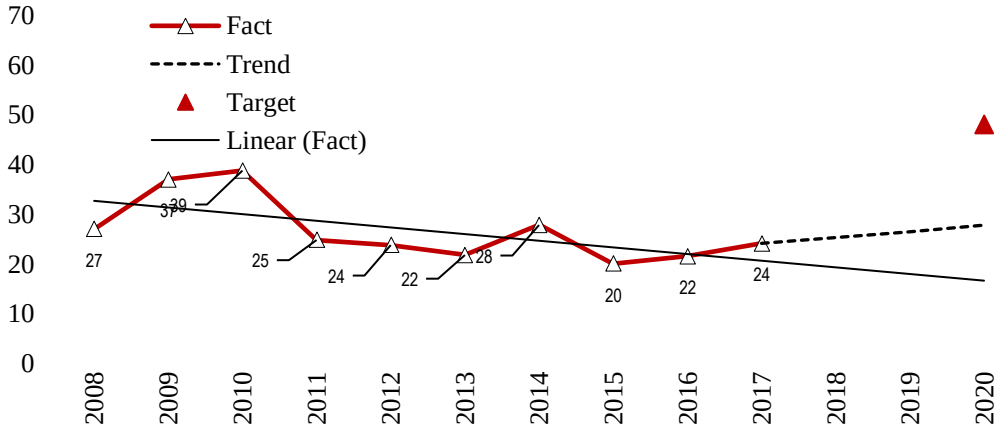

Figure 4.9: Proportional increase in private investment in R&D
Source: Ministry of Economics of Latvia

Total expenditures of Latvia on R&D in 2018 amounted to 186.2 M EUR or 0.63% of GDP. Although the total increase in funding is 26% compared to 2017, it is considerably lower than planned in 2018. The increase was mainly fuelled by renewed European Structural and Investment Funds (ESIF) funding which raised the public funding level to 0.47% of GDP.

The structure and dynamics of R&D financing evidence that investments in R&D in Latvia are low and depend on ESIF. Therefore, it is natural that R&D expenditures cyclically increase and reduce along with investments from the EU funds, at the same time activities are being implemented to increase the share of private investment in R&D and innovations, e.g. encourage large state-owned enterprises to increase their investment in R&D and innovation, inform SMEs about the opportunities of R&D and innovation investment, as well as promote demand-side instruments as public procurement for innovation.

Nevertheless, the volume of investments in R&D is insufficient and it is still lower than the target. Thus, for instance, in order for Latvian R&D expenditures to constitute 1.5% of GDP, in 2020, it should be equal to 462.6 M EUR, where 50% should be public funding and 50% should be private sector funding. Institutional funding in Latvian science – science base funding – is not being paid out in 100% of the amount calculated in accordance with the current legislative framework.

4.3.1. R&D&I support and development of innovative enterprises

Research-based and innovation-driven socio-economic development is based on research and business environment cooperation. In order to contribute to this, during the 2014-2020 period, the policy instruments for MoES and Ministry of Economy were designed to promote the development of human capital and infrastructure for research, knowledge and technology transfer and the creation of export, higher value-added products and services.

In order to link the existing science and innovation policy management model to national needs, as well as, among other things, in response to the recommendations made in the evaluation by EC experts of the Latvian science funding (2017), the following measures have been taken so far:

- In June 2018, amendments to the Law on Scientific Activity entered into force, which enable sectoral ministries to develop and finance their state research programmes in priority sectors of the state. It is important to note that one of such programmes is described above – for the High Energy Physics and Accelerator Technologies.
- Investments in the EU funds support programme "*To ensure better governance in higher education institutions"* are made for modernisation of higher education governance.

As to the increase of R&D funding for projects obtained through a competition, new conditions for financing of fundamental and applied research projects, as well as state research programmes were drafted, ensuring evaluation of projects equivalently to the principles of the Horizon 2020 programme, which is done by foreign experts. Starting from 2018 funding for fundamental and applied research projects has increased from 4.4 M EUR per year to 9.5 M EUR per year.

Additionally, funding from EU funds (*2014-2020*) specific objective "*To Increase Private Sector Investments in R&D* and *To Promote Introduction of Innovations in Enterprises"* measures are being implemented to boost development of innovative enterprises and R&D. For example, such programmes with the aim to support in introduction of new products, innovation motivation programme, support for training of employees, etc.

4.4. Indicators of science, technology and innovation outputs

In 2019, the number of publications produced by Latvian research institution was 7'620, according to the Web of Science (WoS) database. In 2018, around 56% of the publication were submitted by Latvian authors and only 44% in cooperation with an international collaboration, according to the Scimago Journal & Country Rank (SJC). SJC also has a record of publications produced by Latvian institutes, but in this data base the number of publications is given as 8'355. Comparing the total number of publications produced by the neighbouring counties, Estonia and Lithuania, it can be seen that Latvia has so far been unable to surpass them in the number of publications, eoyj Lithuania leading from Estonia. According to the European Innovation Scoreboard 2019 (ESI), the number of scientific publications among the "top 10% most cited" is greatest in Estonia, followed by Latvia. This is a clear indicator that the quality of the publications produced by the Latvian institutes is high.

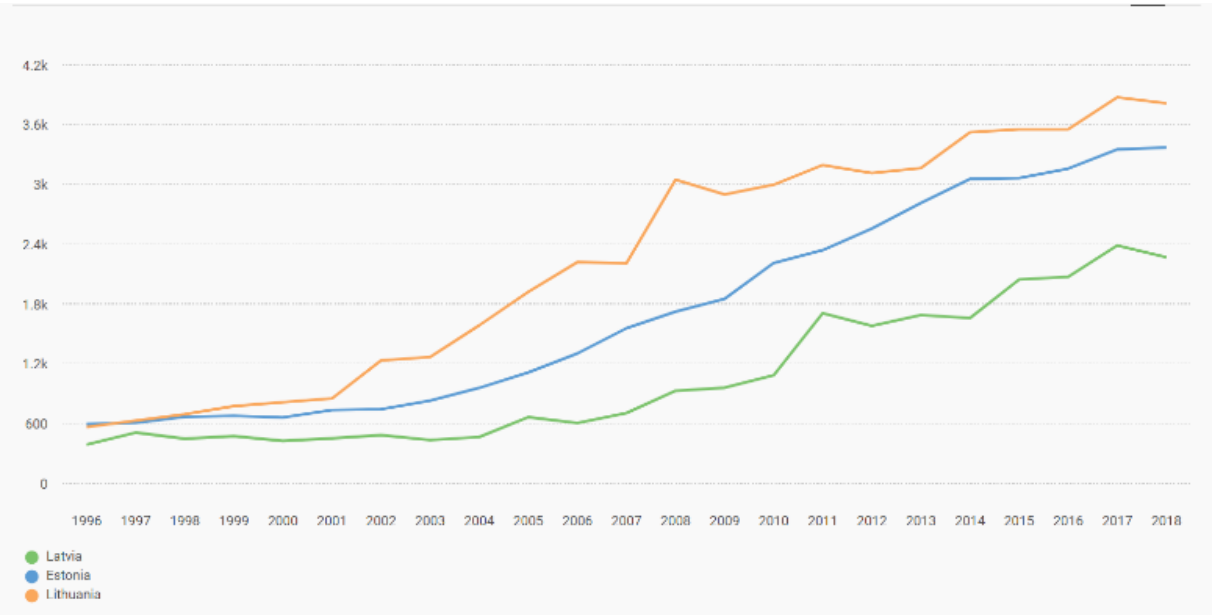

Figure 4.10: Number of scientific publications in Baltic States.
Source: SJC 2019

Latvia has highly cited several domains of research, e.g. physics, medicine and astronomy. Other domains, such as engineering or material are less citated in comparison, but are strong in Latvia nonetheless.

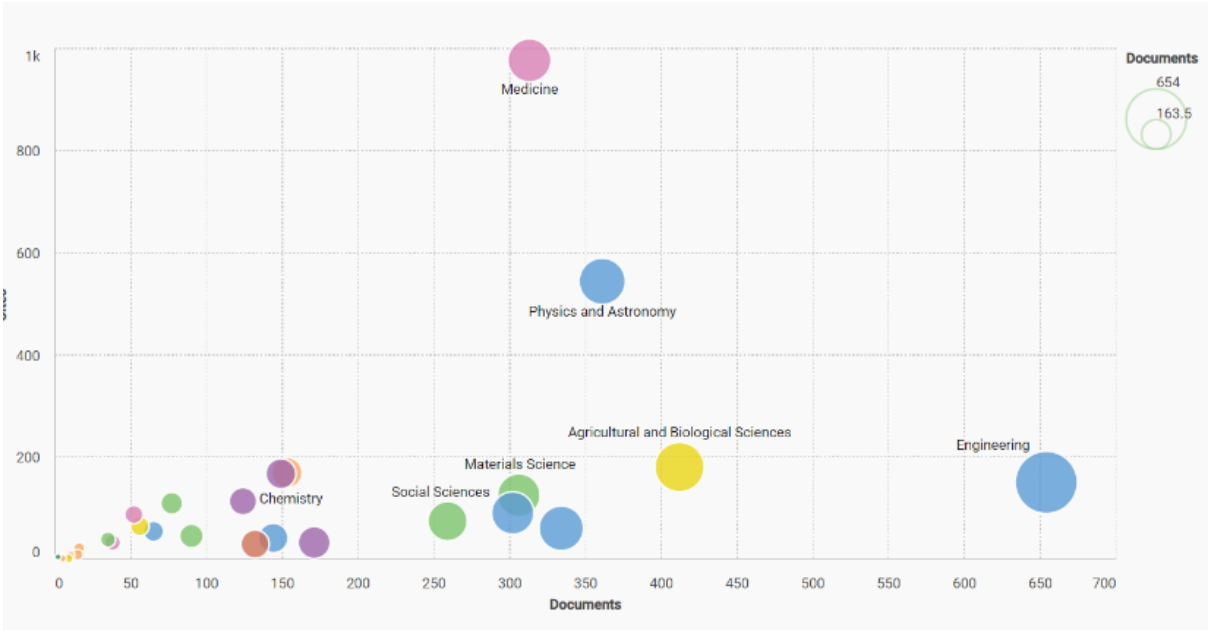

Figure 4.11: Citation per research domain.
Source: SJC 2019

Latvia has a patent office that upholds and safeguards the state policy in the field of industrial property by ensuring registration of the industrial property rights and publicising the information of the registers in an official Gazette in an electronic form. In 2018, 41% of the applications made in the office were inventions and 59% were industrial designs.

	2013	2014	2015	2016	2017	2018	Total 2013-2018
Granted patents for national applications	136	144	147	68	87	51	**633**
Validated European patents	999	1034	1044	1128	1287	1443	**6935**
Extended European patents	107	110	72	57	59	35	**440**
Granted patents - total	**1242**	**1288**	**1263**	**1253**	**1433**	**1529**	**8008**

Table 4.5: Breakdown of granted invention patents.
Source: Latvian Patent Office

		2011	2012	2013	2014	2015	2016	2017	2018	Total 1992-2018
Industrial design applications	Applications Total	63	60	65	36	56	61	49	51	1983
	Applications Domestic	63	55	63	36	56	61	48	49	1549
	Designs Total*	117	123	117	78	102	171	148	157	4159
Industrial design registrations	Registrations Total	48	41	62	33	38	55	47	38	1647
	Registrations Domestic	48	38	58	33	38	55	46	35	1229
	Registered Designs Total*	103	64	103	75	71	163	149	118	3326

Table 4.6: Number of industrial Design Applications and Registrations.
Source: Latvian Patent Office

4.5. Human resources and skills

Latvian education system consists of pre-school education, basic education, secondary education and higher education[80]. General education in Latvia, beginning at age 7, spans 12 years, consisting of nine years of compulsory basic education and three years of secondary education. Additionally, pre-school education at age of 5-6 is compulsory in Latvia. Basic education stage comprises of general basic education (grades 1-9) and vocational basic education. Secondary education stage is comprised on general secondary education, vocational secondary education and vocational education. Higher education is comprised of both academic and professional study programmes.[81]

[80] http://www.aic.lv/portal/en/izglitiba-latvija
[81] http://www.aic.lv/portal/en/izglitiba-latvija

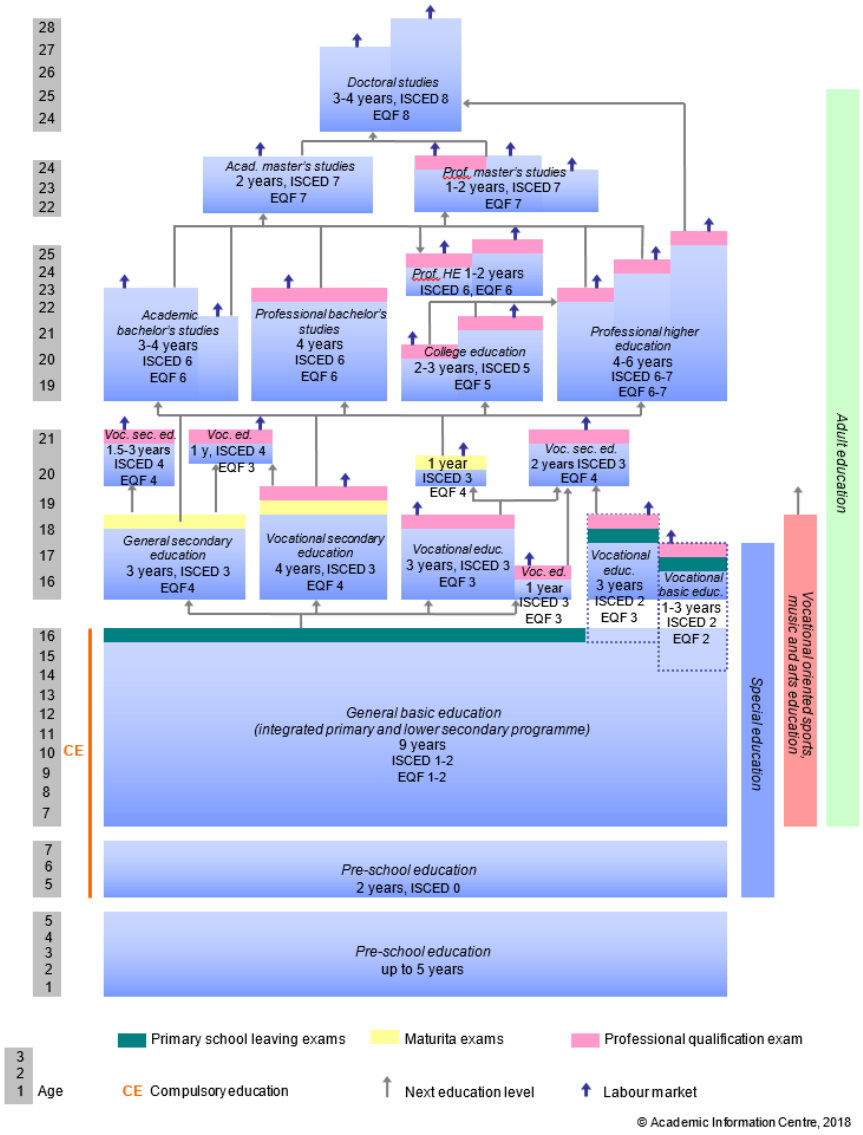

Figure 4.12: The Educational System of Latvia.

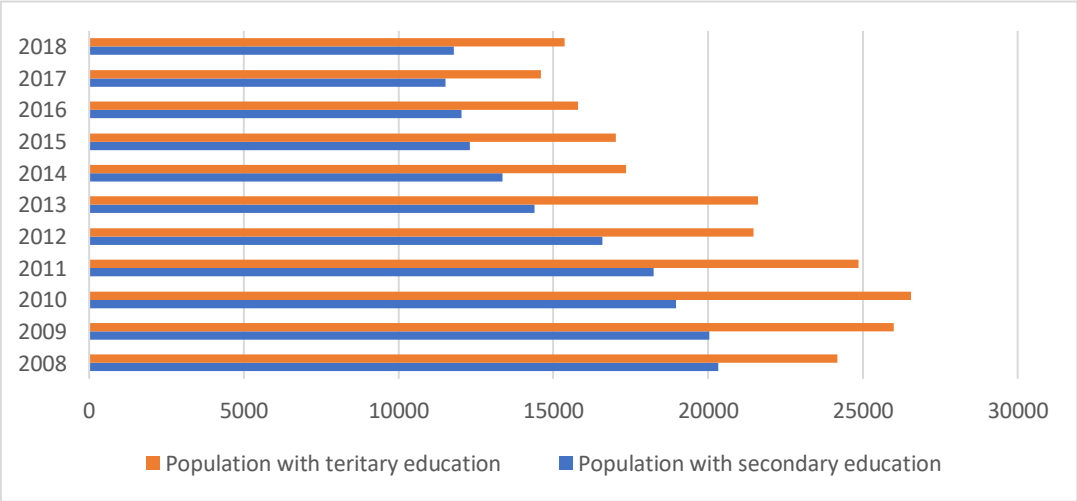

Figure 4.13: Population educational level in Latvia (thousands).
Source: CSB, 2019

4.5.1. Secondary and tertiary education

The fraction of the population with completed secondary education or a university education, according to data of UNESCO[82] (in thousands) Latvia is having positive dynamics in numbers of population with secondary or tertiary education see Figure 14 and 15.

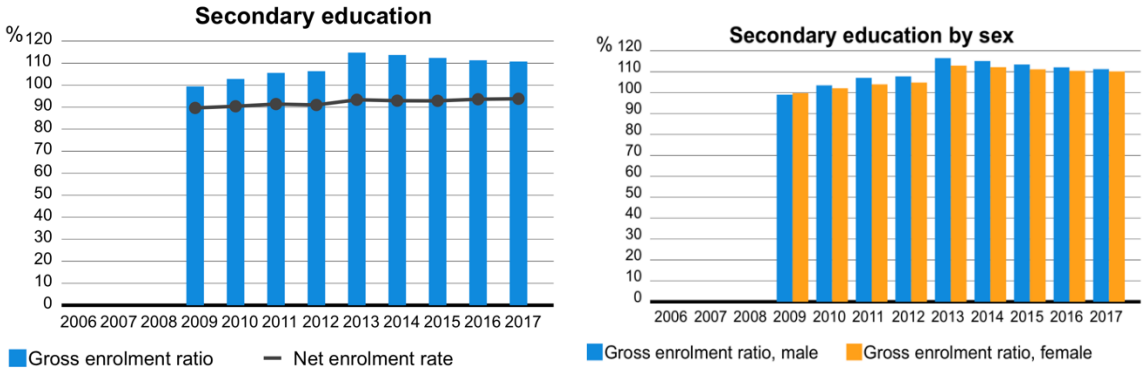

Figure 4.14: Enrolment in the secondary education.

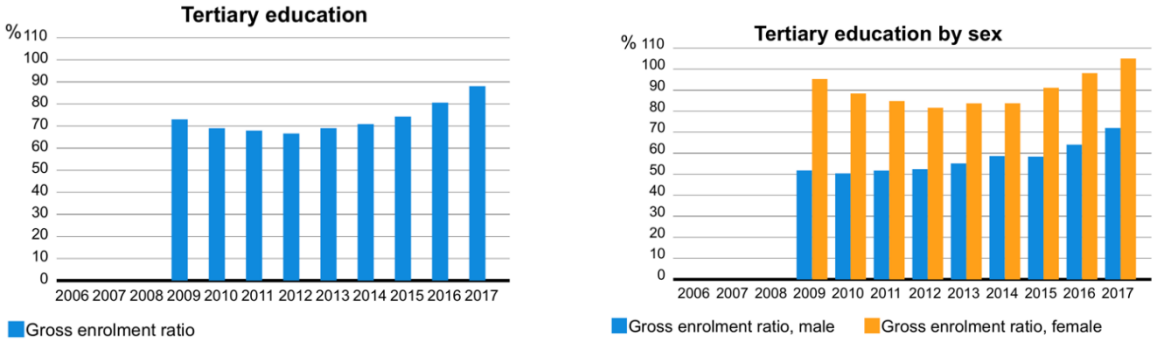

Figure 4.15: Enrolment in the tertiary education.

According to the OECD[83] data, the tertiary education attainment rate among young adults (25-34-year-olds) has improved from 29% in 2008 to 42% in 2018. However, a wide gender gap exists, as 30% of men have a tertiary qualification, compared to 54% among women. Despite above-average tertiary entry rates, the cross-cohort probability of completing a short-cycle tertiary or bachelor's programme by its theoretical duration remains relatively low and is higher for women. Upper secondary general programmes are preferred by young people (over 60% of students in upper secondary education). However, vocational programmes, which including at least a 25% practical training component, as is the case in Latvia, can provide numerous advantages in the labour market.

Net financial returns to a tertiary education are relatively low compared to other OECD countries, especially for men. In addition, the employment rate among 25-34-year-old men with an upper secondary vocational qualification reaches 88%, only 4 percentage points less than those with a

[82] http://uis.unesco.org/country/LV
[83] https://www.oecd.org/education/education-at-a-glance/EAG2019_CN_LVA.pdf

tertiary education (92%). Small class sizes in Latvia inflate the cost of education per student, although it remains the lowest across OECD countries because of teachers' low statutory salaries.

The number of R&D staff[84] in Latvia, measured in full-time equivalents (FTE), fell significantly during the crisis years. In 2008, there were 6'533 FTE researchers, dropping to 5'570 FTE in 2015, a decrease of around 15%. The aim of the research system reform, to be implemented in 2020 is to increase this number to 7'000 FTE and to concentrate the human capital in around 20 strong national research centres. The analysis of the available human resources per scientific discipline shows that the highest concentration of researchers is in natural sciences (44%). Engineering and IT account for 21% and social sciences for 12% of all researchers. Agriculture, humanities and life sciences, as well as the medical field, comprise a smaller share of the total human resources in science, at 6%, 8% and 9%, respectively.

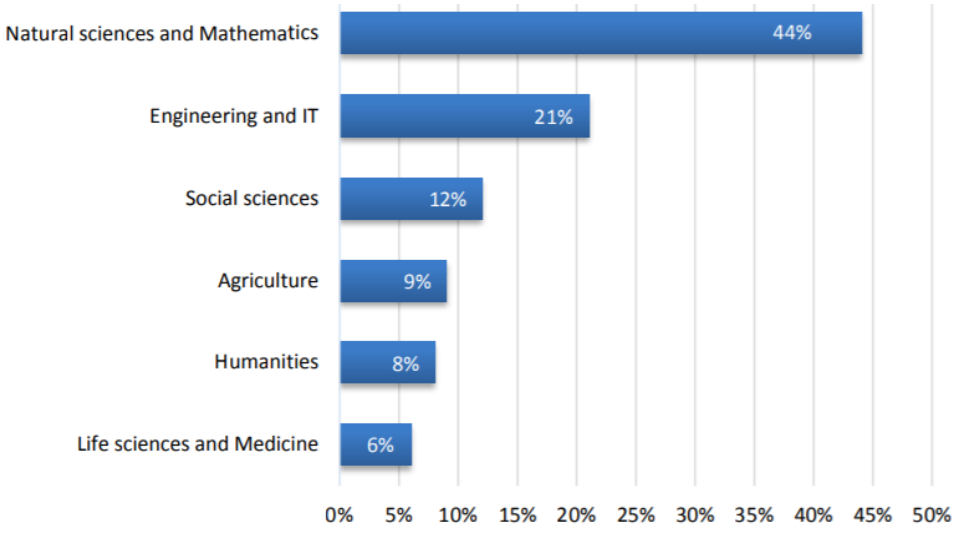

Figure 4.16: Distribution of human resources in science per scientific discipline.
Source: FIDEA, 2013

[84] https://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_personnel

5. Organization of Science in the Country

The MoES and the Ministry of Economics are the lead policy makers regarding the matters of research and innovation in Latvia. The hierarchical structure of the policy makers regarding these field is shown in Figure 5.1 and the key players are discussed below.

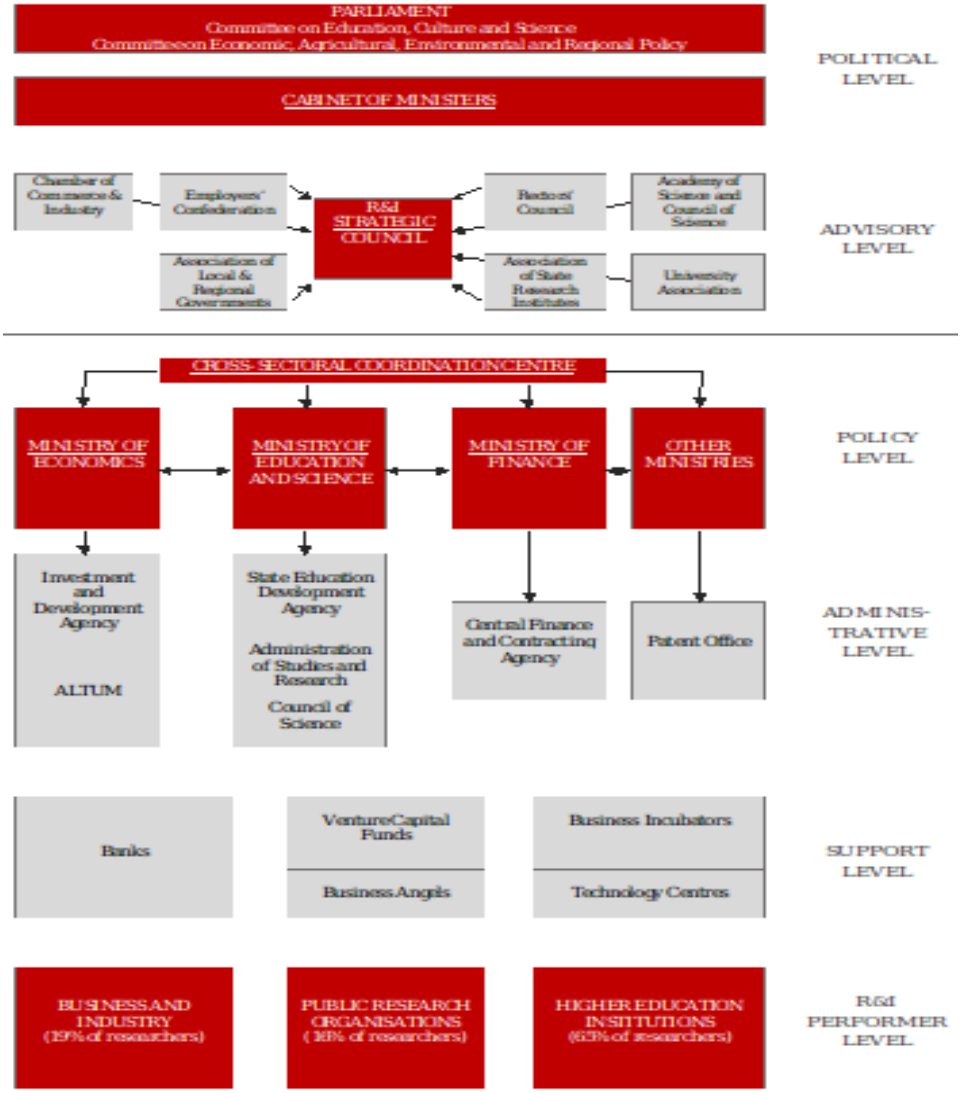

Figure 5.1: Hierarchy of policy makers regarding research and innovation in Latvia.
Source: MoES

Latvia's Parliament - Saeima - and the **Cabinet of Ministers,** are highest-level political institutions in Latvia, and make the decisions on research and innovation policies and funding.

Occasionally, thematic commissions of the Parliament organise hearings and discussions about the relevant policy topics, but this serves mostly as an advisory discussion forum. The Cabinet of Ministers, the executive branch of the Government, approves the regulations related to R&I policy. Both institutions decide on such matters as the budget for research and innovation and assessments of research institutions, as well as determine the research priorities every four years. They are responsible for allocating the budget for R&I policy, setting the evaluation criteria for assessing the

efficiency of research institutions and approving the prioritised research directions and state research programmes (see above State Research Programme in High-Energy Physics and Accelerator Technologies) for financing fundamental and applied research every four years via the Law on Scientific Activity.

The **Research and Innovation Strategic Council** was established in 2014. It aims to provide a coordinated approach towards research and innovation policy implementation and brings together the key R&I players. The Prime Minister leads the Council and takes the initiative to organise the Council meetings. Other ministers participate according to the topics discussed. Higher education institutions, public research organisations, the Academy of Sciences, organisations representing businesses and local governments are also active members of the Council. Although the Council provides a platform for discussing major policy decisions between the key players, recently its activity has been minimal.

The **Cross-Sectoral Coordination Centre** is the body responsible for development of mid-term and long-term policy strategies and coordination of sectoral policies. The centre has developed the National Development Plan of Latvia for 2014-2020 and is currently coordinating work on the upcoming plan for 2027. These long-term policy planning documents also address the topics of research and innovation, and the centre coordinates other policies and their correspondence with the goals defined in these long-term policy documents.

The **MoES** is a key player in research and higher education policy planning. It designs key policy documents and coordinates the implementation of the policy measures. Among others, the MoES also is in charge of developing, implementing and monitoring the Smart Specialization strategy (RIS3).

The **Ministry of Economics** is another key player in research and innovation policy. It is responsible for policies related to business support and innovation, and designs and monitors the structural funds' programmes for business competitiveness and innovation capacity.

Other sectoral ministries may have input in R&I policy development in their respective fields of competence. The Ministry of Finance (MoF) is in charge of the development and coordination of financial policy and budget allocation, as well as the administration of EU Structural Funds and the Cohesion Fund. As in the EU programming period 2014-2020, more emphasis has been put on providing support to RDI, and RIS3 has been set as an *ex-ante* criterion for receiving SF funds, and the MoF has become more involved in R&I policy development.

5.1. Available Funding Instruments and Agencies

The **Central Finance and Contracting Agency** is a part of the MoF and implements the EU structural fund support measures. Although several measures are administered by other agencies with a more direct role in research and innovation matters, the Central Finance and Contracting Agency is also responsible for implementing R&I-related measures. The agency is experienced in administering Structural funds, but has to build the competence in research and innovation matters.

The **State Education Development Agency** is the largest agency with the greatest role in implementing R&I support measures, under the MoES. Besides implementing support measures for research and innovation, it also administers other international programmes, for example, BONUS programme, EUREKA, COST, and ERASMUS+. Due to the simplification efforts, implementation of several EU Structural Funds programmes has been shifted to the Central Finance and Contracting Agency, but some specific programmes are still managed by the State Education Development Agency, as it holds the required competence. One such programme is the support for post-doctoral research, as the

implementation of the programme requires access to international research networks, close relations and familiarity with the higher education and research institutions.

The **Latvian Council of Science** was created in 1990 with the task of formulating and coordinating science policy and acting as a research council, assessing applications for research funding and allocating money according to the competition. The Council provides advice on R&D and higher education policy formulation and implementation, representing the voice of the academic research community, for instance, by providing input to the formulation of state research programmes. The Council operates through five-expert commissions, which act as assessment panels for proposals for scientific research projects and programmes and policy recommendations. It is in charge of the formulation and continual improvement of evaluation criteria for assessing research projects and research-performing institutions. In practice, it tends to function as a funding agency of the MoES, evaluating fundamental or applied research projects and distributing funds in accordance with the procedures specified by the Cabinet of Ministers.

MoES has begun to implement major reforms regarding Latvian science policy implementation system by consolidating its smaller administrative institutions and agencies (Latvian Council of Science, Study and Science administration and State Education and Development Agency). This process will create a **one-stop agency** responsible for all science policy implementation through pro-active management approach and greater flexibility in program design (including greater in-house analytical capacity). The conceptual report, approved by the Cabinet of Ministers, presents a detailed action plan for the following year. The consolidation process will result in a newly formed strong, unified institution for the implementation of science policy, the Latvian Council of Science, which will officially begin its operation on the 1st of July, 2020.

The **Administration of Study and Research** (ASR) is an agency of the MoES. Its main task for science involves administrative and financial oversight of the implementation of state-funded fundamental and applied research projects, as well as interacting with, and supporting, the Latvian Council of Science. Each year, the ASR submits a report to the MoES on the utilisation of state-budget resources allocated to state-funded research programmes and projects (European Commission, 2017 (a)).

Investment and Development Agency of Latvia (LIDA) is an administrative agency under the responsibility of the Ministry of Economy. Its main objectives are to facilitate foreign investment and increase the competitiveness of Latvian entrepreneurs, thereby promoting business development. In 2004, LIDA became one of the main funding agencies responsible for administering EU funds and implementing state support programmes in entrepreneurship and innovation. Currently, it is focusing predominantly on the implementation of national programmes regarding export promotion. In addition, the Latvian Tourism Agency has been merged with LIDA. There appears to be less of a focus on innovation, while the Agency continues to implement some strategic Structural Funds co-financed initiatives like innovation vouchers, business incubators, and technology transfer programmes.

The **JSC Development Finance Institution Altum** (ALTUM) is a financing institution that is fully owned by the state and has three ministries as its shareholders (the MoF, MoE, and Ministry of Agriculture). This new institution was created in April 2015 when the Latvian Guarantee Agency (LGA) merged with the ALTUM and the State JSC Rural Development Fund (RDF) (Kulikovskis et al., 2015). ALTUM provides alternative risk capital funding for businesses with insufficient collateral. Its objective is to provide efficient and professional support to certain business target groups using various financial instruments (loans, guarantees, investments in risk capital funds, etc.) that are supplemented by non-financial support (consultation, training, monitoring, etc.). The aim of this financing institution is to incentivise entrepreneurial activities and promote the growth and expansion of business operations.

Latvia's R&D system underwent major reforms that had a noticeable improvement in the R&D and innovation performance: 3-pillar financing model that introduced performance-based criteria in our R&D funding instruments that became competitive between public RO's. Independent international

evaluation that allows our R&D grants to become more similar (and aligned) to H2020 and more transparent and objective in their evaluation. EU funds in R&D were allocated according to the S3 priorities.

At the end of 2019, the National Information System of Research Activity had as total of **65 scientific institutions** registered, of which 22 were public institutions funded from the state budget.

The main funding lines for the research system include: **Institutional research funding –** funds to enable universities to have and maintain internal research facilities and resources, which the universities are able to spend as they themselves decide, in-line with the principle of university autonomy; nationally financed grants – academically orientated competitive research funding and competitive funding for more applied research in the national Priority Directions in Science; International funding – EU Structural Funds, EU Framework Programme, other international funding.

Funding instrument and source	**Average annual allocations (EUR)**	**Aim of the intervention**
Basic research state budget)	25 M (in 2019)	Ensure institutional stability and continuity of research activity
State Research Programmes (state budget)	4,2 M	High-impact, industry-relevant research in priority areas of national development
Fundamental and applied research grants (state budget)	9.5 M (2019)	Scientific and technological advances, solutions in topical research areas
Practically oriented research grants (ERDF)	14.3 M	Innovative solutions for practical socio-economic challenges, improving intersectoral collaboration and knowledge transfer in RIS3 areas, focus on high commercialisation potential
Grants for postdoctoral research (ERDF)	10.6 M	Postdoc research projects in RIS3 areas, competence building, international mobility and networking, tech-transfer activities
Innovation grants for students (ERDF)	5.6 M	Student research and innovation projects, particularly in STEM areas, life sciences and creative industries
Support for international cooperation projects in R&I (ERDF)	5.4 M	ERA bilateral and multilateral research cooperation project development, networking, strengthening capacity of H2020 national contact points. 1st selection round – national level measures for international research cooperation capacity building 2nd selection round – institutional level measures for international research cooperation capacity building 3rd selection round – implementation of projects which have been evaluated above threshold in Horizon 2020 programme but have not been implemented due insufficient funding
Development of research and innovation infrastructure and strengthening the institutional capacity of scientific institutions (ERDF)	Individual budget for each scientific institution (total 120 M)	Increased institutional capacity of research institutions, concentration of resources by improving the governance and modernising the research infrastructure in RIS3 areas.

Table 5.1: Policy instruments supporting competitiveness in science

In 2018, public research institutions attracted 8.5 M euros R&D of funding from private companies, which was 6.1 % of all R&D funding for public research institutions (similar collaboration rate to other EU countries). Research institutes had the most intense collaboration with private companies (10.6 % of their R&D revenue in 2018) while higher education institutions were less active in collaboration with the industry (4.2 % of their R&D revenue in 2018). In 2019, total annual funding from state budget sources for scientific research is €49,6m and €37.9m is provided by the ERDF for the period 2014-2020.

R&D source of funding	**Enterprise**	**State**	**Foreign**
Funding (M euro) 2017	33.3	60.1	41.1
Funding (M euro) 2018	41.6	63.9	77.3
Increase %	25%	6%	88%

Table 5.2: Private source of finance for R&D.

5.2. Structure of science funding

The science policy has been subject to significant reforms. Since 2014 scientific institutions have been consolidated. Investments from the EU Structural Funds were provided to the 14 best scientific institutions, as well as to the following grant programmes: activity “Researches of practical nature”; activity "Post-doctoral research support"; and activity “Innovation grants for students”.

A new Fundamental and Applied Research Project scheme was launched in 2018. In comparison to the previous years the annual funding has been increased from 4.4 M EUR to 9.5 M EUR. This scheme provides a platform for bottom-up research proposal implementation in all six fields of science (according to the FOS classification), where the focal goal and evaluation criterion is the research excellence. All projects are evaluated by international experts only. In 2018 there were two organised calls by the Latvian Council of Science. During the 1st call (closed on March 8th) 397 proposals were received, from which 61 were funded, for a total budget of 17,8 M euro for three years. First results were positive indications regarding applications numbers (16 % success rate). Also, 74 % of the projects were rated to be above the quality threshold.

The main funding lines for the research system include:

- **Basic research funding**: funds for ensuring scientific activity and resources for maintenance of the scientific institution;
- **Fundamental and Applied Research Grants**: bottom-up research implementation in all six fields of science (according to the FOS classification), where the focal goal and evaluation criterion is the research excellence;
- **State Research Programmes**: State commissions for the performance of scientific research in a specific economic, educational, cultural, or other sector of priority to the state, where the focal goal and evaluation criterion is the research impact;

- **International funding**: EU Structural Funds, allocated nationally; EU Framework Programme, allocated at the EU level; Other international funding (e.g. bilateral cooperation programmes, Baltic Sea Region programmes, etc.).

The **basic research funding** is allocated to those state research institutions, higher education institutions (HEIs), their structural units, and institutes founded by HEIs that are listed in the Register of Scientific Activity. In the framework of science system reform, the procedure of allocating base funding has been amended – it is only allocated to competitive scientific institutions following the specific minimum criteria for the research staff in FTE (for universities and research institutions the minimum research staff is 25 FTE, for other higher education institutions, 10 FTE, and for higher education institutions specialising in arts, 5 FTE). In 2017, MoES listed 22 scientific institutions, which were to receive the base financing. According to the research reform plans, the number of institutions receiving the base financing will be reduced to 20 by 2020. The state will only allocate base financing to those institutions that have received high scores in the research assessment, which, according to the Law on Scientific Activity, is to be carried out every six years.

In 2019, MoES begun the international assessment of scientific institutions. The Cabinet order "Procedure for Organizing the International Assessment of Scientific Institutions", sets out the framework and evaluation principles for the following procedure. Furthermore, the accompanying Cabinet protocol decision enables the MoES to review further linkage of all public R&D funding to the results of the next international assessment exercise, including a review of base funding principles. Assessment will be done by Technopolis Group Eesti and will be completed by November 2020.

The most important institutions in attracting international project funding are the University of Latvia, Riga Technical University, and the Institute of Organic Synthesis. Together, these three scientific institutions have attracted 67% of the overall international funding.

5.3. Short- and Mid-term priorities

Science policy in Latvia is developed in accordance with the Latvian Research and Innovation Strategy for Smart Specialization (RIS3).

The aim of the **national science policy** is to strengthen Latvia's research and innovation capacity in priority directions and RIS3 areas, transforming productive structures towards more resource-efficient activities that create higher added value. This goal is approached by increasing the investments and lessening the institutional barriers. The research and innovation systems are being developed, which encourages the regeneration of human capital and infrastructure, creating new scientific knowledge and boosting technological progress.

Latvia develops its scientific potential on the basis of the existing scientific traditions, particularly in organic chemistry, medical chemistry, genetic engineering, physics, materials science and information technologies. The highest number of inventions, which are patented both nationally and internationally, are made in the branch of medical chemistry.

RIS3, as national research and innovation strategy, was established to articulate and promote the transformation of Latvia's economic structure and to make it more competitive by strategically prioritising efforts in the most promising areas of research. The strategy also facilitates the creation of policy instruments, which release the innovation potential, thus promoting knowledge-intensive socioeconomic development.

RIS3 is a strategy of economic transformation towards a higher value-added, greater productivity and a more efficient use of resources. **The objective** of the strategy is to increase innovation capacity and to establish an innovation system fostering and supporting the technological progress in the national economy. The task of the strategy is to ensure the setting of the development priorities and a regular review thereof.

An RIS3 monitoring system has been in place since 2016, to assess the progress of the implementation and the effectiveness of the invested funding. The purpose of RIS3 monitoring is to assess the progress of the economic transformation over a specific period, in line with the defined indicators of objectives and results to be achieved. The results and conclusions of the data analysis carried out under the RIS3 monitoring will form the basis for the development of the new RIS3 and for the development of an appropriate, mutually integrated national policy.

In line with the RIS3 task, which requires stimulating the production and integration of more technology-intensive, higher value-added and export-potential products, and services at higher levels of global value chains, it is necessary to promote the development of **strategic value chains**, with potentially high added value, at national level. By extending the integration of single value chain actors, a value chain ecosystem is emerging, covering closer and indirect private, public and academic partners at both the local and international level.

The development of the strategy includes a series of interrelated and complex activities. The process of defining a strategy is different for each value chain ecosystem and the duration of its development may change. The development of the strategy shall include the following activities:

- Strategic workshops based on design thinking (collecting, interpreting and clarifying the views of the stakeholders);
- Competitiveness strategy analysis (competitiveness reinforcement methodology);
- The process of defining the short-, mid- and long-term action plan (repeated regularly);
- Paradigm change based on the change of the mindset;
- Identifying of the EU policy initiatives and developments.

In Latvia, 5 **Smart Specialization** areas and one horizontal area – Social Sciences and Humanities – have been defined, taking into account the potential directions of economic transformation and economic development priorities. The five areas are:

- Biomedicine, medical technologies and biotechnology; Chemical and biotechnological methods and products for the production of pharmaceutical and bioactive substances; Development and research of new and existing human and veterinary medicinal products; Molecular and individualized treatment and diagnostic methods and cell technology; Functional foods, therapeutic cosmetics and bioactive natural substances;
- Smart Energy; Development of smart grids; Development of demand-supply systems, smart buildings, home, appliances and home automation systems; Development of next-generation technologies for energy from renewable energy sources; Increasing energy efficiency - energy efficiency of building structures, energy efficiency of residential infrastructure elements; Sustainable energy for transport - new technologies, accelerating their implementation, electric mobility;
- Advanced IT - Innovative knowledge management, system modelling and software development methods and tools; innovative sectoral IT hardware (hardware) and software (software) applications; cyber-physics systems, language technologies and the semantic web; bulk data and knowledge infrastructure; information security and quantum computers; computer system testing methods;

- Smart materials, technology and engineering - Implant materials, composite materials, thin layers and coatings, equipment, machinery and working machines, glass fibre products and smart glass-based materials;
- Knowledge intensive bio-economy - Sustainable and productive forest growing in changing climatic conditions; Full use of wood biomass for chemical processing and energy; Innovative, risk-reducing plant and animal breeding technologies; Development of innovative high value-added niche products from wood, traditional and unconventional agricultural plant and animal raw materials; Technological solutions for the use of plant and animal breeding and processing by-products; Food safety.

5.3.1. Priority directions in science 2018-2021

The national priority directions in science are revised every four years with the aim of focusing scientific activities towards strategically significant areas for the sustainability and development of Latvia. These priority directions are also accompanied by financing from the state budget. They are implemented via two research programs: the Fundamental and Applied Research Program and the National Research Program.

The MoES commissioned a report, where sectoral stakeholders (relevant ministries, professional associations, non-governmental organizations and enterprise actors) were surveyed about the most important challenges for society and the future requirements for Latvia's knowledge base and sectoral human capital development. These recommendations were then integrated into the priority directions in science for 2018 – 2021:

1. Technologies, materials and systems engineering for increased value-added products and processes, and cybersecurity;
2. Strengthening security of energy supply, development of the energy sector, energy efficiency, and sustainable transport;
3. Climate change, nature protection, environment;
4. Research and sustainable use of local natural resources for the development of a knowledge-based bioeconomy;
5. Latvia's statehood, language and values, culture and art;
6. Public health;
7. Knowledge culture and innovations for economic sustainability;
8. Demographics, sports, open and inclusive society, welfare and social resilience;
9. State and public safety, and defence.

In terms of the R&D personnel in Latvia, though its share of total labour force is not very high, it shows that there is enough potential to be a global player in our key R&I priorities, RIS3 areas and their specific sub-themes, which are directly aligned with our investment programmes in R&D. According to the data of the Central Statistical Bureau - total number of research staff in 2018 was 12'129 (5'806 FTE) and the total number of researchers was 7'439 (3'456 FTE).

Innovation ecosystem in Latvia is also improving, from a "modest" to a "moderate" innovator in European Innovation Scoreboard in 2016. Major improvements were noted in a series of key performance indicators related to the innovation performance – increasing productivity, growth of the high-technology exports and the steadily growing Business R&D sector.

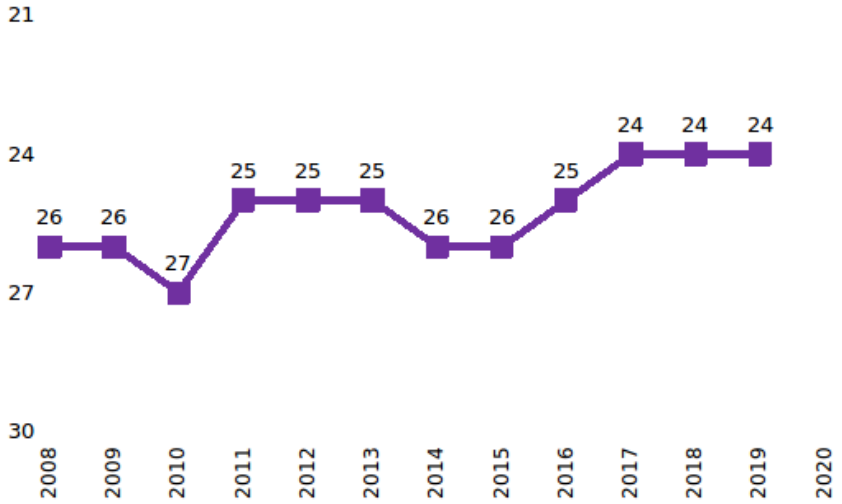

Figure 5.2: Latvia's position in the European Innovation Scoreboard.

Latvia's major R&I asset is its highly educated workforce, especially among young adults who are beginning to enter the labour force. For adults aged 30-34, more than 42% have a higher education degree and positive trends can be seen in other key specialization areas e.g. a high share of students who are studying IT. Furthermore, Latvia has remarkable gender equality figures in research with the highest share of female researchers (55 %) among European countries. This gender inclusivity holds also true for Latvia's involvement in H2020 projects. 38 % of all eligible and 43% of all funded projects have been submitted by females.

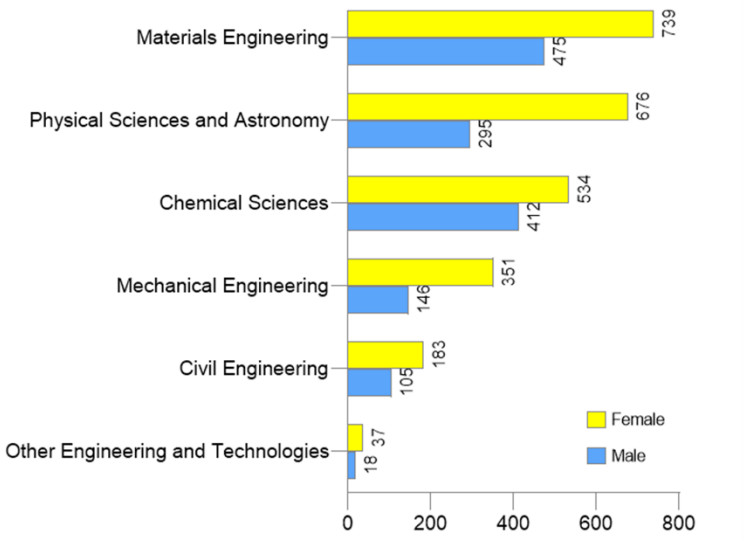

Figure 5.3: Research output by subject area and gender in Latvia; number of researchers with at least one publication by subject area and gender from 2014 to 2018.
Source: Web of Science

5.3.2. The future priorities of the Latvian R&D

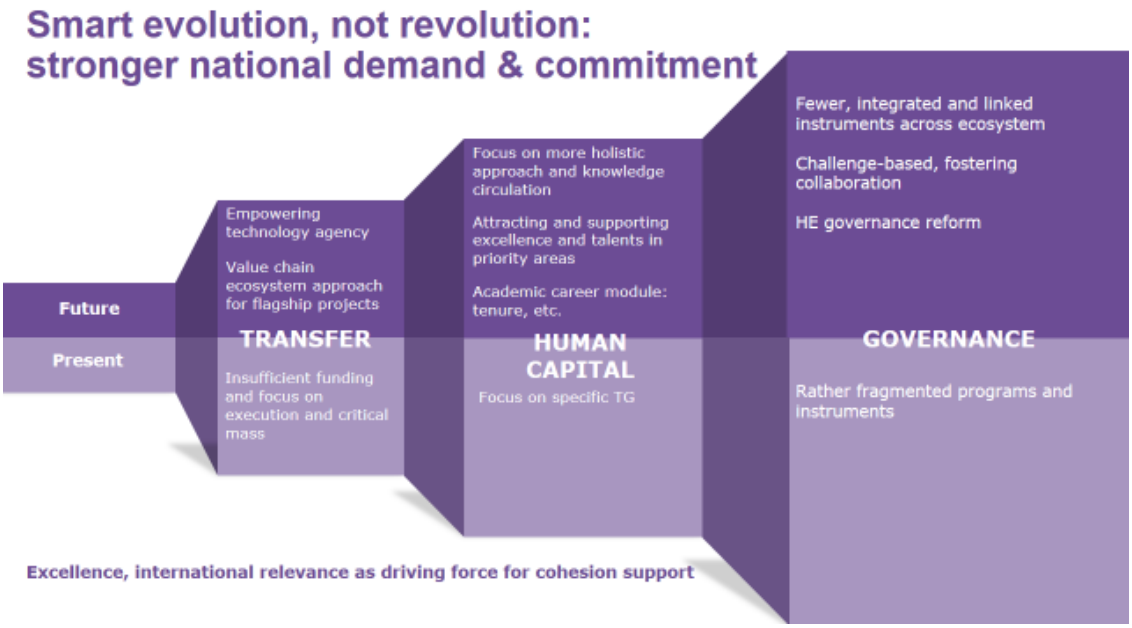

Figure 5.4: Present and future R&D priorities.

For the next planning period the main challenges facing the MoES are related to the human capital development for R&D. The public R&D investments will continue to be aligned with the five defined RIS3 specialization areas for which sufficient human capital development and further excellence development is needed to foster innovation ecosystems through global value chain approach. The five RIS3 priority areas for 2021-2027 will remain the same but a more detailed approach will be necessary for the next planning period.

5.4. The main actors: universities, institutes and national laboratories

In 2018, a goal as set to reduce the number of state-funded research institutions from 40 to 20 by 2020. This was done as a part of the Guidelines for the Development of Science, Technology and Innovation for 2014-2020. This goal has been nearly reached, with 21 institutions funded at the present date. At the moment, basic research funding is aligned with measures that promote resource concentration and consolidation, ie. precluding state funding for poorly evaluated research institutions.

RIS3 specialization area	Main research institutions
Knowledge intensive bio-economy	Latvia University of Life Sciences and Technologies; University of Latvia; Riga Technical University; Daugavpils University; Institute of Agricultural Resources and Economics; Institute of Horticulture; Latvian State Forest Research Institute "Silava"; Institute of Food safety; Animal Health and Environment "BIOR"; Latvian State Institute of Wood Chemistry; Latvian Institute of Aquatic Ecology; National Botanic Garden of Latvia;
Biomedicine, medical technologies and biotechnology	University of Latvia; Riga Stradins University; Riga Technical University; Latvian Biomedical Research and study centre; Latvian Institute of Organic Synthesis;
Smart materials, technology and engineering	University of Latvia; Riga Technical University; Institute of Solid-State Physics; University of Latvia;
Advanced IT	Riga Technical University; University of Latvia; Ventspils University College; The Institute of Mathematics and Computer Science; University of Latvia; Institute of Electronics and Computer Science;
Smart Energy	Riga Technical University; University of Latvia; Institute of Physical Energetics;

Table 5.3: Research institutions implementing research in each of the RIS3 specialisation areas.

5.5. The education in science and engineering

For the last 10 years, the number of students in Latvia has been on the decline. At the beginning of academic year of 2018/19, there were 80’400 students enrolled in the higher educational institutions,

which is 1.5% less than in the previous academic year. Moreover, it is 38.7% less than in academic year of 2005/06, when the student enrolment in Latvia peaked. In 2018/19, 33'200 study places, or 41.3% of the total number of those available, were funded from the state budget.

Due to the overall number of students decreasing, the proportion of those funded from the state budget is increasing over time. Taking into consideration the medium- and long-term labour market demand forecasts, in 2019, 57% of the state-funded study places were in industries aligned with the national priorities: natural sciences, engineering sciences, health care as well as in masters' and doctoral programs, which is important for the grooming of academic personnel and scientists. 41% of the state-funded study places are allocated for the STEM programs.

The country's is goal to improve the provision of modern equipment, facilities and technologies to the priority academic disciplines, such as the natural sciences, mathematics, IT, engineering, manufacturing and construction, and to make a rational use of the public and private funding.

To ensure a state-of-the-art academic and research environment for STEM programs, including healthcare and the creative industries, the EU funds are used - a total of 44.6 M EUR, including 37.9 M EUR funding from ERAF. At the same time, EU funding is used to support the improvement of the study environment in colleges for Level 1 professional higher education in STEM programs, including healthcare and creative industries. The total funding here is 14.2 M EUR, including 12 M EUR from ERAF.

In 2018, the implementation of six projects was completed, and 17 projects were ongoing. The project implementation will continue until December, 2022.

From 2014 to 2015, the total number of the bachelor and master students matriculated and graduated in STEM was 30'868 and 12'795, respectively (source: State Education Information System). The doctoral students matriculated and graduated in STEM in the same period was 1'105 and 405, respectively. RTU and UL are the two leading higher education institutions providing bachelors, masters, and doctoral studies in STEM.

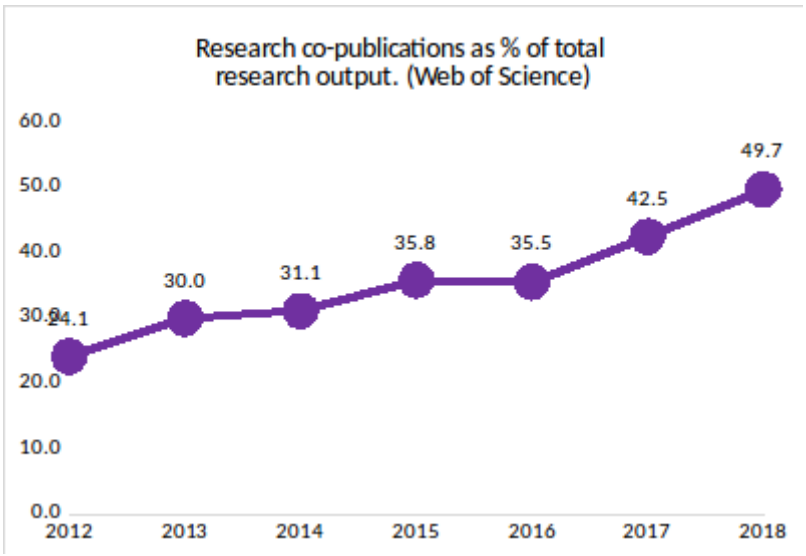

Figure 5.5: Research co-publications as a percentage of the total research output.
Source: Web of Science.

Despite of the decline in total number of graduates, the ratio of graduates in natural sciences and engineering remains relatively stable.

	2017	**2018**	**2019**
Total Graduates	15292	16250	12961
Natural sciences and Engineering* graduates	2872	2891	2479
Natural sciences and Engineering* graduates %	**19%**	**18%**	**19%**
Source: State Education Information System			

*Diplomas awarded in natural sciences, math and statistics, information technologies, engineering, architecture and construction, pharmacy

Table 5.4: The number of graduates in natural sciences and engineering.

Employees in knowledge-intensive sectors earn a significantly higher average hourly wage in Latvia. The number of jobs in these sectors is mostly growing showing a high demand in the respective sectors of the labour market.

Profession	**Average hourly rate, EUR**	**Number of jobs**	**Difference versus 2018**
Scientists, senior specialists in physics and Earth Sciences	10.8	3479	105%
Mathematicians, actuaries and statisticians	12.1	416	105%
Senior Specialists of Natural Sciences	9.5	800	100%
Engineers (excluding electro-technology engineers)	10.6	7900	100%
Electrical-technology engineers	10.8	2989	98%
Architects, planners, geodesia engineers and carthographers	8.9	3368	107%
Industrial pharmacists	9.2	13	93%
Chemical engineers	9.0	501	98%
Optometrists	9.1	221	108%
Information and Communication Technology Managers	22.7	1081	101%
Senior Specialists of Databases and Networks	14.3	5513	105%
Programmers and application makers/analysts	18.8	8441	109%
Latvian average	7.5		

Table 5.5: Hourly wage and number of positions in selected sectors.
Source: State Revenue Service of Latvia

5.6. International collaborations

Latvia has made enormous improvements over the last years regarding international collaborations. For example, according to the European Innovation Scoreboard, Latvia´s international scientific co-publication rate rose from 21.4% in 2010 to 75.5% of the EU level in 2016. The number of foreign doctoral in the country shows a similar trend. In 2010, this number stood at 2.3% of the overall EU level, but this rose to 36.9% by 2016 (European Commission, 2017). According to the Guidelines for Science, Technology Development and Innovation 2014-2020, internationalisation of science and international cooperation is one of the top priorities in the Latvian research and innovation policy. The

MoES has addressed this strategic goal by implementing a large number (71) of activities and programmes in order to support research internalisation and deeper integration into the European Research area. A selection is given below:

- "Support to international cooperation projects in research and innovation", discussed in Section 5.1., promotes Latvia's participation in the EU research and technology development programmes (HORIZON 2020, Joint Programming initiatives, and activities under Article 185 and 187). Furthermore, a state budget programme was designated to support the participation of Latvian entities in the EU research and development programmes with annual funding of €1.5-5 M;
- Bilateral collaboration has been implemented with Belarus, Taiwan and Lithuania. In the beginning of 2016, a collaboration programme with Ukraine in the fields of science and technology was launched;
- The participation of Latvian groups in the European Space Agency (ESA) projects receives an annual funding of €1.4 M;
- The Cabinet of Ministers has approved Latvia's participation in eight prior consortia and platforms of the ESFRI Roadmap;
- Future plans include joining five EU Joint Programming Initiatives, CERN and ESA, as well as the enhancement of bilateral co-operations (China, Baltic states).

Apart from these concrete support schemes, peer review, project selection and monitoring have largely been aligned to European standards, mainly H2020, both in terms of criteria, processes and experts involved. Moreover, the progress in internationalisation has been made through the support of H2020 projects with a seal of excellence under the ESIF, if the project proposal has reached threshold, but was not financed due to insufficient funds.

Overall, the H2020 results of Latvian research institutions, compared to other EU countries, are very good. This is the first framework programme where our benefits are higher than our financial contribution in the programme. We currently have attracted more than 80 M EUR funding from H2020 and we expect that our overall European Commission investments will reach approx. 90 M EUR before the end of 2020. Latvia has one of the highest return rates in the H2020 programme. In 2016, it accounted for approx. 10% of all R&D funding, showing that this programme is directly tied to our R&I system. Highest impact from the H2020 programme is through widening on the existing activities (CAMART2 and BBCE). In addition, Latvia's results in the Industrial Leadership and Societal Challenges pillars are good.

	FP5 1999-2002	**FP6 2002-2006**	**FP 7 2007-2013**	**H2020 2014-2019***
Total project proposals	**667**	**1027**	**1127**	**2385**
Total project participation proposals	776	1206	1424	2961
Supported projects	**178**	**217**	**240**	**325**
Participations in supported projects	204	258	337	409
Coordinated projects	**2**	**11**	**30**	**44**
Success rate	26.7%	21.1%	21.3%	13.4%
Total EC funding (M EUR)	**14.6**	**21.6**	**49.04**	**81.55**

Table 5.6: Latvia's key performance indicators in European Union framework programmes.

Latvia has seen a noticeable increase of international collaboration for our researchers in recent years, mostly due to our participation in H2020 activities and partnerships. It is great that this increase is both in total volume and as a part of our R&I system. It can also be seen that the country's innovation performance is outgrowing its financial investment rate in R&D. That means that Latvia's overall R&D productivity has considerably improved in the recent years. EU countries are the main partners for Latvian researchers, however, in recent years, the USA, as well as a number of Asian and South-American countries, have also become important partners for scientific and research cooperation. Germany is the leading collaboration partner for Latvia in research. In the past 5 years Latvia has 1'744 co-publications with Germany, which is 17% of the total publication count. Moreover, since 2012, there has been a notable increase in collaboration with the European innovation leader – Sweden (European Innovation Scoreboard, 2019), accounting for 13% of the total publications by Latvian researcher institutions in 2019.

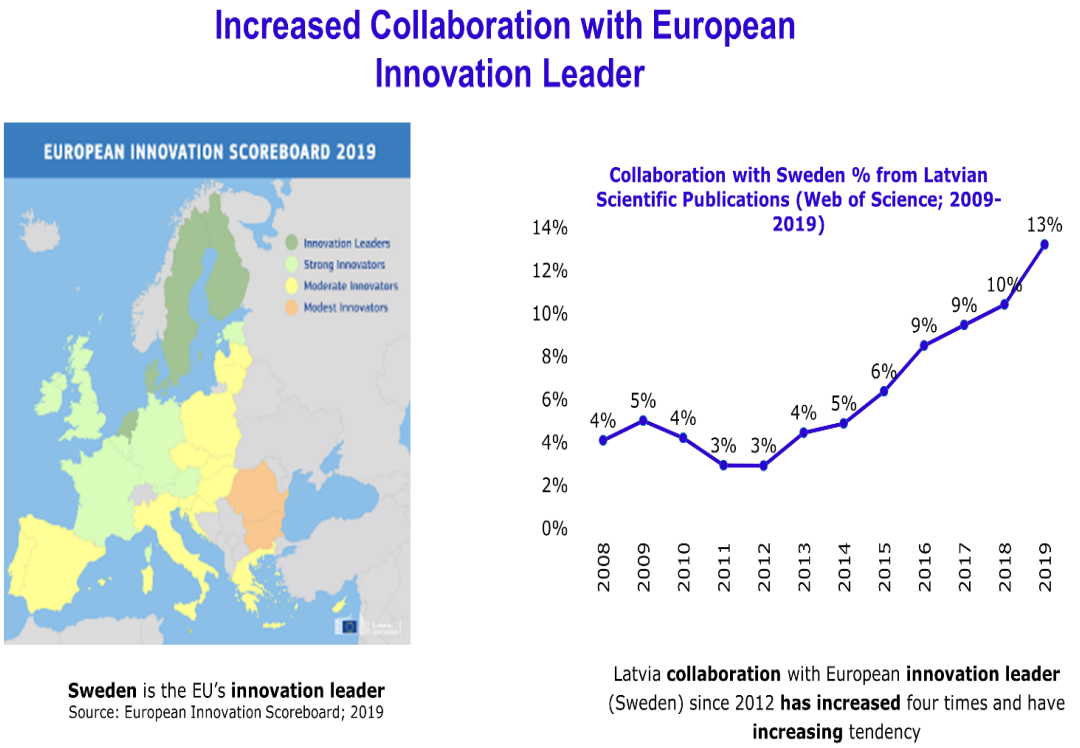

Figure 5.6: Increased collaboration with European innovation leader.

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