Roadmap for Finnish Research Infrastructures 2021–2024

ACADEMY OF FINLAND

Contents

Cover image
Earth-Space Research Ecosystem (E2S) radar
at Tähtelä measurement station.
Photo: Timo Rantala.

1. Introduction

Finland's first national roadmap for research infrastructures was published in 2009. Since then, research infrastructures have become increasingly important in research, development and innovation activities both in Finland and around the world. Research infrastructures are built to enable research that could not be carried out without infrastructures in areas such as the environment, health, physical sciences, society or data and computing sciences.

The aim of the Research and Innovation Council is that Finland will be the most attractive and competent environment for experimentation and innovation in 2030 and that the share of research, development and innovation (RDI) will increase to 4% of GDP. Research infrastructures play an important role in building innovative and inspiring research and development environments and utilising research results not only in science but also in society at large. For example, in the fight against the coronavirus pandemic, international and national research infrastructures have played a major role in supporting the development of vaccines, monitoring the disease situation and preparedness. In addition to international and national research infrastructures, the role of local and regional research infrastructures in RDI activities is also becoming more important.

Research infrastructures have a long lifecycle, which is why sufficient resources are needed for their construction, development, use and dismantling throughout the lifecycle. Resources should be allocated to the construction and operation of the most high-quality and effective research infrastructures in order to maximise the benefits of the available funding. This requires a strategic systematic approach and long-term commitment to the activities.

The Academy of Finland opened a roadmap call 2021–2024 on the basis of the Strategy for National Research Infrastructures 2020–2030 and the Sustainable Growth Programme for Finland. The previous national roadmap for research infrastructures was published in 2014. Updating the roadmap is one of the measures of the National Roadmap for Research, Development and Innovation, and it contributes to the development of the RDI partnership model.

The growing importance of research infrastructures is reflected in the increasing interest of actors to participate in the construction and operation of international and national research infrastructures. When comparing the roadmap for Finnish research infrastructures 2021–2024 with the roadmap for 2014–2020, it is noticeable that the network of research infrastructure owner organisations has clearly intensified and diversified as the number of research organisations that own roadmap infrastructures has increased.

Although the objective of each research infrastructure is to support RDI activities in its own field, research infrastructures and their development also have common features, such as issues related to digitalisation and data, and the impact of research infrastructures on the green transition. These were taken into account when selecting research infrastructures for this roadmap.

The measures to support the green transition described by the research infrastructures that were selected for the roadmap were usually related to research data produced by the research infrastructure and its applications as well as to the possibilities for remote use of the research infrastructure. Additionally, many research infra-

structures consider efficiency, versatility and recyclability in their equipment purchases. The policies of owner organisations, including the principles related to measuring and reducing the carbon footprint, will be important in guiding the operation of research infrastructures during the green transition.

As the landscape of research infrastructure diversifies and the significance of research infrastructures increases, it is even more important that, in addition to high-quality service production, the ownership, financial responsibilities and development plans of each infrastructure are clear and genuinely support the everyday life of the research infrastructure. This will maximise the benefits of investments in research infrastructures throughout their lifecycle.

The development of research infrastructures is about significant choices and investments. The task of the Finnish Research Infrastructure Committee (FIRI Committee) is to monitor and develop national and international research infrastructure activities in Finland. The task includes evaluating Finnish research infrastructures, selecting the best projects and co-financing them. According to data from roadmap applications, research infrastructures selected for the roadmap for 2021–2024 have been funded from different sources by a total of EUR 1 billion between 2015 and 2019. Research organisations have accounted for more than 60% of total funding. The estimated total funding need for the research infrastructures on the roadmap for 2020–2030 is EUR 2.7 billion.

Based on international peer reviews, the FIRI Committee supports the construction and upgrading of research infrastructures by EUR 20 million annually. Membership fees for interna-

tional research infrastructures are also funded through the Academy of Finland every year by approximately EUR 20 million. Additionally, one-off funding of approximately EUR 100 million has supported Finland's participation in EuroHPC activities and the construction and development of national and local research infrastructures on the basis of the Recovery and Resilience Plan that is part of the Sustainable Growth Programme for Finland.

This report presents 29 research infrastructures selected by the FIRI Committee for the Roadmap for Finnish Research Infrastructures 2021–2024. The report also describes the national and international landscape of research infrastructure that is important for Finland in a broader sense. Research infrastructures and their networks support high-quality and high-impact RDI activities locally, nationally and internationally.

2. Finnish research infrastructures in the 2021–2024 roadmap and memberships of international research infrastructures

Definition of a national research infrastructure

A national research infrastructure is a research infrastructure of national and/or international importance that promotes the quality of research and education. A national research infrastructure also has an impact on business life and society as a whole. The ownership and organisational structure of a national research infrastructure are clear, and the key competence needs of the management and personnel are known. A national research infrastructure must have a long-term plan for the maintenance and development of services. The services and data produced by the research infrastructure must be openly accessible. A national research infrastructure must consider the change needs created by digitalisation and data intensity in its operations. A national research infrastructure must consider the sustainable development goals in its operations. The funding base of a national research infrastructure must be sustainable and cannot rely too much on competitive funding from the Academy of Finland.

The roadmap for Finnish research infrastructures defines the significant national research infrastructures that are part of the Finnish ecosystem. The roadmap document also lists international research infrastructures to which Finland has joined through treaties or other agreements. The Finnish research infrastructures and international memberships of the roadmap 2021–2024 are listed in Table 1. The research infrastructures selected for the roadmap represent service packages that meet the criteria for national research infrastructures that have been prioritised on the basis of an international peer review. The roadmap provides a good basis for many strategic decisions concerning the development of research infrastructures, such as Finland's membership in international research infrastructures. The roadmap also serves as a basis for planning and prioritising long-term infrastructure investments.

One of the characteristics of a national research infrastructure is that it is of broad national interest and has international impact. A national research infrastructure must have a long-term plan for maintenance, funding and use as well as a broad user base. A national research infrastructure is used for high-quality research, and it must be open and accessible to all researchers. The data produced using it follows the principles of open science or strives systematically towards them. National research infrastructures are so extensive that individual research groups cannot manage them themselves. A national research infrastructure uses the latest available technology (Figure 1). The research infrastructures in the Finnish roadmap for 2021–2024 are presented in Chapter 6. For a more detailed list of international memberships, see Chapter 4, Table 2.

Figure 1. Characteristics of a national research infrastructure.

Finland's national roadmap research infrastructures		Finland's memberships in international research infrastructures
Research infrastructure	Abbreviation	
Biosciences and health		
Biobanking and Biomolecular Resources Research Infrastructure of Finland	BBMRI.fi	BBMRI-ERIC
Biocenter Finland	BF	EATRIS
European Life-Science Infrastructure for Biological Information	ELIXIR Finland	ELIXIR
"Euro-BioImaging: Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences"	EuBI-Fi	EMBL sis. EMBC
European Infrastructure of Screening Platforms for Chemical Biology	EU-OS FI	EU-OPENSCREEN
Integrated Structural Biology Infrastructure	FinStruct	Euro-BioImaging
		INFRAFRONTIER
		Instruct-ERIC
Data and computational sciences		
CSC's Research Infrastructure Services	CSC	EuroHPC JU
Partnership for Advanced Computing in Europe	EuroHPC/PRACE Finland	IML
Finnish Computing Competence Infrastructure	FCCI	NeIC
Finnish Quantum Computing Infrastructure	FiQCI	PRACE
Research Infrastructure for Future Wireless Communication Networks	FUWIRI	
Physical sciences, engineering and energy		
ALD center Finland	ALD center Finland	CERN
Bioeconomy Infrastructure	BIOECONOMY RI	EFDA-JET
Finnish National Infrastructure for Light-Based Technologies	FinnLight	ESA
Accelerator Laboratory of the University of Jyväskylä	JYFL-ACCLAB	ESO
Otaniemi Micro- and Nanotechnology Research Infrastructure	OtaNano	ESRF
Printed Intelligence Infrastructure	PII	FAIR
RawMatTERS Finland Infrastructure	RAMI	ITER
		JHR MTR
		MAX IV
Social sciences and humanities		
European Social Survey (ESS)	ESS Finland	CESSDA
Common Language Resources and Technology Infrastructure	FIN-CLARIAH	CLARIN
Finnish Research Infrastructure for Population Based Surveys	FIRI-PBS	ESS
Finnish Infrastructure for Public Opinion	FIRIPO	
Finnish Social Science Data Archive & CESSDA ERIC's Finnish Service Provider	FSD	
Environmental sciences		
Earth-space research ecosystem	E2S	EISCAT (+3D)
Finnish Biodiversity Information Facility	FinBIF	EURO-ARGO ERIC
European Plate Observing System	FIN-EPOS	GBIF
Finnish Marine Research Infrastructure	FINMARI	ICDP
Integrated Atmospheric and Earth System Science Research Infrastructure	INAR RI	ICOS
Measuring Spatiotemporal Changes in Forest Ecosystem	Scan4est	IODP

3. Development of national and international research infrastructure landscape

The Finnish research infrastructure landscape has achieved its current state over several decades. Finland concluded the first treaties on research infrastructures in the 1980s and 1990s (EMBL and CERN). Since the Second World War, research in physics and space have been some of the strongest builders and users of research infrastructures. With the help of very large and expensive hardware sets, it has been possible to focus on topics that we could not study before. The investment and maintenance costs of such research infrastructures are very high and therefore their co-financing has been agreed upon at the national level. With the development of technology and science, the role of research infrastructures has also grown strongly in biotechnology, medicine and environmental research. Cultural and social research also benefits from extensive, multinational research infrastructures and data resources. Therefore, strategies and roadmaps for research infrastructures have been produced to support decision-making both in the EU and in many countries (Figure 2).

Milestones in developing research infrastructure activities

Finnish Research Infrastructure Committee established in 2014

Strategy for National Research Infrastructures in Finland 2020–2030

FIRI expert group 2012–2014

RIC recommendation to launch RI activities 2011

Roadmap for National Research- Infrastructures in Finland 2021–2024

Finland's Strategy and Roadmap for Research Infrastructures 2014–2020

Finland's first RI roadmap 2009

Finland's Strategy and Roadmap for Research Infrastructures 2014–2020 (interim review 2018)

Finland joins CERN in 1991

ESFRI 2018 roadmap

ESFRI 2021 roadmap

Finland joins EMBL in 1984

ESFRI 2016 roadmap

EMBL established in 1974

ESFRI 2010 roadmap

ESO established in 1962

Finland joins ESO in 2004

ESFRI 2008 roadmap

CERN established in 1955

The first ESFRI 2006 roadmap

Figure 2. Stages of the development of research infrastructure activities in Europe and Finland.

Diverse impact of research infrastructures

Successful scientific breakthroughs and innovations require multidisciplinary and multiparty cooperation, networking and structures, such as the development of new types of research infrastructures. The fast-paced development of science and technology today opens up opportunities for new sustainable solutions that respond to global challenges.

The services provided by research infrastructures play an important role, not only in enabling the work of researchers and achieving scientific results and breakthroughs, but also in society at large. They play an important role in promoting digitalisation and achieving the sustainable development goals, strengthening economic renewal and developing education (Figure 3).

Today, Finland's landscape of research infrastructures is diverse and largely based on the needs of high-quality research. It includes international, national, local and regional research, development and innovation (RDI) infrastructures (Figure 4).

Figure 4. Research infrastructures are important for Finnish research, development and innovation activities locally, regionally, nationally and internationally.

Figure 3. Research infrastructures offer diverse services for the development of competence and society.

Strategy for national research infrastructures

Provisions on the Finnish Research Infrastructure Committee are laid down in the Act on the Academy of Finland. According to the Act, the task of the Finnish Research Infrastructure Committee (FIRI Committee) is to monitor and develop national and international research infrastructure activities, to submit a long-term plan for research infrastructures to the Academy Board, to decide on the funding of research infrastructure projects and to monitor funded projects, and to take care of the research infrastructure tasks assigned by the Academy Board.

A ten-year strategy for national research infrastructures was published in 2020. The vision of the strategy is that high-quality research infrastructure services increase the impact and international attractiveness of the Finnish research, education and innovation system. In order to achieve the vision, the quality, renewal and competitiveness of research will be promoted, the diverse impact of research environments will be strengthened, and national and international cooperation will be increased through six development areas.

Based on the strategy, the FIRI Committee will open roadmap and funding calls and, together with other actors, develop national and international research infrastructure activities in the coming years.

The research infrastructure has a long lifecycle and includes many different phases from planning to termination (Figure 5). Lifecycle thinking requires the ability to understand the responsibilities of actors and the role of different funding sources at different stages of the lifecycle. The amount and quality of sup

port required for the research infrastructure varies depending on the stage of the lifecycle.

One of the objectives of the strategy term is to clarify what ownership of research infrastructures means, what are its characteristics and which kinds of rights and obligations are associated with ownership (ownership of research infrastructures, in Finnish). Research organisations promote the construction, development and maintenance of strategically important research infrastructures for them systematically, proactively and in cooperation with various stakeholders.
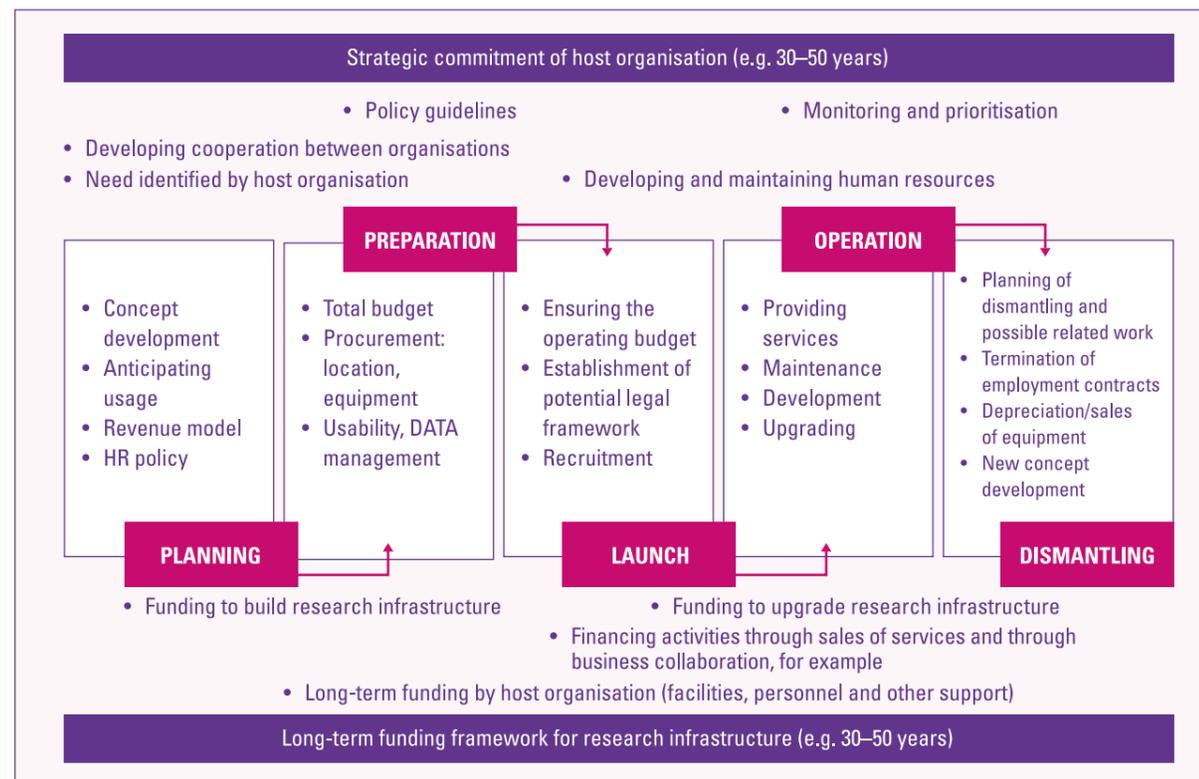

Figure 5. The lifecycle of a research infrastructure and typical activities related to its phases.

Funding of national research infrastructures

Research infrastructures are an integral part of a high-quality, dynamic and internationally attractive RDI environment. Long-term, diverse research infrastructure services require a stable funding base that extends beyond government terms. Research infrastructures are funded through various channels, which include, for example, their host organisations, research funders, ministries, the EU and the users of research infrastructure services. A stable funding base requires proactive and versatile revenue logic and long-term financial planning from parties maintaining the research infrastructures.

The Strategy for National Research Infrastructures 2020–2030 addresses the "FIRI funding" distributed through the Finnish Research Infrastructure Committee within the framework of the "Long-term perspective and responsibility" development area. During the strategy term, the aim is to produce collaborative models and incentives to support research infrastructure actors for long-term but also dynamic technology and financing solutions as well as for expanding the funding base. The development work must consider the financial perspectives that exceed government terms. The FIRI Committee has published a policy describing the Academy of Finland's research infrastructure funding (FIRI funding, in Finnish)

The primary role of the FIRI Committee in the funding of research infrastructures is to identify and select the best research infrastructures that Finnish RDI activities will need in the next 10 to 15 years. The objective of the Committee's research infrastructure funding is to promote the quality, renewal and competitiveness of research, strengthen the diverse impact of research environments and increase the amount of national and international cooperation. The funding is divided into project type funding and membership fee funding of international research infrastructures.

In the form of project funding (FIRI funding), the FIRI Committee supports the construction or upgrading of research infrastructures by EUR 20 million a year. FIRI funding is not intended for the running, maintenance or permanent operating costs of a research infrastructure. The funding base for the research infrastructures to be funded must be sustainable and the funding plan must be long-term. Funding for research infrastructure should not rely too much on competitive funding granted by the Academy of Finland. FIRI funding is always based on international peer reviews and competition. No separate portion has been reserved for international memberships. Additionally, the Finnish Parliament has granted a total of about EUR 100 million in one-off funding to research infrastructures through the Academy of Finland. These funds have supported Finland's participation in EuroHPC activities, and they have constituted targeted support for the construction and development of national and local research infrastructures on the basis of the Recovery and Resilience Plan that is part of the Sustainable Growth Programme for Finland.

Together with other funders, the FIRI Committee has funded the national research infrastructures of the roadmap by a total of EUR 1 billion between 2015 and 2019. Research organisations have accounted for more than 60% of total funding. The estimated total funding need for the research infrastructures on the roadmap for 2020–2030 is EUR 2.7 billion (Figure 6). The Finnish Parliament has also granted the Academy of Finland a funding of approximately EUR 20 million annually to cover membership fees of certain international research infrastructures.

FIRI funding also supports infrastructure projects that are not on the national roadmap. They have laid the foundation for internationalisation and developed new services for many fields of research.

Figure 6. Funding for national research infrastructures is based on co-financing. The data is based on applications from the national research infrastructures selected for the roadmap.

4. International research infrastructure memberships

Finland's membership in international research infrastructures is an integral part of the Finnish landscape of research infrastructures (Table 2). Finland is currently a member of 30 international research infrastructures. They provide Finnish scientific and business communities with the opportunity to use research infrastructure services that could not be offered by Finnish means alone. International research infrastructures are a collaborative platform for international RDI activities, and they can be used to implement cooperation and scientific diplomacy between different countries. The Academy of Finland pays most of the membership fees arising from Finland's participation in international research infrastructures.

Finland hosts three international research infrastructures: ICOS, Euro-BioImaging and LUMI. ICOS (Integrated Carbon Observation System) is a research infrastructure for greenhouse gas observation, Euro-BioImaging is a biological imaging research infrastructure and LUMI is a supercomputer located in CSC's data centre in Kajaani. Upon completion in 2022, LUMI will be Europe's fastest and the world's third fastest supercomputer. Finland is also prepared to host the ACTRIS research infrastructure (Aerosol, Clouds and Trace Gases Research Infrastructure). ACTRIS produces information on aerosols, clouds and trace gases. All the above-mentioned research infrastructures have been built with co-financing from the EU and European countries.

Table 2. The table lists 30 international research infrastructures in which Finland is a member by sector (situation in 2021). The table does not include AnaEE ERIC, which was established in 2022 and to which Finland joined as a founding member. EuroHPC includes the LUMI supercomputer. (TEM: research infrastructures whose membership fee is paid by the Ministry of Economic Affairs and Employment; LVM: research infrastructures whose membership fee is paid by the Ministry of Transport and Communications).

Biosciences and health (8)	E-research infrastructures and mathematics (4)	Physical sciences, engineering and energy (9)	Social sciences and humanities (3)	Environmental sciences (6)
BBMRI-ERIC Biobanking and Biomolecular Resources RI	**EuroHPC JU** European high performance computing	**CERN** European Organization for Nuclear Research	**CESSDA** Consortium of European Social Science Data Archives	**EISCAT (+3D)** European Incoherent Scatter Association
EATRIS European Advanced Translational Research Infrastructure	**IML** Mittag-Leffler Institute	**EFDA-JET** Joint European Torus, TEM	**CLARIN** Common Language Resource and Technology Infrastructure	**EURO-ARGO** ERICEuropean contribution to the ARGO Program, LVM
ELIXIR European life science infrastructure for biological information	**NeIC** Nordic e-Infrastructure Collaboration	**ESA** European Space Agency, TEM	**ESS** European Social Survey	**GBIF** Global Biodiversity Information Facility
EMBL incl. EMBC European Molecular Biology Laboratory	**PRACE** Partnership for Advanced Computing in Europe	**ESO** European Southern Observatory		**ICDP** International Continental, Scientific Drilling Program
EU-OPENSCREEN European high-capacity screening network		**ESRF** European Synchrotron Radiation Facility		**ICOS** Integrated carbon observation system (Hosting country)
Euro-BioImaging European Research Infrastructure for biomedical Imaging (Hosting country)		**FAIR** Facility for Antiproton and Ion Research		**IODP** Integrated Ocean Drilling Program
INFRAFRONTIER The European Infrastructure for phenotyping and archiving of model mammalian genomes		**ITER** International Thermonuclear Experimental Reactor, TEM		
INSTRUCT-ERIC Integrated Structural Biology Infrastructure		**JHR MTR** Jules Horowitz Materials Testing Reactor, TEM		
		MAX IV Synchrotron Radiation Facility		

International agreements

The operation of national research infrastructures often involves international cooperation as well, which is usually defined by agreements. Agreements set boundary conditions for ownership and define ownership objectives. International research infrastructure memberships are based on agreements between states or organisations. The accession of the State of Finland to an international research infrastructure takes place by decision of the Government. Finland has joined international organisations such as CERN, and several European Research Infrastructure Consortia (ERIC), with a Government decision. Additionally, international research infrastructures are established through other agreements in which the parties are, for example, the host organisations of the research infrastructure, not the State of Finland.

Funding for international research infrastructures consists of membership fees, Member States' self-financing contributions and external funding, such as EU funding. In Finland, the funding is organised in cooperation between the parties. The Academy of Finland may undertake to pay the membership fee (usually for five years at a time) and the organisations hosting the research infrastructures will bear the other costs in a manner agreed between them. Organisations can also apply for funding from the Academy of Finland's research infrastructure calls (FIRI) for constructing or upgrading a research infrastructure. Access to FIRI funding is always based on international peer reviews and competition, and there is no reserved share for international infrastructures.

In spring 2020, the benefits of international research infrastructure membership for Finland were mapped out. The survey was prepared in cooperation with the Swedish (Vetenskapsrådet) and Dutch (NWO) sister organisations of the Academy of Finland. The joint survey was sent to research infrastructures in which each country is a member. The survey was used to collect information on personnel, publication volumes, cost structure and training offered by the research infrastructure. A total of 26 research infrastructures in which Finland is a member participated in the survey. Data was collected for 2016–2019.

Based on the survey, research infrastructures play an important role as employers and creators of new career paths. The maintenance of research infrastructures requires scientific, technical, administrative and financial expertise. The European Commission has provided training for research infrastructure personnel, including through framework programme funding. Know-how is also one of the devel-opment areas of the Strategy for National Research Infrastructures in Finland 2020–2030. Funded projects are used to monitor the development of competence in research infrastructures operating in Finland. Based on the survey targeted at international research infrastructures, research infrastructures employ more than 7,000 people, of whom approximately two per cent are Finns (Figure 7).

Research infrastructures are used by both public and private actors. Users may be individuals or research groups using the service provided by the research infrastructure physically on-site or remotely. The service portfolio of most research infrastructures also includes the sharing of data. In this case, access is registered using, for example, an IP address or login. Based on the survey targeted at international research infrastructures, they had 20–28 million users each year in 2016–2019. The annual number of Finnish users varied by research infrastructure from 60,000 to 150,000 (Figure 8).

Number of employees in international research infrastructures

98%

7,177

2% 172

■ Others
■ Finns
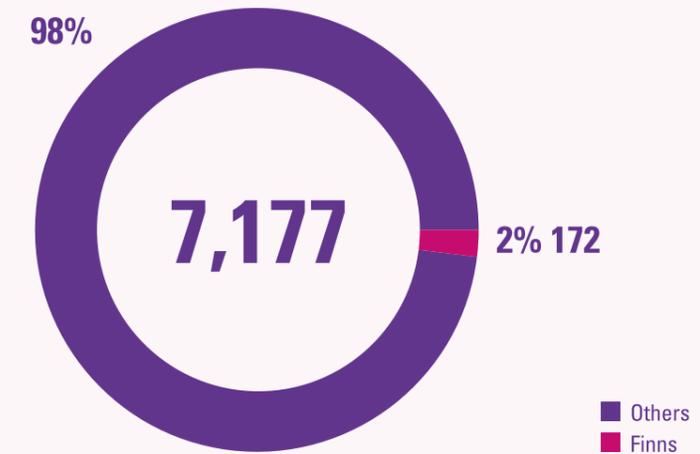
Figure 7. The number of employees working in the research infrastructures targeted by the survey. The number stands for the number of employees in 2019.

Number of users

■ All countries
■ Finland

	2016	2017	2018	2019
All countries	27,728,544	20,590,701	20,963,674	25,949,959
Finland	96,021	63,300	106,167	153,328
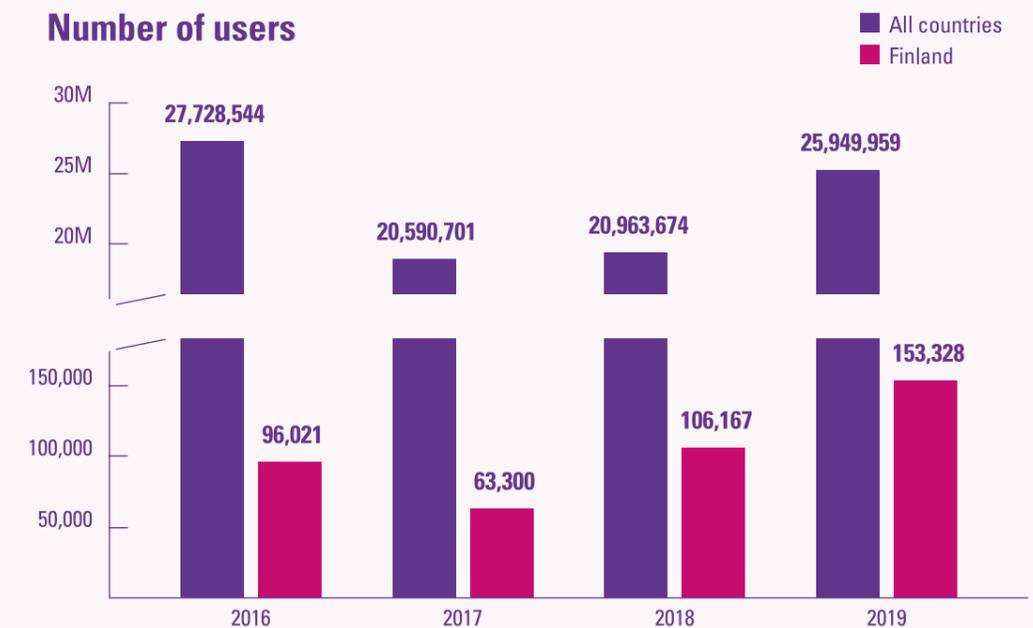
Figure 8. Number of users in international research infrastructures in 2016–2019.

Ministry of Education, Science and Culture (Academy of Finland) and Ministry of Economic Affairs and Employment finance membership fees for international research infrastructures (e.g., CERN and ESA, see also Table 1) annually by approximately EUR 40 million. Finland also promotes the construction of European High Performance Computing (EuroHPC) with significant investment.

Table 3 presents Finland-specific key figures for 24 international research infrastructures. The data is based on the survey conducted in 2020 in cooperation with the Swedish (Vetenskapsrådet) and Dutch (The Dutch Research Council NWO) sister organisations of the Academy of Finland.

Table 3. The table lists the membership fees for the international research infrastructures that are paid by the Academy of Finland.

International research infrastructure	Years	Finland's membership fees (€1,000)	Finland's proportion of membership fees (%)	"Total income from membership fees (€1,000)"	Total budget (€1,000)	Share of membership fee income from total budget (%)
BBMRI-ERIC	2016–2019	202	3%	7 623	9 741	78%
CERN	2017–2019	40 057	1,20%	3 220 223	3 565 260	90%
CESSDA	2016–2019	29* (2017-2019)	0,50%	7 768	8 343	93%
CLARIN	2016–2018	82	3%	3 194	3 406	94%
EATRIS	2016–2018	350	8%	4 206	5 122	82%
EISCAT (+3D)	2016–2018	1 125	6%	19 421	19 471	99,70%
ELIXIR	2016–2018	232	1,50%	15 682	18 739	84%
EMBL	2016–2018	4 290	1,30%	321 153	723 00	44%
ESO	2016–2019	9 467	1,20%	815 897	895 316	91%
ESRF	2016–2018	2431	0,9%	277 146	368 550	71,70%
ESS	2017–2018	94	2%	5 433	6 166	88%
EU-OPENSCREEN	2018	62	7%	948	1 114	85%
Euro-BioImaging	2019	0	0%	617	617	100%
FAIR	2016–2019	23* (only 2019)	0,01%	641 746	642 388	99,90%
GBIF	2016–2019	269	N/A	N/A	N/A	N/A
ICDP	2016–2019	104	0,80%	12 872	14 654	88%
ICOS	2017–2018	139	0,50%	29 631	48 984	60%
IML	2018	50	5%	1 043	1 661	63%
INFRAFRONTIER	2018–2019	61	N/A	N/A	N/A	N/A
Instruct-ERIC	2016–2019	79	2%	3 503	4 256	82%
IODP	2016–2019	279	0,50%	61 782	104 333	59%
MAX IV	2017–2019	729	0,70%	111 282	111 756	99,60%
NeIC	2016–2018	1 096	N/A	N/A	13 735	N/A
PRACE	2016–2019	611	N/A	N/A	N/A	N/A

5. Roadmap for national research infrastructures 2021–2024

Based on the Strategy for National Research Infrastructures in Finland 2020–2030, the Academy of Finland opened a roadmap call in 2020. The roadmap for national research infrastructures is part of the measures in the National Roadmap for Research, Development and Innovation (RDI) and it contributes to supporting the new partnership model.

29 research infrastructures were selected for Finland's national roadmap for 2021–2024. When making roadmap decisions, the expected impact of the research infrastructure on national and international research infrastructure activities and national perspectives were considered, for example in the development areas mentioned in the Strategy for National Research Infrastructures in Finland 2020–2030. In addition to strategic development objectives, the decisions were also based on the results of international peer reviews, the strategic commitment of research organisations and the statements of the Academy of Finland's scientific committees.

The research infrastructures selected for the roadmap are located in several different branches of science (Figures 9 and 10).

Figure 9. A word cloud created based on the branches of science designated by research infrastructures. They could name 1 to 5 branches in the application. Although some broad fields, such as chemistry or ecology, are generally represented in the scientific spectrum of research infrastructures, the roadmap's research infrastructures also support a wide range of different branches of science in Finland.
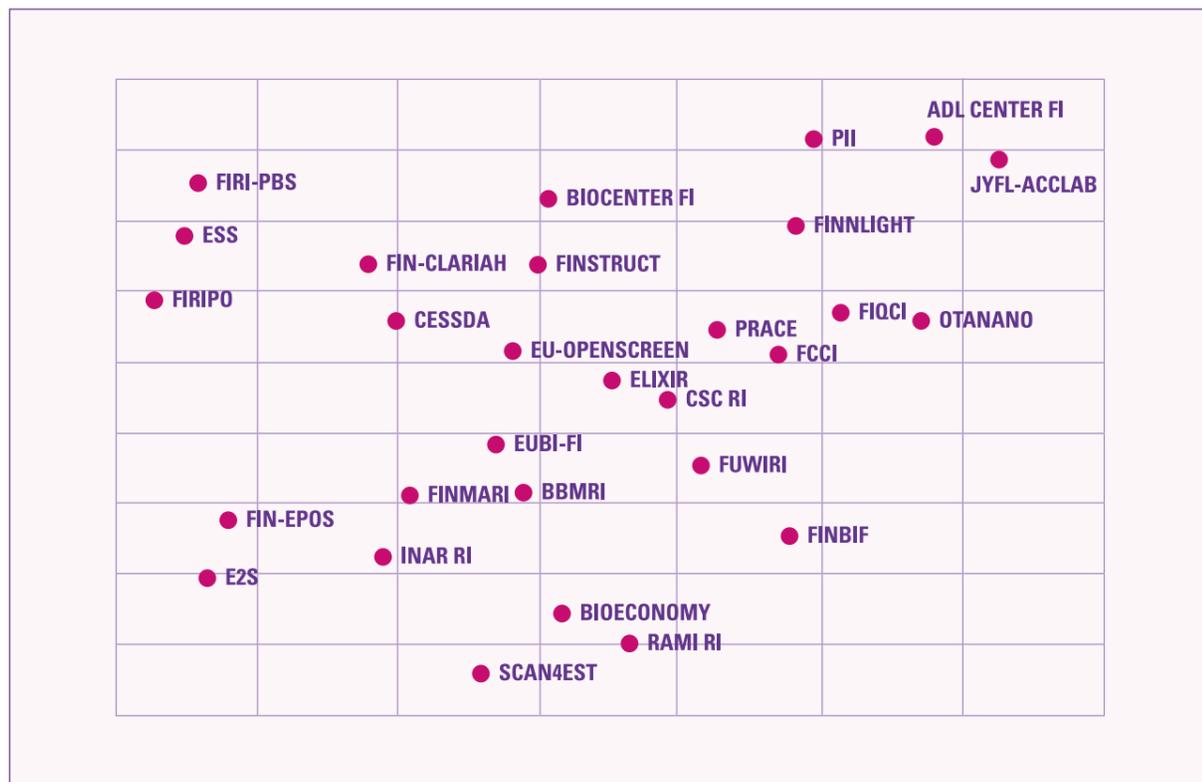
Figure 10. The roadmap's research infrastructures are placed in the figure based on the research field data listed in the roadmap application. They could name 1 to 5 branches in the application. The more research areas two research infrastructures have in common in their roadmap applications, the closer the research infrastructures are to each other in the figure. When interpreting distances, it should be noted that the sample size is 29. The image is therefore only indicative.
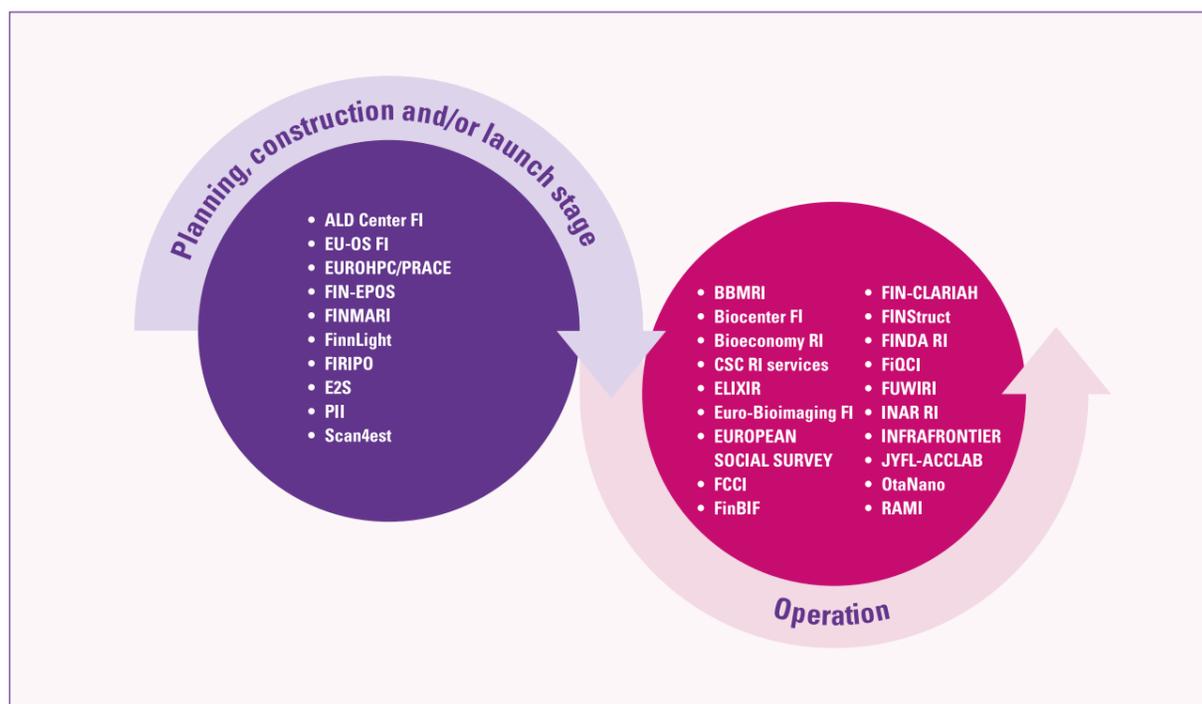
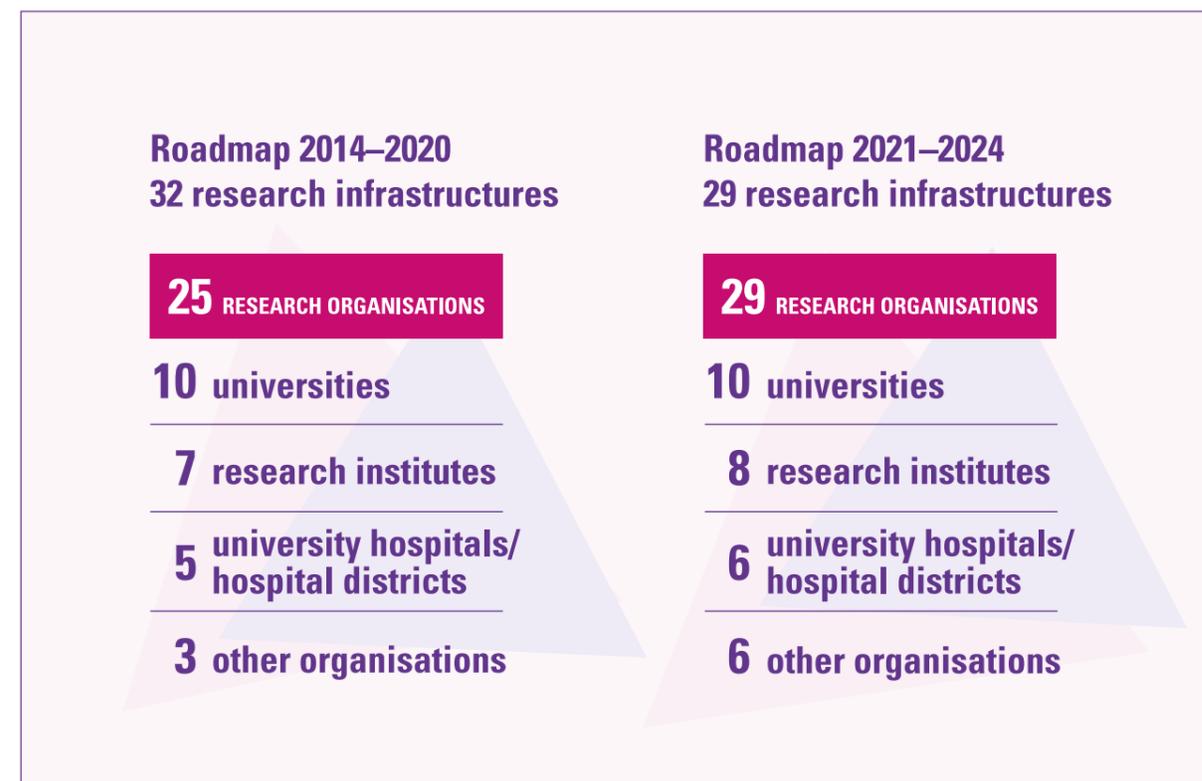**Figure 11.** The roadmap's research infrastructures broken down by lifecycle phase. The research infrastructures have themselves defined their lifecycle phase in the roadmap application.

Ten of the research infrastructures selected for the roadmap are in the construction or start-up phase and 19 are in the operational phase (Figure 11). Ten of the national roadmap research infrastructures belong to international research infrastructure networks in which Finland is a member at the state level.

Cooperation between research infrastructure owner organisations increased during the roadmap term 2014–2020. The 32 research infrastructures on the roadmap published in 2014 were owned by 25 different research organisations, while the 29 research infrastructures of the current roadmap are owned by 30 research organisations (Figure 12).

Figure 12. The number of organisations owning research infrastructures has increased even though the number of research infrastructures on the roadmap has decreased.

When examining the number of connections between research organisations, there is a significant increase in connections between roadmap terms, while there are five more owner organisations of research infrastructures (Figure 13). When examining the number of organisations, it is also a good idea to consider changes in their structures, such as the merger of the University of Tampere and the Tampere University of Technology.

Roadmap 2014–2020

HY · OY · SYKE · TAYS · HYKS · KYS · TK · AALTO · ÅA · LUT · TY · IL · GL · KSSHP · TAY · THL · TTY · MML · PPSHP · ISY · JY · GTK · CSC · KA · VTT

Roadmap 2021–2024

KUOPIO NATURAL HISTORY MUSEUM

AALTO · SYKE · HUS · HY · THL · KYS · FINBB · OY · KA · ISY · ÅA · LUT · TY · LUKE · TTL · IL · TAU · KSSHP · VY · TAYS · OYS · JY · GTK · MML · CSC · KOTUS · VTT · TYKS · SPR
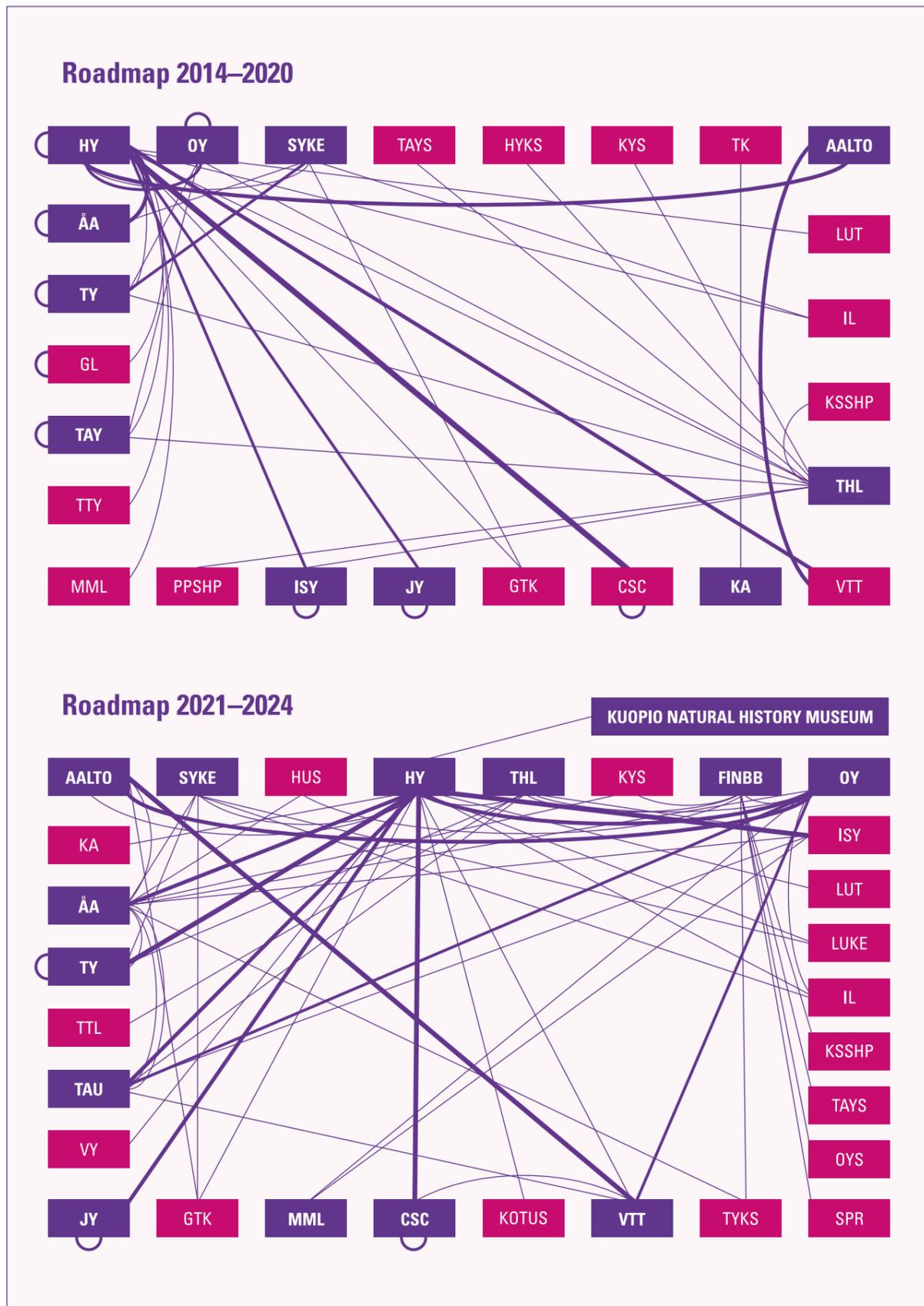
Figure 13. Connections between research organisations have increased. The thicker the line, the more research infrastructure ownerships they share. An arched line indicates that the organisation has a research infrastructure that it owns alone. Host organisations are marked with a blue box. (The Finnish Geodetic Institute, GL, merged with the National Land Survey of Finland, MML, 2015.)

- Scientific publications
- New initiatives

Scientific results

International networks

- Mobility
- Ideas
- Strengthening cooperation

Business collaboration

- Innovations
- Patents

Training

- Versatile training programmes
- RI staff training
- User training
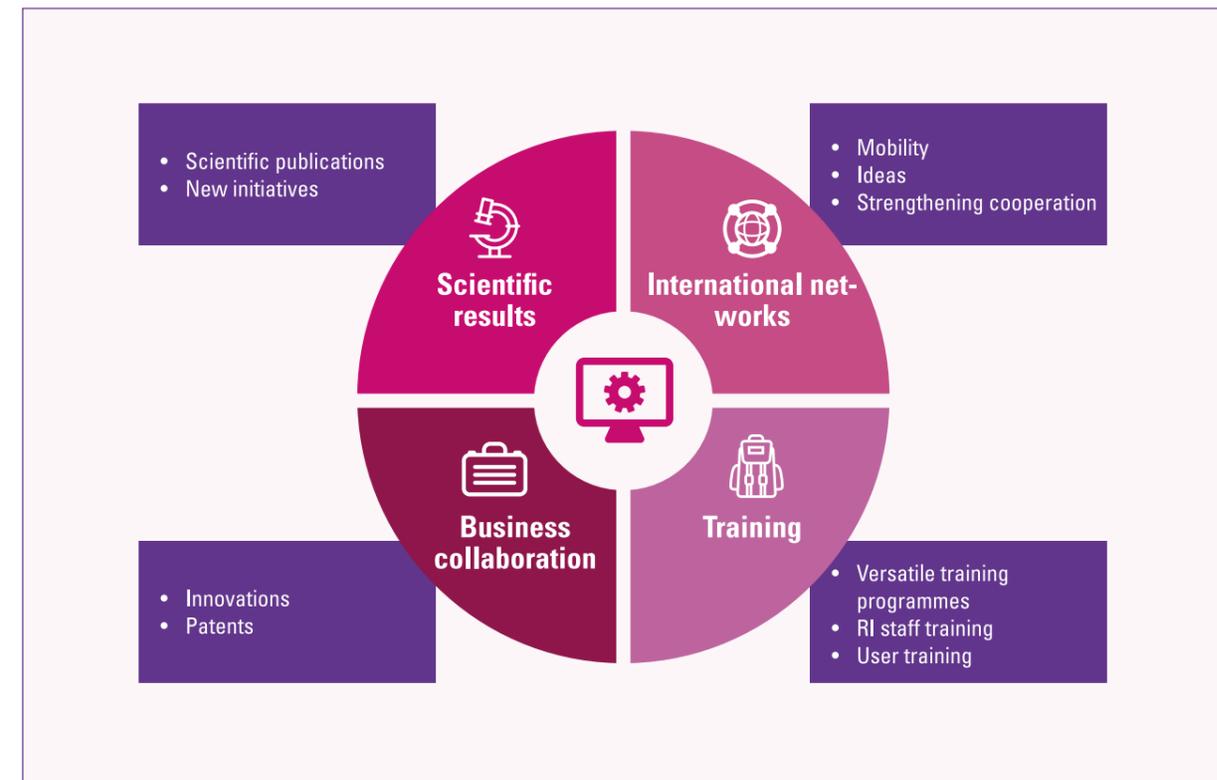
Figure 14. The impact of research infrastructures extends to many sectors of society in the long term.

The roadmap's research infrastructures have a diverse impact as an enabler of high-quality science and business cooperation, as a provider of education and as a promoter of international cooperation (Figure 14). The application material shows that research infrastructures are used to produce approximately 7,000 scientific articles annually in Finland. The number of users of the roadmap research infrastructures varies from 100 users to thousands per year. The number of users of an individual research infrastructure depends on the nature of the research infrastructure and the stage of its lifecycle.

Several roadmap research infrastructures organise training for their users in order to make the use of the infrastructure more efficient. Also, they are often partners in Finnish and foreign higher education institutions and are part of higher education degree programmes and projects. They also provide training and educational materials online and provide courses for secondary schools in areas related to the operation of the research infrastructure.

Approximately 50% of the roadmap's research infrastructures have significant business cooperation. Research infrastructures implement business cooperation roughly in two ways: companies use research infrastructure services either directly or indirectly through research cooperation, or companies, in particular start-ups, rely on the technologies offered by research infrastructures. The largest research infrastructures engaged in business cooperation are located in the fields of life sciences, medicine, data and computing sciences and physical sciences. These corporate partnerships involve several hundred companies each year, ranging from large international companies such as Stora Enso Oyj, UPM-Kymmene Oyj, AstraZeneca plc, Bayer AG, Dell Inc. and Vaisala Oyj, to start-up companies established in Finland, such as Bluefors Oy, Herantis Pharma Oyj, Infinited Fibre Company Oy and RECENART Oy.

Research infrastructures play an important role in achieving national and international carbon neutrality objectives. Monitoring climate change and environmental diversity

would be impossible without high-quality research infrastructures. On the other hand, the construction and use of research infrastructures also burden the environment. In fact, responsibility and sustainable development is one of the six strategic development areas identified in the Strategy for National Research Infrastructures 2020–2030.

The research infrastructure package included in Finland's Recovery and Resilience Plan (RRP) aims to promote the renewal and development of research infrastructures with a focus on the objectives of the green and digital transitions. The activities of research infrastructures in the green transition were mapped out for the first time in the FIRI funding call of spring 2021, in the action plan guidelines. Of the 50 million euros granted at the time, EUR 20 million was received through the Recovery and Resilience Fund (RRF).

Data on the green transition activities for research infrastructures was collected from applications submitted in the FIRI2021 call for roadmap research infrastructures and international research infrastructure memberships (N=36). The answers to the questions on the green transition could be summarised in seven different themes:

- Travel/transitions
- Procurements/equipment
- Greenhouse gases/CO_2 emissions (quantification & compensation)
- Waste & recycling
- Buildings
- Produced data
- General/other

The most common measures described by the research infrastructures were related to research data produced by the research infrastructure and its applications as well as to the possibilities for remote use of the research infrastructure. Additionally, many research infrastructures consider efficiency, versatility and recyclability in their equipment purchases. The policies of owner organisations, including the principles related to measuring and reducing the carbon footprint, will be important in guiding the operation of research infrastructures during the green transition.

6. Roadmap 2021–2024, descriptions of research infrastructures
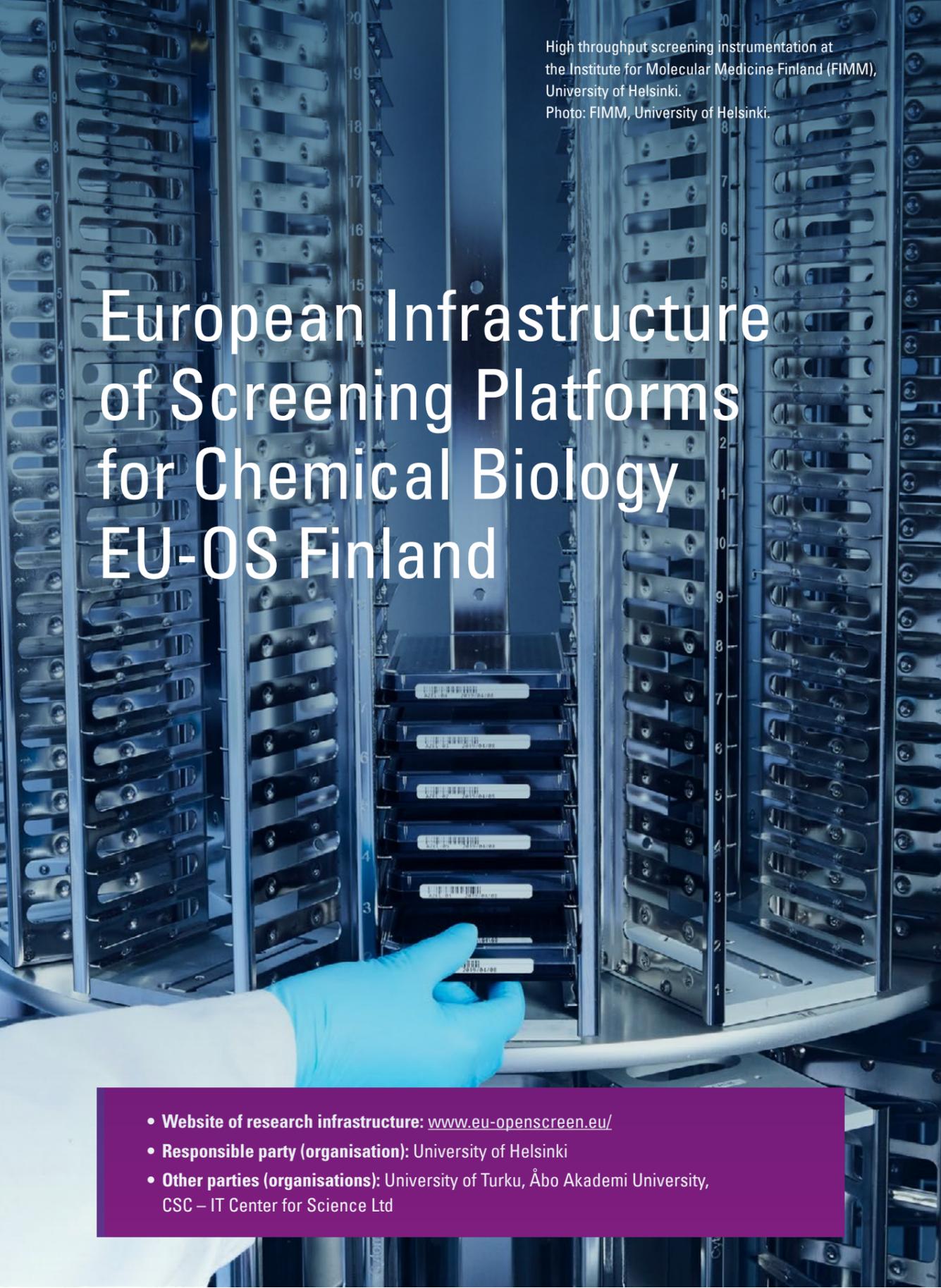
High throughput screening instrumentation at the Institute for Molecular Medicine Finland (FIMM), University of Helsinki.
Photo: FIMM, University of Helsinki.

European Infrastructure of Screening Platforms for Chemical Biology EU-OS Finland

- **Website of research infrastructure:** www.eu-openscreen.eu/
- **Responsible party (organisation):** University of Helsinki
- **Other parties (organisations):** University of Turku, Åbo Akademi University, CSC – IT Center for Science Ltd

EU-OPENSCREEN (EU-OS) is a European Research Infrastructure Consortium (ERIC) since 2018 and consists of eight European member countries, including Finland. EU-OS brings together top European screening and medicinal chemistry platforms to establish a distributed infrastructure for chemical biology to provide researchers with infrastructures and technologies to develop novel bioactive small molecule tools, i.e. chemical probes, for the benefit of all fields of life sciences. EU-OS has a unique European compound collection and an open-access chemical biology database allowing the scientific community to fully explore generated information for maximal scientific, educational and societal impacts of research investments.

The Finnish ESFRI node, EU-OPEN-SCREEN FI (EU-OS FI) hosted by the University of Helsinki (UH), joined EU-OS as a founding member. EU-OS FI currently includes two accepted EU-OS partner sites at UH: 1) FIMM High Throughput Biomedicine Unit (High Capacity Screening Partner Site) and 2) Faculty of Pharmacy (Specialised Screening Partner Site). The EU-OS FI Consortium also involves Turku Screening Unit (University of Turku and Åbo Akademi University) and CSC supporting the Finnish partner sites in data management.

The highly efficient, large-scale, coordinated tool compound pipeline of EU-OS, including chemical optimisation of hits, will operate in synergy with assay development, virtual screening, bioprofiling, drug repositioning, personalised medicine and other services of the linked national RIs. EU-OS amplifies the impact of national investments to the European scale and provides the chemists and

biologists in Finland access to a wider European screening platform network and access for its user network to the screening facilities in Finland. Active Finnish participation in EU-OPENSCREEN brings domestic scientists outstanding opportunities for high-quality research breakthroughs, innovations, access to a unique chemical library and to technologies and services not currently available in Finland, as well as collaboration opportunities through incoming projects.

Services offered by research infrastructure

- Open access to Europe's leading screening and medicinal chemistry RIs. The distributed character of EU-OS allows users to draw upon complementary expertise and technologies from its partner institutions in high-throughput screening, specialised screening and medicinal chemistry. EU-OS offers access to chemical knowledge, instrumentation and expertise, from across Europe, allowing users to select the partner or combinations of partners which fit their project needs.

- Open access to a chemically diverse European Chemical Biology Library (ECBL). The EU-OS compound collection comprises 1) diversity set of 100,000 compounds, 2) academic compounds crowd-sourced from chemists and pharmacologists, 3) 5,000-compound pilot library incl. 2,500 known bioactive molecules, and 4) a 1,000-fragment library.

- Open access EU-OS bioactivity database. EU-OS promotes further utilisation of data by making its research findings available in an open access database, the European Chemical Biology Database (ECDB), after a reasonable grace period for users to secure intellectual property (IP). Data are disseminated according to the FAIR data principles, allowing communities across academia, SMEs and industry to benefit from EU-OS activities.

Biocenter Finland BF

Biocenter Finland laboratory.
Photo: Biocenter Finland.

Biocenter Finland (BF) is a distributed, nation-wide RI supporting frontier research, innovation and industry-academia collaboration in life sciences. It is openly accessible to 17,000 researchers in universities, research institutes, biobanks, hospitals and industry. BF coordinates investments and operations of nationally important RIs and promotes collaboration and division of responsibilities and joint investments according to a long-term plan anchored to the strategies of its host universities, the University of Eastern Finland, the University of Helsinki, the University of Oulu, Tampere University, the University of Turku and Åbo Akademi University.

BF is organised into 15 Technology Platforms located in the universities' biocenters. The Platforms have a four-year mandate renewable upon assessment by BF's international Scientific Advisory Board, which also approves new Platforms according to needs of the renewal of science. The current Platforms are BioImaging, Biobank Technologies, Bioinformatics, Drug Discovery & Chemical Biology, Genome-Wide Methods, FinGMice, Metabolomics, National Plant Phenotyping, Non-Mammalian Model Organisms, Proteomics, Real-Time Imaging, Single-Cell Omics, Stem Cells & Genome Editing, Structural Biology, and Viral Gene Transfer & Cell Therapy.

The technology services have attracted collaboration with several Finnish and international companies and have been instrumental in translating research innovations into drugs, diagnostics and services.

Services offered by research infrastructure:

- bioinformatics
- biological imaging
- drug discovery & chemical biology
- genome-editing
- genome-wide methods
- mouse models
- non-mammalian model organisms
- proteomics
- metabolomics
- real-time imaging
- stem cells
- single-cell omics
- structural biology
- viral gene transfer & cell therapy.

- **Website of research infrastructure:** www.biocenter.fi
- **Responsible party (organisation):** University of Helsinki
- **Other parties (organisations):** Tampere University, University of Eastern Finland, University of Oulu, University of Turku, Åbo Akademi University

ELIXIR Finland – CSC's data centre.
Photo: CSC – IT Center for Science Ltd.
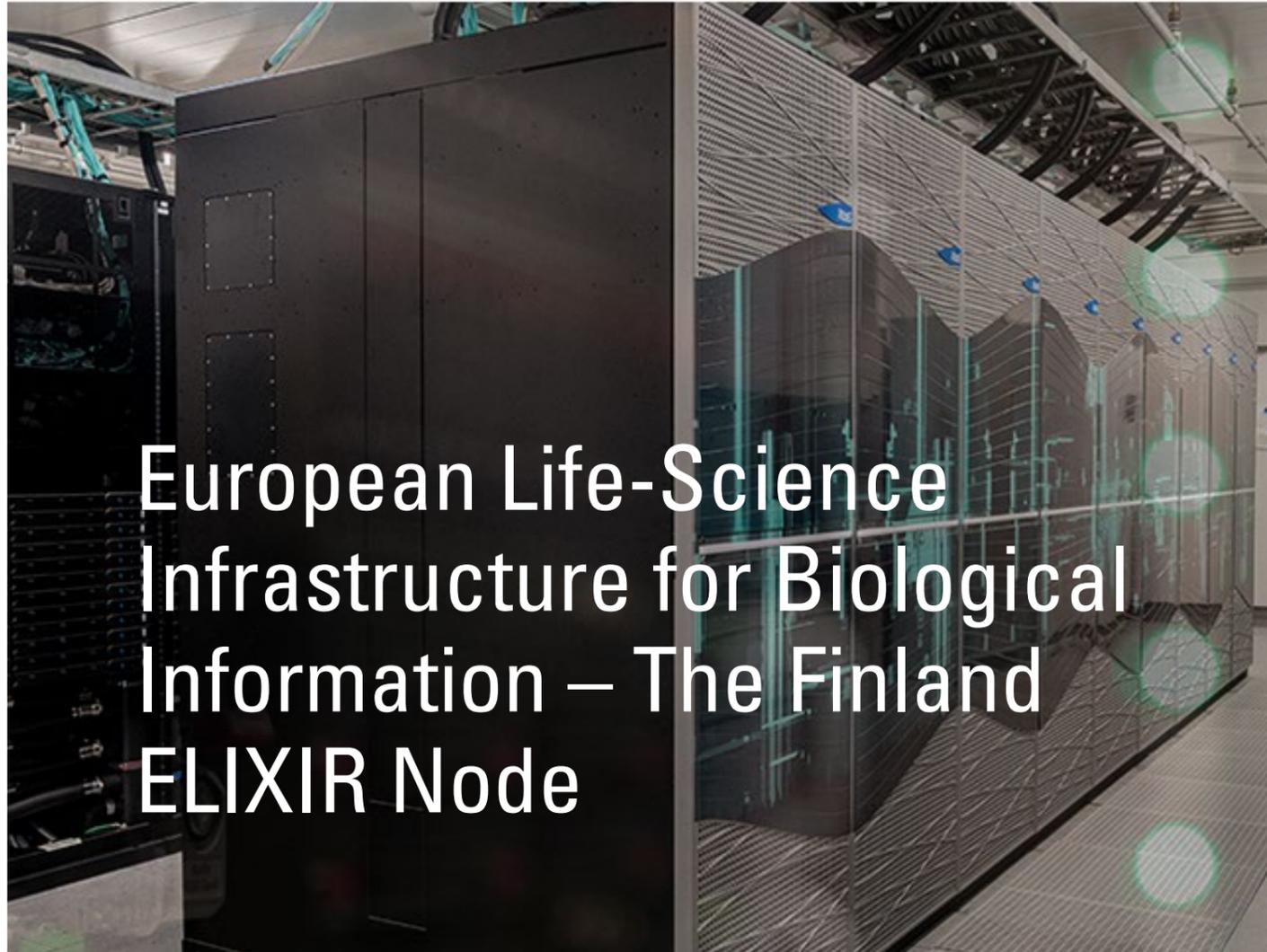
European Life-Science Infrastructure for Biological Information – The Finland ELIXIR Node

ELIXIR Finland is a major national life science research infrastructure in Finland and part of Finland's national research infrastructure roadmap. ELIXIR Finland is part of ELIXIR – European life-sciences infrastructure for biological information (www.elixir-europe.org), which brings together life science resources across Europe. ELIXIR Finland is operated by CSC – IT Center for Science Ltd, one of Northern Europe's largest scientific computing centres.

ELIXIR provides Europe with a strategy for long-term sustainability for biological information resources across member states. It enables bioinformatics users in academia and industry to reuse these data and access services that are vital for research. In collaboration with international partners, ELIXIR develops interoperability of life science data in the context of the European Open Science Cloud. The services provided for Finnish researchers as part of the national roadmap thus

align with the European data infrastructure objectives and strategy.

The ELIXIR Finland development programme positively influences CSC competences to manage health and biological data. It ensures CSC services specialisation and interoperability with the European infrastructure. Finland is specialised in secure human data coupled with high-performance computing, including a focus on secure scientific cloud and container services, international user authentication and data access services, and training targeted at life science communities.

The ELIXIR Finland long-term vision is to be a leading research data management infrastructure that facilitates world-class bioinformatics and novel data analysis, especially on human data. For example, ELIXIR Finland together with ELIXIR Czech operates ELIXIR AAI, the ELIXIR Compute Platform service for authenticating researchers and managing their access to pan-European ELIXIR services. At the end of 2020, 5,863 users had an ELIXIR ID to access 102 services that rely on ELIXIR AAI. ELIXIR AAI operations are funded as an ELIXIR infrastructure service by the ELIXIR Hub. This service is a critical building block for secure sharing and processing of sensitive data.

Services offered by research infrastructure

- As part of the European ELIXIR life science infrastructure network, ELIXIR Finland offers Finnish life scientists access to research infrastructure both in Europe and Finland. ELIXIR Core Data Resources and ELIXIR Deposition Databases offer large biological datasets for Finnish researchers (elixir-europe.org/services) compliant with FAIR principles.
- CSC – IT Center for Science and ELIXIR Finland provide services, tools and software (docs.csc.fi/apps/) for managing research data management throughout the project life cycle (rdmkit.elixir-europe.org/).
- The national bioinformatics services of CSC cover computing environments, analysis programs, tools for storing and sharing data during the project as well as opening and discovering research data (research.csc.fi/home) including versatile training events (www.csc.fi/en/training).
- Services that are particularly suitable for managing sensitive data are in part under development at the moment (research.csc.fi/sensitive-data).
- Services are subject to CSC terms and principles agreed with the Finnish Government (research.csc.fi/principles-of-allocating-resources).

- **Website of research infrastructure:** www.elixir-finland.org
- **Responsible party (organisation):** CSC – IT Center for Science Ltd

European Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences Euro-BioImaging Finland

Biological and biomedical imaging are revolutionising life sciences. Imaging technologies are in high demand on all scales relevant to modern life science: from understanding organism development and function at a molecular level to the development of novel therapies to combat devastating diseases with enormous economical and societal burden, such as cancer and Covid-19. Euro-BioImaging (www.eurobioimaging.eu) is a European Research Infrastructure Consortium (ERIC) that provides open access to Europe's best biological and biomedical imaging technologies, training services and data solutions for academic and industri-

Biological and medical imaging in Euro-BioImaging Finland. Image: Joanna Pylvänäinen.

- **Website of research infrastructure:** www.eurobioimaging.fi
- **Responsible party (organisation):** Åbo Akademi University
- **Other parties (organisations):** Aalto University, University of Eastern Finland, University of Helsinki, University of Oulu, University of Turku, Helsinki University Hospital, Kuopio University Hospital, Turku University Hospital

al users worldwide, through a growing network of 33 Nodes in 15 countries.

Euro-BioImaging Finland (www.eurobio-imaging.fi) is the service organisation of Euro-BioImaging in Finland, consisting of two multi-sited Nodes: Finnish Advanced Light Microscopy Node (FiALM) and Finnish Biomedical Imaging Node (FiBI). Euro-BioImaging Finland assembles together Finland's top imaging expertise from six universities and three university hospitals, and it has been on the national roadmap of research infrastructures since 2014. Euro-BioImaging Finland is an internationally well-known service provider, with some facilities being among the most popular in Euro-BioImaging. Annually, Euro-BioImaging Finland facilities are used in approximately 400 peer-reviewed scientific publications from various fields, and provide training for approximately 1,000 scientists.

Euro-BioImaging Finland has played a major role in several important scientific discoveries that ultimately impact the health and lives of people at large, with an increasing number of such discoveries to be expected in the future, for instance in the areas of drug development, cancer and diabetes research. Euro-BioImaging Finland services have also been actively used in Covid-19-related research. Euro-BioImaging Finland actively collab-

orates with several other Finnish and international research infrastructures. It is also a strong and trusted partner of the pharma industry, collaborating successfully with major global companies, such as Novartis, Roche, and AstraZeneca. Euro-BioImaging Finland and both its Nodes are led from Turku, where also the headquarters of Euro-BioImaging ERIC are located.

Services offered by research infrastructure

Euro-BioImaging Finland offers open access to biological and medical imaging technologies for academic and industrial users from Finland and abroad. In total, approximately 30 technologies are available, including several new proof-of-concept technologies.

- Spearhead technologies include super-resolution microscopy,
- correlative light and electron microscopy,
- high-throughput microscopy,
- mesoscopic imaging,
- preclinical and clinical PET and tracer development,
- preclinical high-field MRI,
- human neuroimaging with MEG and preclinical optical intravital imaging.

Euro-BioImaging Finland also offers training courses and workshops in imaging-related topics for researchers, students and staff, as well as services in image data management and analysis. Certain services are available also remotely.

Biobanking and Biomolecular Resources Research Infrastructure of Finland BBMRI.fi

Researcher and a pipette.
Photo: Shutterstock / FINBB.

Services offered by research infrastructure

- National infrastructure management: management and decision-making capabilities and processes to enable integrated actions.
- Biobank quality support and management: implementation of advanced quality standards for BBMRI.fi biobanks.
- Ethical and legal issues: services for biobanks and conformation of BBMRI.fi to state-of-the-art national and international legal and ethical standards.
- Data management services: to ensure BBMRI.fi biobanks have state-of-the-art systems in place to make their sample and data collections findable, accessible, interoperable and reusable.

BBMRI.fi (www.bbmri.fi) is a research infrastructure comprising all ten public and academic biobanks in Finland. The Finnish biobanks were established and are hosted by the participating organisations listed above. BBMRI.fi is the Finnish National Node of the European-level BBMRI-ERIC (Biobanking and BioMolecular Resources Research Infrastructure – European Research Infrastructure Consortium) infrastructure (www.bbmri-eric.eu).

Since January 2020, the Finnish Biobank Cooperative FINBB has been the national coordinator of BBMRI-ERIC, coordinating, developing and serving the operative actions of all Finnish biobanks. The vision of BBMRI-ERIC is to build and strengthen value-added sustainable biobanking, enabling clinical translational research

in academia and industry and facilitating new treatments and new innovations in personalised medicine.

Finnish biobanks and the coordinator FINBB actively participate in the implementation of the BBMRI-ERIC Work Programme with specific emphasis on providing common services for management, IT, quality and ethical and legal issues. The mission is to build a state-of-the-art biobank network in Finland. To read more about research conducted at the biobanks, please visit the use cases at site.fingenious.fi/en/fingenious-news-and-updates. More information regarding sample collections and publications can be found at site.fingenious.fi/en.

- **Website of research infrastructure:** finbb.fi/fi/what-is-finbb
- **Responsible party (organisation):** Finnish Biobank Cooperative FINBB, national coordinator of the European-level BBMRI-ERIC (Biobanking and BioMolecular Resources Research Infrastructure – European Research Infrastructure Consortium) infrastructure (www.bbmri-eric.eu)
- **Other parties (organisations):** THL Biobank, Finnish Institute for Health and Welfare; Auria Biobank (University of Turku, hospital districts of Southwest Finland, Satakunta and Vaasa); Hematological Biobank (FHRB Biobank) (Finnish Hematology Association, Finnish Red Cross Blood Service, Institute for Molecular Medicine Finland FIMM (University of Helsinki)); Finnish Red Cross Blood Service Biobank; Helsinki Biobank (hospital districts HUS, Kymsote, Eksote and Päijät-Häme, and University of Helsinki); Biobank Borealis of Northern Finland (Oulu University Hospital, University of Oulu, NordLab and the healthcare districts of Kainuu, Lapland, Central Ostrobothnia and Länsi-Pohja); Finnish Clinical Biobank Tampere (FCBT) (Pirkanmaa Hospital District, Tampere University, joint municipal authority of the Etelä-Pohjanmaa hospital district and joint municipal authority of the Kanta-Häme hospital district; Biobank of Eastern Finland (Hospital District of Northern Savo, University of Eastern Finland, Hospital District of Itä-Savo and Joint Municipal Authority Essote and Siun SOTE Joint Municipal Authority); Central Finland Biobank (University of Jyväskylä and Central Finland Health Care District); Arctic Biobank (University of Oulu).

Integrated Structural Biology Infrastructure Instruct-ERIC Centre Finland

X-ray generator.
Photo: University of Turku.

for more than 10,000 registered users and is made up of a consortium of 15 members. Its infrastructure services are delivered from eleven Instruct Centres located in national facilities where research excellence is globally recognised, including the distributed Instruct-ERIC Centre Finland.
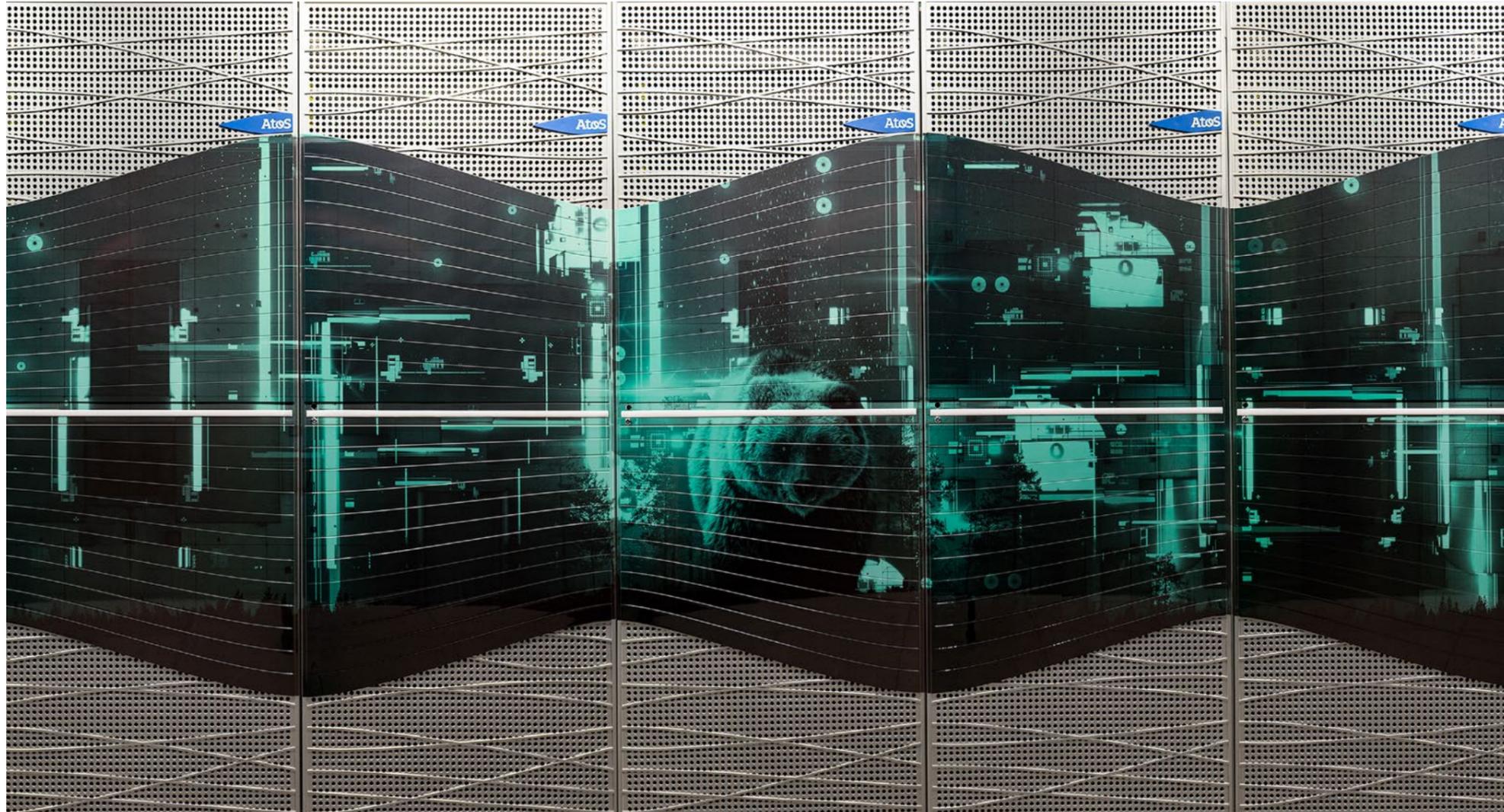
Structural biology, by showing molecules in 3D at molecular and atomic levels, helps us understand how they work and interact, providing information and new avenues for many scientific and industrial disciplines. Structural Biology Finland (FINStruct) is a national, coordinated, multi-institution and open-access research infrastructure established to provide integrated structural biology services and training to support research and innovation in academia and industry. It spearheads international R&D, providing services in sample preparation, functional and structural analysis, data processing, structural bioinformatics and structural determination. It innovates with industry, increasing patent applications, diagnostic and therapeutic tool development. It makes structural biology

expertise and local innovations available to businesses and their corporate partners to be driving forces in Finland's medical industry.

Since 2019, Finland is a member of Instruct-ERIC (Integrated Structural Biology RI in Europe), a landmark member of the European Strategy Forum on Research Infrastructures (ESFRI). Instruct-ERIC is the single point of access for new and emerging high-level European technologies and expertise for structural biology research, complementing limited national offerings. Through its specialist research centres, Instruct-ERIC offers funded research visits, training, internships and R&D awards. By promoting integrative methods, Instruct-ERIC enables excellent science and technological development

- **Website of research infrastructure:** FINStruct www.helsinki.fi/en/infrastructures/integrated-structural-cell-biology/finstruct Instruct-ERIC Centre FI www.instruct-eric.eu/centres/instruct-fi/ Instruct-ERIC www.instruct-eric.eu/
- **Responsible party (organisation):** FINStruct (University of Helsinki), Instruct-ERIC Centre FI (University of Helsinki)
- **Other parties (organisations):** FINStruct (University of Oulu, University of Eastern Finland, University of Turku, Åbo Akademi University), Instruct-ERIC Centre FI (University of Oulu, University of Eastern Finland)

Instruct-ERIC Centre Finland services

- Biomolecular Complex Purification (Biocomplex) instruct-eric.eu/platform/biomolecular-complex-purification-biocomplex-helsinki-finland/ (Minna Poranen), University of Helsinki, Finland
- Cryo-Electron Microscopy instruct-eric.eu/platform/electron-microscopy-helsinki-finland/ (Sarah Butcher), University of Helsinki, Finland
- Protein production with Isotope Labelling for NMR instruct-eric.eu/platform/protein-production-with-isotope-labelling-for-nmr-helsinki-finland/ (Hideo Iwai), University of Helsinki, Finland
- NMR instruct-eric.eu/platform/nmr-helsinki-finland/ (Hideo Iwai), University of Helsinki, Finland
- Single-cell Proteomics (SCoPE-MS) instruct-eric.eu/platform/single-cell-proteomics-scope-ms-helsinki-finland/ (Markku Varjosalo), University of Helsinki, Finland
- Macromolecular Crystallisation instruct-eric.eu/platform/macromolecular-crystallisation-oulu-finland/ (Lari Lehtiö), Biocenter Oulu, University of Oulu, Finland
- Molecular Biophysics instruct-eric.eu/platform/molecular-biophysics-oulu-finland/ (Lari Lehtiö), Biocenter Oulu, University of Oulu, Finland
- X-ray Diffraction instruct-eric.eu/platform/x-ray-diffraction-oulu-finland/ (Lari Lehtiö), Biocenter Oulu, University of Oulu, Finland
- Native Mass Spectrometry instruct-eric.eu/platform/native-mass-spectrometry-joensuu-finland (Juha Rouvinen), Biocenter Kuopio, University of Eastern Finland, Finland

Services offered by research infrastructure

- Biomolecular Complex Purification (Biocomplex) www2.helsinki.fi/en/infrastructures/integrated-structural-cell-biology/biocomplex-purification (Minna Poranen), Faculty of Biological and Environmental Sciences & Helsinki Institute of Life Science HiLIFE, University of Helsinki
- CryoEM Core Facility www2.helsinki.fi/en/infrastructures/integrated-structural-cell-biology/infrastructures/cryoem (Sarah Butcher), Helsinki Institute of Life Science HiLIFE / Institute of Biotechnology, University of Helsinki
- Finnish Biological NMR Center www2.helsinki.fi/en/infrastructures/integrated-structural-cell-biology/infrastructures/finnish-biological-nmr-center (Hideo Iwai), Helsinki Institute of Life Science HiLIFE / Institute of Biotechnology, University of Helsinki
- High-resolution Mass Spectometry Facility, Native-MS www.oppi.uef.fi/wanda/kemia/research/protein/ (Juha Rouvinen), Biocenter Kuopio, University of Eastern Finland
- Biocenter Oulu Structural Biology core facility https://www.oulu.fi/biocenter/structural-biology-core-facility (Lari Lehtiö), Biocenter Oulu, University of Oulu
- Protein Crystallisation Facility www2.helsinki.fi/en/infrastructures/integrated-structural-cell-biology/infrastructures/crystallization (Tommi Kajander), Helsinki Institute of Life Science HiLIFE / Institute of Biotechnology, University of Helsinki
- Protein Structure and Chemistry Core Facility bioscience.fi/services/protein-structure-and-chemistry/services/ (Tassos Papageorgiou), BioCity Turku, University of Turku
- Structural Bioinformatics Laboratory https://www.abo.fi/en/structural-bioinformatics-laboratory/ (Tiina A. Salminen), BioCity Turku, Åbo Akademi University

Supercomputer Mahti.
Photo: CSC – IT Center for Science Ltd.

Services offered by research infrastructure

- National research platform for data management, data analytics and scientific computing.

- National research and education network Funet.

- Puhti supercomputer, with a CPU partition of almost 700 nodes with a range of memory sizes and local storage options; from interactive single-core data processing to medium-scale simulations spanning multiple nodes.

- Mahti supercomputer, designed for massively parallel jobs requiring large floating point performance and a capable interconnect; from medium- to large-scale simulations requiring Petaflops of computing power.

- Allas modern object storage environment to store, share or move research data across the CSC computing infrastructure.

- LUMI is one of the three European pre-exascale supercomputers under installation. The Finnish national share of LUMI resources is 25% of total capacity. The access and support for the use of the national share will be tightly connected to the CSC RI.

- cPouta & ePouta: The Pouta services provide Infrastructure as a Service (IaaS) computing services. The Pouta platforms are generic resources suitable for a large variety of scientific IT support, and not targeted at a specific user group.

- Rahti is a modern container orchestration platform for easily deploying research pipelines and services. Rahti is not targeted at specific user bases but a generic IT platform that can be used to support research.

- The Fairdata service portfolio offers easy-to-use storage, sharing and publication services for research data, including preservation services that ensure usability for decades and up to centuries.

- Paituli is a spatial data download service providing prominent Finnish datasets openly for research and education purposes. Unlike other spatial data services in Finland, Paituli also includes historical versions of its datasets. Paituli currently includes 249 datasets totalling 12TB of data.

- Chipster is an easy-to-use bioinformatics software developed by CSC. It enables noncoding bio/medical researchers to analyse high-throughput data by providing a web interface to more than 450 analysis tools that run in Rahti.

- REMS (Resource Entitlement Management System) is a generic tool, part of the wider Data Access tool set, that allows data custodians to accept applications for their data, manages the electronic approval process, stores data access decisions and provides interfaces for these decisions to be enforced in analysis environments.

- Notebooks provides easy-to-use environments for working with data and programming. Users can access everything via a web browser, and the CSC cloud environment is used for computing in the background. Different versions of Jupyter Notebooks, RStudio Server and Apache Spark tools are provided via Notebooks.

CSC's Research Infrastructure Services

CSC is a Finnish centre of expertise in ICT, providing services at an internationally high level of quality for research, education, culture, public administration and enterprises to help them thrive and benefit society at large. CSC is owned by the state of Finland (70%) and Finnish higher education institutions (30%). CSC supports a European-wide customer base of thousands of researchers in disciplines such as biosciences, environmental science, linguistics, physics, chemistry and mathematical modelling.

- **Website of research infrastructure:** www.csc.fi
- **Responsible party (organisation):** CSC – IT Center for Science Ltd

Finnish Computing Competence Infrastructure

Equipment of the FCCI research infrastructure.
Photo: Finnish Computing Competence Infrastructure (FCCI).

The Finnish Computing Competence Infrastructure (FCCI) is Finland's Tier-2-level computing infrastructure, which coordinates the scientific computing activities of Finnish universities. At the heart of the FCCI is the concept of smart specialisation supported by the EU: the FCCI strengthens Finland as one of the leading countries in scientific computing.
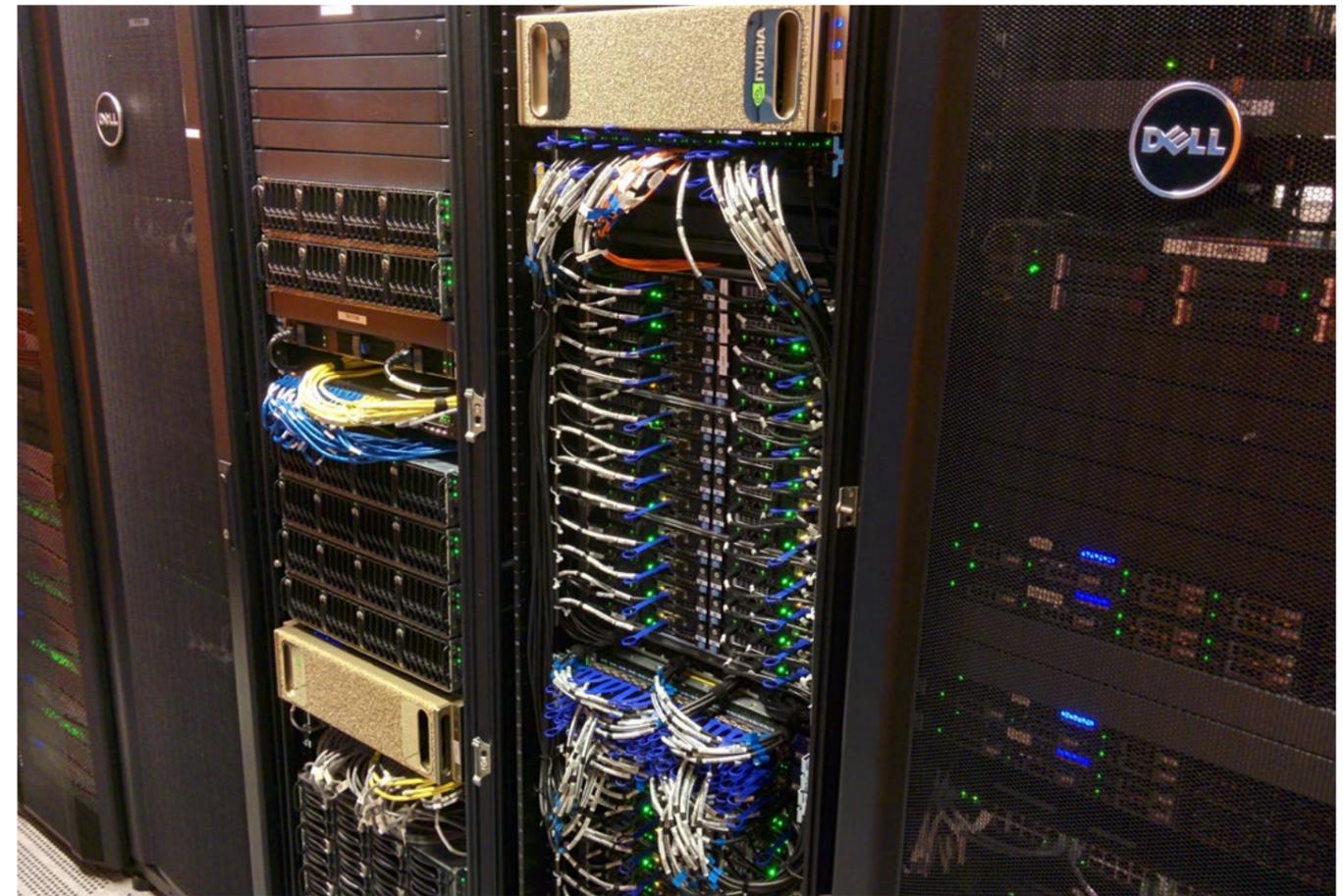
The highest-level computational Tier-0 and Tier-1 infrastructures (maintained by CSC – IT Center for Science Ltd) available in Finland are among the best in the world, but they do not succeed without strong Tier-2 capacity, which is an essential part of the computational ecosystem. The FCCI provides this service.

The core mission of the FCCI is to provide all partner universities with computational and data storage resources, local scientific computing experts, and competence training actions that support each university's specific research and training activities, thus supporting the national profiling of the universities and their infrastructure strategies. The FCCI integrates these capacities into a single entity that is coordinated and developed centrally and integrated with CSC's Tier-1 and Tier-0 services.

The FCCI is based on the latest technologies and specifically supports data-intensive research, machine learning, AI, and high-performance computing. The FCCI user groups cover all scientific fields as well as the arts, and the FCCI is a key research infrastructure for many cutting-edge research environments, including four Finnish Flagships funded by the Academy of Finland. In Finland, the FCCI supports researchers using more than 40 other research infrastructures. A central part of the FCCI's activities is the training

of top scientific computing professionals for use in all sectors of society. With the FCCI, Finland's computing infrastructure is unique worldwide. It acts as a competitive asset in recruiting the best researchers, raising Finland to the forefront of science worldwide and profiling Finland as one of the world's leading science countries for scientific computing, digitalisation and the green transition.

Services offered by research infrastructure

- The FCCI provides researchers with distributed Tier-2 computing and data storage capacity that renders high-quality computational and data science possible.
- The FCCI has centralised management and technical support, with additional support given by local university IT.
- The FCCI develops Research Software Engineer (RSE) support services in which the key is the RSE-to-researcher support for software, computing and data science.
- To optimise researchers' effectiveness and user-friendly service, the FCCI infrastructure and its software are matched seamlessly to the Tier-1 and Tier-0 resources at the CSC, and the user interface is made as easy as possible.
- The FCCI provides a broad training programme for scientists and IT experts.
- The FCCI acts as a national network in computational science, thus bridging related people in all sectors (public and private) and organising conferences to get the people together.
- The FCCI provides services to an exceptionally large user base (e.g. life sciences, arts, economics, computer sciences including AI, data science, physics and chemistry, materials research, and humanities).
- The FCCI promotes open data and open access.

- **Website of research infrastructure:** www.helsinki.fi/fcci
- **Responsible party (organisation):** University of Helsinki
- **Other parties (organisations):** Aalto University, Lappeenranta-Lahti University of Technology, University of Eastern Finland, University of Oulu, University of Jyväskylä, Tampere University, University of Turku, Åbo Akademi University, CSC – IT Center for Science Ltd

Finnish Quantum Computing Infrastructure

Quantum computer.
Photo: VTT Technical Research Centre of Finland Ltd.

The Finnish Quantum Computing Infrastructure (FiQCI) aims to provide an open-access platform for quantum computing, with state-of-the-art classical quantum simulators and physical quantum computers surpassing the capabilities of classical quantum simulators. The infrastructure is newly founded and currently provides access to a classical 30-qubit quantum simulator. Quantum computers are planned to be included in the following years, and by 2025, FiQCI will provide access to two quantum computers of about 20 and 50 qubits. In addition to this, services such as access to the computers and simulator, training and software libraries will be developed to support the efficient use of the infrastructure.

Quantum computers promise a revolution in computing, enabling to solve problems that are impossible for classical computers. For example, modelling of the structure of chemical compounds is an inherently quantum-mechanical problem that quantum computers could crack in the future along with applications in finance, optimisation, cyber security and artificial intelligence. Finland has decades of top-level academic experience currently culminating in the Academy of Finland Centre of Excellence in Quantum Technology (QTF) lead by Aalto University, applied research at VTT, and European industrial champions such as Bluefors Oy and IQM Finland Oy. Together with the high-performance computing services of CSC, the Finnish ecosystem is uniquely placed to develop and provide a quantum computing service.

FiQCI will be led by VTT, which hosts the quantum computers with Aalto, thanks to their top-level hardware expertise. CSC will provide a user interface and high-level access to software developers. In the beginning, most users will be academics, but the number of industry users is expected to increase rapidly. Library development and training activities will be undertaken to make the infrastructure easily accessible to industrial applications and experts.

Beyond 2025, we will review the status of the quantum computers of different physical realisations continuously and plan to maintain FiQCI as a leading quantum-computing service provider and upgrade the quantum computers and simulators with the best technology available in the market. FiQCI actively aspires to collaborate at the European level, for example with the EuroHPC programme, where CSC together with a European consortium is building a 202 million euro supercomputer installation (LUMI) in Kajaani, Finland. Including quantum computers in the Lumi infrastructure is a long-term vision for FiQCI.

- **Responsible party (organisation):** VTT Technical Research Centre of Finland Ltd
- **Other parties (organisations):** Aalto University and CSC – IT Center for Science Ltd

European High Performance Computing Research Infrastructure

Construction of the LUMI supercomputer in Kajaani in March 2021.
Photo: Juha Torvinen, CSC.

- **Website of research infrastructure:** the European wide RIs EuroHPC JU eurohpc-ju.europa.eu PRACE prace-ri.eu LUMI www.lumi-supercomputer.fi
- **Responsible party (organisation):** CSC – IT Center for Science Ltd

EuroHPC/PRACE Finland – access to world-class computing resources

In the digital era, high-performance computing (HPC) has become a key enabling technology for all advanced economies. HPC is at the core of major advances and innovation, enabling world-class science and industrial competitiveness.

The EuroHPC Joint Undertaking (EuroHPC JU) is pooling EU and national resources to develop a world-class supercomputing ecosystem in Europe, by acquiring leadership-class supercomputers, and to deploy HPC services for science, industry and SMEs. Finland has taken a prominent position in EuroHPC by hosting one of the three first generation systems, LUMI, in CSC's data centre in Kajaani. Once operational in early 2022, LUMI will be one of the most competitive and green supercomputers in the world.

The Partnership for Advanced Computing in Europe (PRACE) has been offering supercomputing services for over a decade. In the era of EuroHPC, PRACE will coordinate the main allocation mechanism of the EuroHPC JU resources, and will likely continue to have a key role in HPC training, given the PRACE experience and expertise in this area.

The PRACE Training Center in Finland is operated by CSC since 2012. The EuroHPC/PRACE Finland virtual research infrastructure is essentially a reboot of the successful PRACE Finland RI. It reflects the evolution towards a world-class computing and data management eco-

system in Europe in the era of EuroHPC. The overall objective of EuroHPC/PRACE Finland is to proactively support and facilitate access for Finnish researchers to state-of-the art computational and data resources for performing world-class science. EuroHPC/PRACE Finland will work on a national level to ensure that research and innovation benefit as much as possible from the EuroHPC JU, LUMI and PRACE initiatives.

Services offered by research infrastructure

- Promote the EuroHPC (including LUMI) and PRACE resources and capabilities among the Finnish research communities, including training opportunities offered by the Finnish PRACE Training Center and the EuroHPC Competence Center Finland.
- Support Finnish resource applications to the European systems, taking into account the new conditions of the EuroHPC systems, as well as a more diverse Finnish user base.
- Run the process of organising the Finnish extreme scale calls on LUMI, with focus on the peer-review process and post-processing of each allocation. A rigorous peer review is central to ensure the highest scientific excellence and impact from the national part of the LUMI resources.
- Enable Finland, represented by CSC, to continue to play an active role in PRACE governance on the European level.
- Enhance LUMI computing environment with added value and user-friendly software services.

Research Infrastructure for Future Wireless Communication Networks

Equipment of the FUWIRI network.
Photo: Jonne Renvall.

> • **Website of research infrastructure:** www.oulu.fi/cwc/
>
> • **Responsible party (organisation):** University of Oulu
>
> • **Other parties (organisations):** Tampere University, Aalto University, VTT Technical Research Centre of Finland Ltd

FUWIRI is in essence a mobile cellular network that is deployed on the FUWIRI partners' campuses, making each partner a local mobile network operator. FUWIRI sites are connected together. FUWIRI supports using 5G devices, higher frequency bands, cognitive management functionalities and system testing tools for new solutions. FUWIRI feature evolution follows 5G research and standardisation progress, acting as a verification platform for theoretical 5G research.

The cellular network is composed of nearly 100 LTE small cell base stations (2.1, 2.6 GHz) and dozens of macro cell base stations with different LTE (700MHz, 2.3 GHz, 2.6 GHz, 3.5 GHz). The network has dozens of 5GNR base stations (3.5 GHz) complemented with user equipment from MediaTek and several mobile phone vendors that are easily integrated to any device. The network is currently complemented with mmW (24–28 GHz) base stations. The network is controlled by operator-grade EPC (Evolved Packet Core) with own SIM production for mobile devices. The current EPC version is 5G-NSA-compliant and will be complemented to support 5G SA.

The networks within the campuses are complemented by a wireless sensor networks (IoT, internet of things) extension with thousands of different kinds of sensors with wireless connectivity through NB-IoT, LTE-M and LoRa. Furthermore, the network has big data computing serv-

ers for network data analytics purposes. Some of these servers are distributed within the network, thus allowing multi-access edge computing (MEC) as well as caching services. The NOKIA EPC has open application programming interfaces (virtualised EPC), which makes it possible to integrate new services to network management, for example.

FUWIRI will evolve towards 6G over the next five years. Additionally, FUWIRI integrates state-of-the-art RF signal generation and analysis environments and flexible software defined radio capabilities for versatile over-the-air testing and measurements of up to 100 GHz.

Services offered by research infrastructure

• Device loans

• Wireless access to controlled 4G and 5G network

• Research and co-creation of wireless services, applications, testing methods and cellular network solutions

• Research and co-creation of IoT services

• Research and co-creation of positioning services

• Research and co-creation of radio-frequency imaging and sensing services

• RF measurement environments of up to 100 GHz.

The newest equipment of the ALD centre connects the ALD reactor to surface analysis methods.
Photo: Veikko Somerpuro.
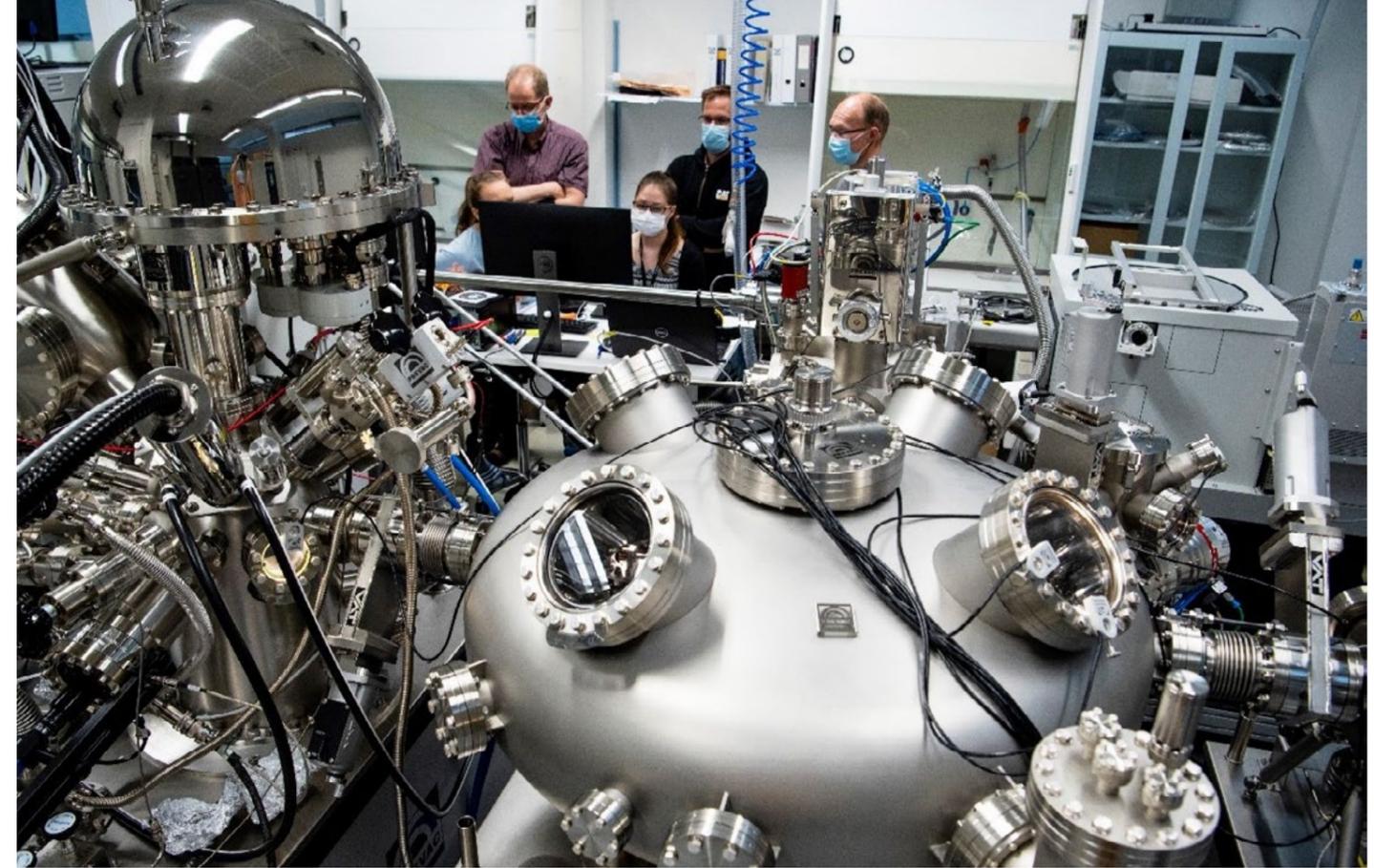
ALD center Finland
- Research infrastructure for atomic layer deposition and etching

ALD Center Finland is a national research infrastructure in atomic-layer-level materials processing techniques: atomic layer deposition (ALD), atomic layer etching (ALEt) and molecular layer deposition (MLD). ALD, in particular, has assumed an important role in the semiconductor industry and also has other significant industrial applications of high volume, such as in the manufacture of solar cells.

ALD Center Finland also supports other research fields where special methods are needed for thin-film characterisation and research on surface chemistry: thin-film technologies in general, microelectronics, heterogeneous catalysis and energy technology materials.

ALD Center Finland is located on the University of Helsinki Kumpula Campus and hosted by the Departments of Chemistry and Physics. The centre builds on the long-term expertise of the HelsinkiALD research team and the accelerator and X-ray laboratories. As a national infrastructure, it brings the development of research methods to a new level and thus contributes to ensuring that Finland maintains its key position in research in the field, despite the tightening of international competition.

ALD Centre Finland has significant industrial impact thanks to the applications developed from the materials and processes created and studied there. The centre actively cooperates with companies, and companies in the sector are also active users of the centre.

Services offered by research infrastructure

The centre's services are open to all users and include the following equipment

- ALD/ALEt reactors combined with surface-analysis devices for the examination of reaction mechanisms.
- ALD/ALEt reactors for testing precursors and developing processes.
- Thin-film characterisation techniques.

- **Website of research infrastructure:**
  www.helsinki.fi/en/infrastructures/ald-center-finland
- **Responsible party (organisation):** University of Helsinki

VTT's industrial biotechnology laboratory in Bioeconomy research infrastructure. Photo: Timo Kauppila.

BIOECONOMY RI

The BIOECONOMY research infrastructure (RI) is a unique, openly accessible research, education and innovation research environment hosted by Aalto University and VTT. It supports activities tackling global challenges such as climate change and resource sufficiency. The BIOECONOMY RI allows methods for upgrading forest raw materials and biobased waste and side streams to high-value products. The RI development areas cover (i) new value-added products from lignocellulose, (ii) efficient circular bioeconomy and process concepts, (iii) synthetic biology and industrial biotechnology processes, and (iv) AI-driven process and product development. The RI enables academic research discoveries and scale-up of novel technology concepts.

The BIOECONOMY RI is openly accessible for all interested parties, for example through collaborative projects, contract research, education, or training for user operation. It offers research, development and piloting services for academia, research and technology organisations and industry in the field of process chemistry, industrial biotechnology and material sciences.

Aalto University and VTT participate in European RI cooperation and network projects to establish globally competitive open-access bioeconomy RI networks across Europe. The industrial biotechnology of the BIOECONOMY RI is part of EU-IBISBA, which was added onto the ESFRI (European Strategic Forum on Research Infrastructure) roadmap in September 2018.

Services offered by research infrastructure

The unique offering of the BIOECONOMY RI is to provide research services practically throughout the whole value chain of circular and bioeconomy technologies. The services include facilities and research excellence needed for developing new products and process concepts. The service portfolio covers:

- services for curriculum education and lifelong learning
- digital and knowledge-based services (e.g. process simulations and feasibility assessments)
- experimental research and innovation services for a wide TRL range, including piloting services operated by VTT.

- **Website of research infrastructure:** www.bioeconomyinfra.fi
- **Responsible party (organisation):** Aalto University, School of Chemical Engineering (Aalto)
- **Other parties (organisations):** VTT Technical Research Centre of Finland (VTT)

Finnish National Infrastructure for Light-Based Technologies FinnLight
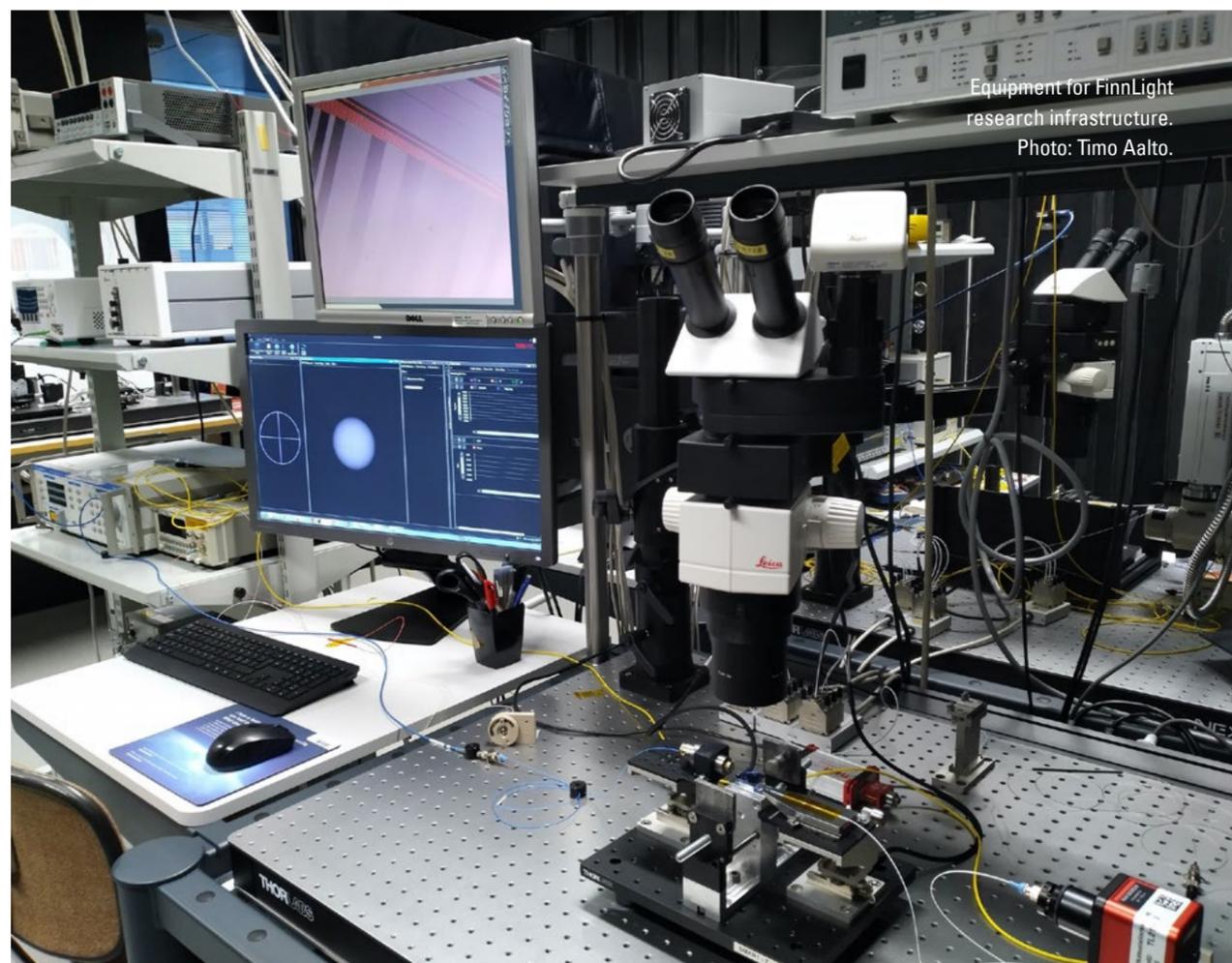
Equipment for FinnLight research infrastructure.
Photo: Timo Aalto.

The development of photonics technologies is a multi-level process that requires advanced design and fabrication methods, testing and integration capabilities, as well as extensive characterisation techniques. FinnLight is a platform of advanced infrastructure with centralised and coordinated operation offering a wide range of services for the fabrication, characterisation and integration of photonics and light-based technologies.

FinnLight provides a comprehensive combination of technologies covering all classes of photonics materials as well as full-scale process lines for device fabrication and assembly. The infrastructure enables the development of new materials, advanced light sources, optical and integrated components for sensors and LIDAR applications, quantum technologies, photovoltaic technologies, AR/VR, and communications.

Photonics is a rapidly growing field in Finland. FinnLight significantly enhances the capabilities needed across the entire photonics innovation value chain contributing to fulfilling the current and future needs of the Finnish photonics ecosystem. Researchers, commercial users and companies can benefit from FinnLight research and technology development capabilities within the framework of collaboration projects or through direct contracting. FinnLight offers services performed by dedicated and competent staff, open access to the instrumentation, tailored researcher training, scientific consultation, or equipment rental.

Services offered by research infrastructure

FinnLight capabilities cover the full innovation chain from design and fabrication to assembly and characterisation of photonic technologies. The services areas include but are not limited to:

- Optical design and free-form optics
- Measurement and testing
- Micro- and nanofabrication
- Material characterisation
- Optical integration and component packaging
- Fibre optics
- Optical materials
- Advanced light sources.

- **Website of research infrastructure:** prein.fi/home/finnlight
- **Responsible party (organisation):** Tampere University
- **Other parties (organisations)** University of Eastern Finland, VTT Technical Research Centre of Finland Ltd

With the help of laser light, the accelerator laboratory at the University of Jyväskylä has been able to more than double the jet current of a SNICS negative ion source.
Photo: Ville Toivanen.
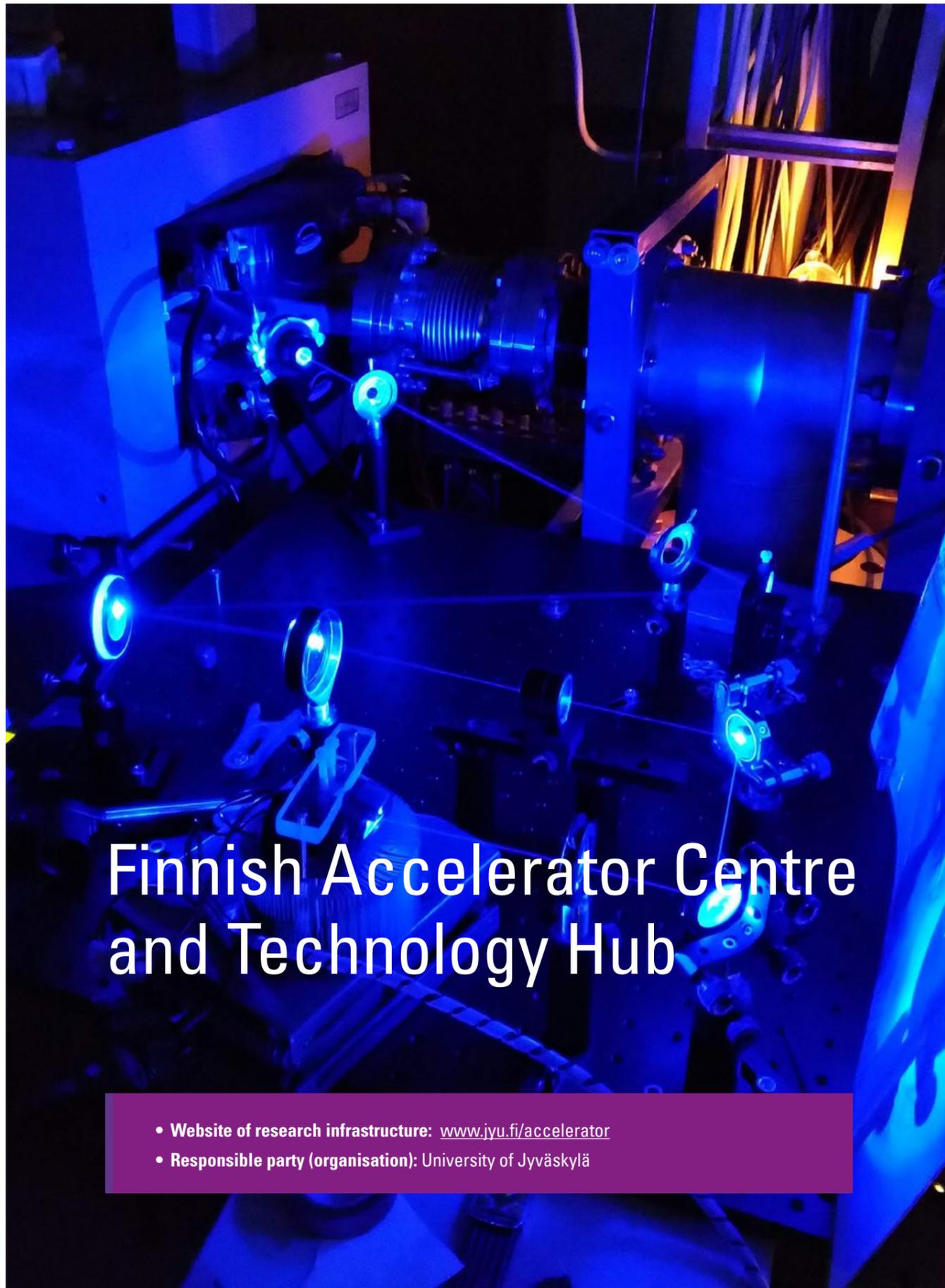
Finnish Accelerator Centre and Technology Hub

- **Website of research infrastructure:** www.jyu.fi/accelerator
- **Responsible party (organisation):** University of Jyväskylä

The Accelerator Laboratory of the Department of Physics, University of Jyväskylä (JYFL-ACCLAB) was established in 1992. JYFL-ACCLAB is a multi-user facility hosting four accelerators providing heavy ion (p to Au), electron and photon beams for a large national and international user base. The users of JYFL-ACCLAB represent a multidisciplinary range of fields, addressing research into nuclear and atomic physics, nuclear astrophysics and fundamental interactions, radiation effects in electronics and materials, ion source development and plasma physics, nanoscience, materials characterisation and thin-film research.

JYFL-ACCLAB also provides a wide range of analysis, irradiation and expert consultancy services to industrial partners. JYFL-ACCLAB also operates the RADiation Effects Facility (RADEF), recognised as an External European Component Irradiation Facility by the European Space Agency (ESA). Access to the laboratory is granted in several ways – through calls for experimental proposals evaluated by an external panel of experts (Program Advisory Committee), through various EU Transnational Access Programmes, or on a commercial basis for industrial partners using the irradiation services.

Services offered by research infrastructure

Nuclear Science Hub

- alpha, gamma, beta, charged particle spectroscopy
- multi-parameter list mode data acquisition
- high-resolution mass spectrometry
- high-resolution laser spectroscopy
- digital electronics and pulse signal processing
- analysis software development
- atom and ion trapping

Technology Hub

- component irradiation facilities
- irradiation services
- ion beam optics and simulations
- GEANT4 simulations
- radiation detector development
- analysis of plasma composition and properties
- micro and nanomachining (<10nm)
- sub-nm imaging
- STA radiation protection consultancy
- STV radiation protection training

Materials Science Hub

- elemental depth profiling using ToF-ERDA
- thin-film elemental analysis using RBS
- ultra-high-resolution trace element analysis using PIXE and TES
- ToF-ERDA analysis software development and MC simulation
- development of novel applications for ALD processes
- high-resolution imaging and chemical analysis of nanostructures.

Otaniemi Micro- and Nanotechnology Research Infrastructure

Parts of the OtaNano research infrastructure.
Photo: Mikko Raskinen.

OtaNano (www.otanano.fi) is the national research and development centre for micro- and nanotechnology. It serves as a state-of-the-art working environment for internationally recognised research fields, such as quantum technology, nanoelectronics, micro- and nanophotonics, and new materials. It provides centralised access to advanced nanofabrication, nanomicroscopy and low-noise measurement facilities only 15 minutes away from the Finnish capital Helsinki, at the heart of the leading Nordic innovation hub in Otaniemi, Espoo. OtaNano operates as a national hub in relevant European research infrastructure (RI) collaborations, covering all of its fields of operation.

OtaNano was established in its present form in 2013 to enhance nanoscience and nanotechnology research in Finland. It builds on longstanding experience and collaboration in research infrastructure (RI) development and demonstrates the strong vision of its host organisations, Aalto University and VTT. OtaNano serves as a first-rate educational centre for young researchers and as a node for scientific and technological collaboration as well as commercial development. The facilities accommodate more than 500 users annually, and more than 30 companies collaborate in and utilise the facilities of the RI.

Services offered by research infrastructure

- User training for the safe and productive operation of the facilities. This is a prerequisite for entry to the facilities and ensures that the users are able to work in a productive way. Annually more than 150 new users are trained to use the facilities.

- Equipment training to be able to use the equipment of the infrastructure individually. The training is given by the permanent staff of the RI, and it usually includes guidance on selecting the relevant processing parameters or materials.

- Process development to achieve a competitive edge by having the measurement and fabrication processes that are in line with the requirements of the research groups or CoEs.

- Operator services of the equipment on behalf of the researchers or companies. Typically manufacturing for proof-of-concept testing or demonstrators. Services include also very challenging manufacturing, imaging or measurement tasks for the customers by the RI staff.

- Pilot manufacturing to test and demonstrate fabrication-scale-up of new technologies and devices, facilitating entry into the market. Provided by the infrastructure operators typically on batch sizes of tens of silicon wafers.

- Visits to the infrastructure for external academic or industry experts. Presentations on, for instance, available instruments and access principles complemented with an infrastructure tour. Provided by the RI manager and/or field-specific experts.

- Tailored courses and seminars for the users of the RI, but also other interested academic and industry professionals.

- Data management of the data produced using the RI equipment.

- Consulting to maximise the feasible utilisation of the tools. Provided by the infrastructure operators or advanced users.
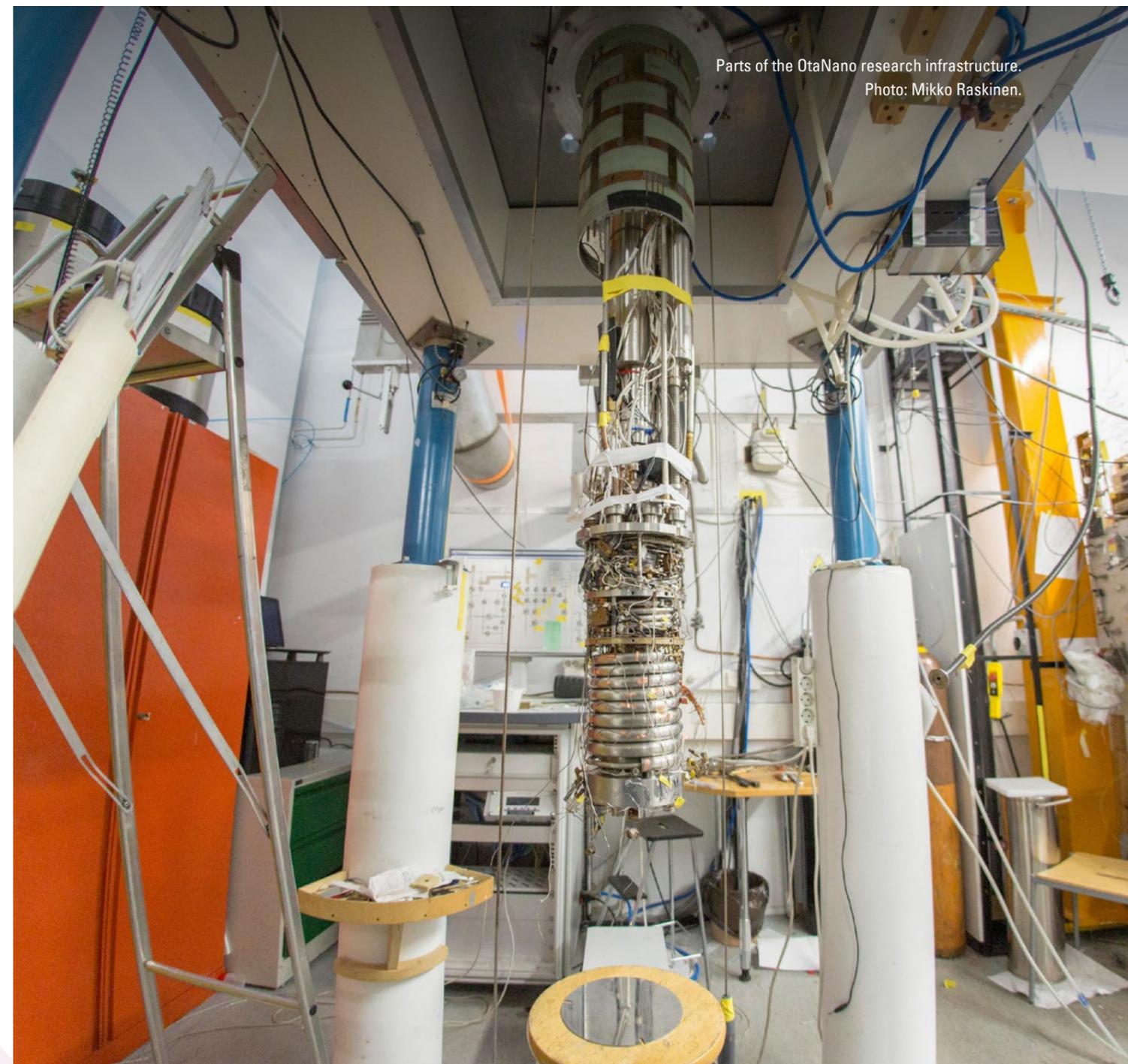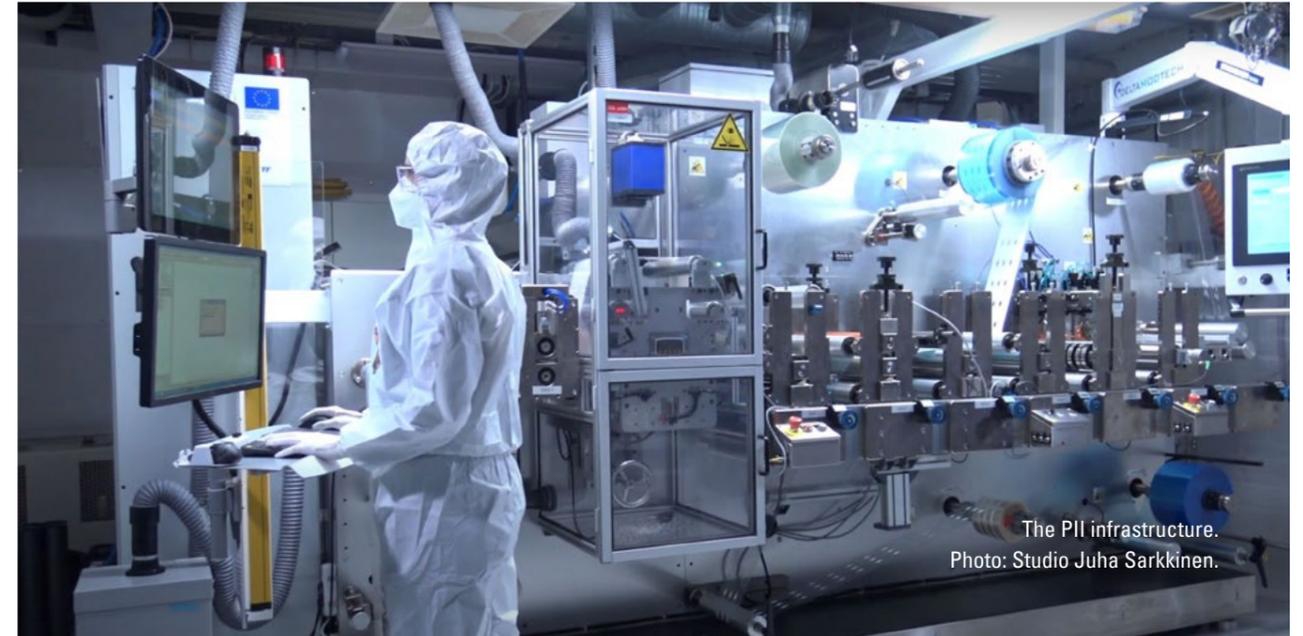
- **Website of research infrastructure:** www.aalto.fi/fi/otanano
- **Responsible party (organisation):** Aalto University
- **Other parties (organisations):** VTT Technical Research Centre of Finland Ltd

Printed Intelligence Infrastructure

The PII infrastructure.
Photo: Studio Juha Sarkkinen.

Printed intelligence is a rapidly emerging field of technology, being a key enabler for next-generation technology products such as flexible, thin, light-weight and cost- and resource-efficient electronics and photonics. The Printed Intelligence Infrastructure (PII) provides a world-class research and development environment to researchers and technology developers in academia and industry. It offers an efficient use of and easy access to a modern research and pilot manufacturing infrastructure covering the whole research/development path from (i) materials via (ii) functional printing, (iii) components and devices to (iv) circuits and systems. The application areas of the studied functional systems are, for instance, sensors for distributed systems (Internet of Everything), diagnostics, skin-augmented electronics and personalised drug dosing.

This distributed printed intelligence infrastructure has been systematically constructed over the past ten years by the participating organisations. The PII consortium does not only provide access to the infrastructure but also serves the whole community in the field with its expertise in science, education and technology. Building a new era for printed intelligence, PII's major target is sustainability in a very broad scope, including not only technological aspects but also environmental, social and economic ones.

- **Website of research infrastructure:** www.oulu.fi/pii/
- **Responsible party (organisation):** University of Oulu
- **Other parties (organisations):** Tampere University, VTT Technical Research Centre of Finland Ltd, Åbo Akademi University

Services offered by research infrastructure

The different PII service categories relate to 1) materials research, 2) component development, 3) system development and 4) application development as follows.

- Materials: The characterisation tools of the infrastructure include a full setup of equipment for piezoelectric poling, optical and electrical (frequency up to 67 GHz) characterisation, reliability testing and multiphysic modelling of devices. In addition, mechanical, thermal and optical properties can be characterised. For more detailed material characterisation, there is a range of imaging tools, such as SEM, AFM and an X-ray diffractometer (XRD). For ink development, the rheological properties and wetting characteristics and for the printability the determination of the structural (thickness, lateral dimensions, roughness, etc.), morphological (crystallinity) and functional properties (electrical, optical, etc.) of printed structures (printing quality) can be studied.

- Component development: The processes include various thin/thick film coating and pattern printing, surface micro- and nanostructuring, layer lamination and encapsulation of the structures. The transfer from device level technologies to functional systems requires integration step(s) that can be performed by sequential processing of different layers resulting in a monolithic platform. Alternately, discrete components (printed or other devices) can be mounted on a printed platform resulting in a hybrid structure. Additionally, hybrid in-mould integration technology enables seamless integration of novel optical, electrical and mechanical features into 3D plastic products. The printing facility includes multiple printing platforms including inkjet, gravure, flexographic, screen and microplasma printers. Specifically, several inkjet printers; industrial/pilot printer with integrated post-processing units, a flexo-gravure-screen, a gravure printer, a flexography printer, screen printers, Super-fine inkjet printer

for μm and sub-μm features, a microplasma printer for high resolution digital surface energy patterning, 3D printed electronics system, and Atomic Layer Deposition (thermal and plasma) in same glove box system with evaporator and inkjet to create uniform layers for transistors and barriers.

- System development: The transfer from the device level technologies to functional systems requires integration step(s) that can be performed by sequential printing of different layers resulting in a monolithic platform. Alternatively, the discrete components (printed or others) can be assembled by sheet- or roll-based processing on a printed platform resulting in a hybrid structure. Additionally, hybrid in-mould integration technology enables seamless integration of novel optical, electrical and mechanical features into 3D plastic products. PII offers various types of printed intelligence applications and services from feasible studies to pilot-scale production trials. The manufactured sub-modules are used as inserts in the injection moulding process, in which the 3D module and mechanical interconnections are implemented.

- Application development: PII as a whole offers the full value chain for different applications including new materials, designs and optimised fabrication methods when approaches are needed to take the first step to increase the technology readiness level (TRL). Additionally, it supports efforts of all collaborators to pursue sustainable printed intelligence through collected and researched know-how.

Circular Raw Materials Research Infrastructure

Equipment of the RAMI research infrastructure.
Photo: Pasi Puukko.

The RAMI Circular Raw Materials Research Infrastructure (RI) is hosted by Aalto, GTK and VTT. It is designed to strengthen the long-term core expertise to place Finland among the world leaders in natural and new inorganic material research needed for the circular economy. The RAMI RI provides a holistic approach at all stages of the circular raw materials value chain: product design, primary and secondary production, new materials, and use and recovery. It supports activities related to closing the raw material loops and sustainable energy research, to increasing the value of primary and secondary raw materials, their processing, and sustainable use in high-performance applications. These include, for example, structural materials, catalysts, batteries, metal recovery at End of Life (EoL) via reuse, remanufacturing and recycling (like WEEE and batteries).

Within the RAMI consortium, Aalto competence is in multifunctional materials design, synthesis tools for enhanced energy efficiency, energy storage materials and state-of-the-art facilities for battery recycling. These are augmented by essential expertise in pyro- and hydrometallurgy as well as experimental thermodynamics at high temperatures and in aqueous solutions. GTK's service offerings cover geomaterials, resource calculation, exploration and extraction, recycling and process optimisation. VTT provides services in digital material design, integrated computational material engineering (ICME), (bio)hydrometallurgy, mechanical separation and additive manufacturing.

Services offered by research infrastructure

The equipment and services can be found on the website www.rami-firi.fi. The RAMI RI's facilities provide a foundation for the practical training of experts to meet the future demands of industry and academia. The openly accessible infrastructure provides users with advanced high-tech tools, promotes high-impact scientific research in Finland, on a European scale, for example via the EIT RawMaterials ZeroWaste Cluster and globally through international collaborators.

- **Website of research infrastructure:** www.rami-firi.fi
- **Responsible party (organisation):** Aalto University, School of Chemical Engineering (Aalto)
- **Other parties (organisations):** Geological Survey of Finland (GTK), VTT Technical Research Centre of Finland (VTT)

# Common Language Resources and Technology Infrastructure

FIN-CLARIAH is a research infrastructure (RI) consortium for social sciences and humanities (SSH) that comprises two components, FIN-CLARIN and DARIAH-FI. Taking as its core the well-established best practices developed in the language resource and language research community, FIN-CLARIAH seeks to broaden the scope of infrastructural support. CLARIAH Finland is the common RI for its two components, which function as the national nodes of the corresponding international RIs. Of these, Finland is already a member of CLARIN ERIC.

FIN-CLARIAH makes available large collections of textual and multimodal resources as well as tools for analysing and enriching them. The collections span different periods, genres and regions as well as different modalities such as text, audio, pictures and video containing or accompanied by natural language. The primary goal of FIN-CLARIAH is to provide tools and databases consisting of millions of documents as well as to curate research data and tools produced by SSH researchers in Finland to be used throughout CLARIAH Finland and beyond. This will let the SSH scholars reach similar replicability of research results as is common in natural sciences. Many claims based on intuition can be supported or rejected by broader and more objective evidence. This makes the research and research-based teaching of hundreds of researchers, teachers and advanced students more rewarding and efficient.

The tools and materials serve researchers of various branches of the Humanities, such as scholars of languages, culture, literature and history, as well as researchers in Social Sciences, Law, Medicine and Computer Science. In computer science, CLARIAH Finland serves the areas of data science, visualisation, machine learning and artificial intelligence (AI), forming an integral part of modern digital humanities, social and legal science research. In particular, language technology-related AI research crucially depends on access to substantial language resources. The relevance of the RI lies in the amount and diversity of materials as well as in their seamless access for researchers.

- **Website of research infrastructure:** www.fin-clariah.fi
- **Responsible party (organisation):** Helsingin yliopisto
- **Other parties (organisations):** Aalto University, CSC – IT Center for Science, Institute for the Languages of Finland, National Archives of Finland, National Library of Finland, Tampere University, University of Eastern Finland, University of Jyväskylä, University of Oulu, University of Turku, University of Vaasa
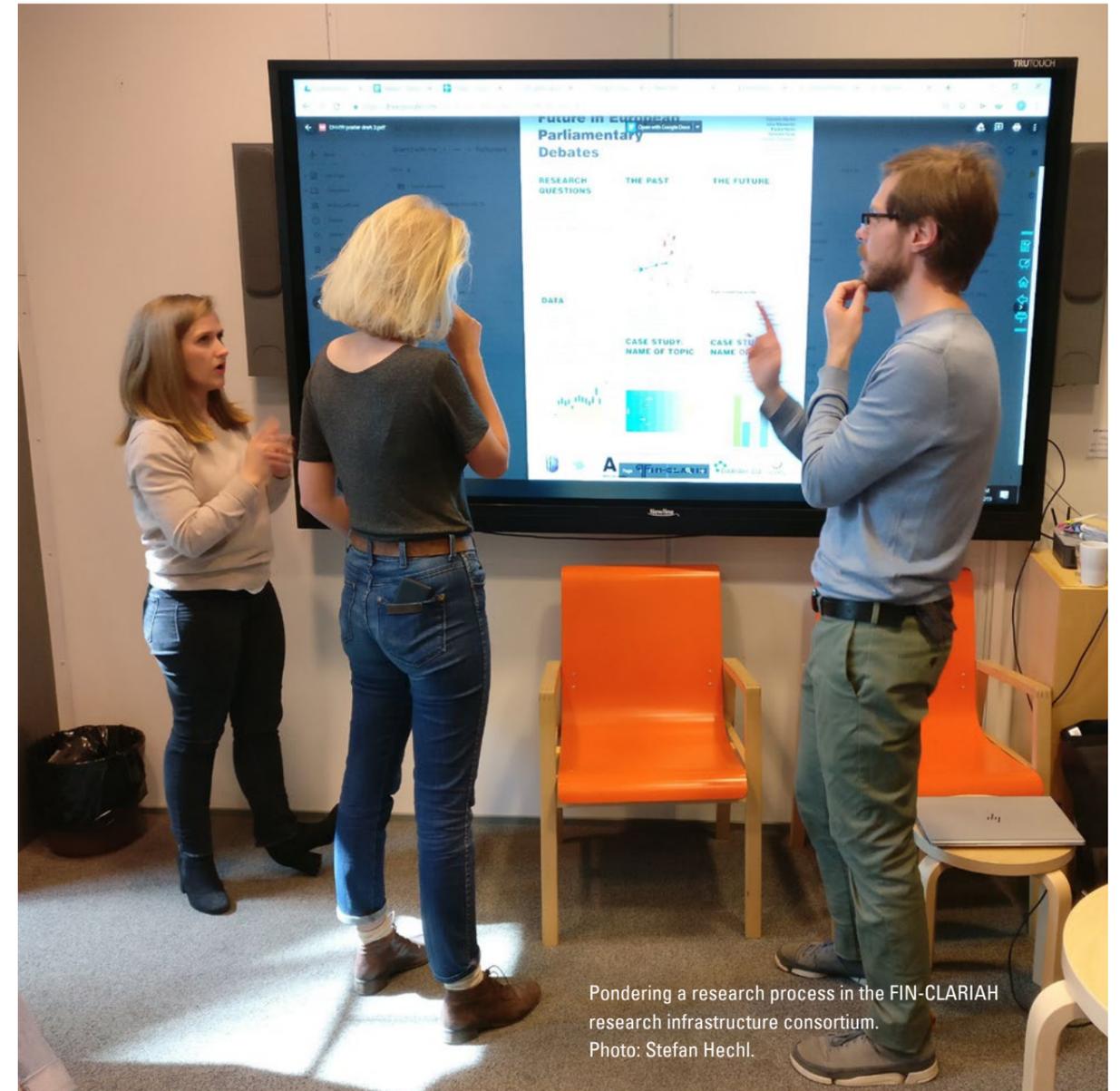
Pondering a research process in the FIN-CLARIAH research infrastructure consortium.
Photo: Stefan Hechl.

Services offered by research infrastructure

FIN-CLARIAH (FIN-CLARIN and DARIAH-FI) provides tools and resources via the online service centre The Language Bank of Finland (www.kielipankki.fi). The RI features several online collaboration platforms such as The Helsinki Term Bank for the Arts and Sciences (www.tieteentermipankki.fi) and the Digital Collections of the National Library (digi.kansalliskirjasto.fi) as well as meta data platforms such as the Linked Data Finland platform (ldf.fi) and the ONKI ontology services (onki.fi). The main user communities are in SSH, while many of the platforms also serve other fields of arts and science.

European Social Survey ESS Finland

The European Social Survey (ESS ERIC) is an extensive European comparative survey that measures the values, attitudes and behaviour of the population of European countries as part of societal change. Since 2002, the ESS has collected research data from 38 European countries. By the end of 2021, time series data has thus already accumulated for a total of ten rounds over a period of 20 years.

In all countries, the ESS follows very high and comparable uniform quality standards for the collection of data and the compilation of indicators, from sampling to fieldwork methods and archiving. Methodological research and indicator development are an integral part of ESS activities. The research data and documentation as well as the paradata are openly available to the public, free of charge. ESS data are used by more than 175,000 researchers from different disciplines around the world. The ESS has provided data resources for thousands of peer-reviewed articles, scientific books and other publications.

Services offered by research infrastructure

- Research data ESS R1 (2002)–R9 (2018) data & documentation (all individual survey data grouped by country and year).
- ESS Cumulative Data Wizard (combined data and Wizard tool for selecting rounds, countries and variables to be included in the material, as appropriate).
- Online analysis (web-based statistical analysis program).
- Methodological data (data on sampling, fieldwork and indicator testing).
- Multilevel data (collection of key country-level indicators combined with individual-level data).
- ESS EduNet, web-based learning laboratory survey methodology.
- Shared User Resources, guidelines for the coding and processing of variables for researchers.
- Seminars and conferences.

- **Website of research infrastructure:**
  www.europeansocialsurvey.org; www.sites.utu.fi/europeansocialsurvey
- **Responsible party (organisation):** University of Turku, Department of Social Research
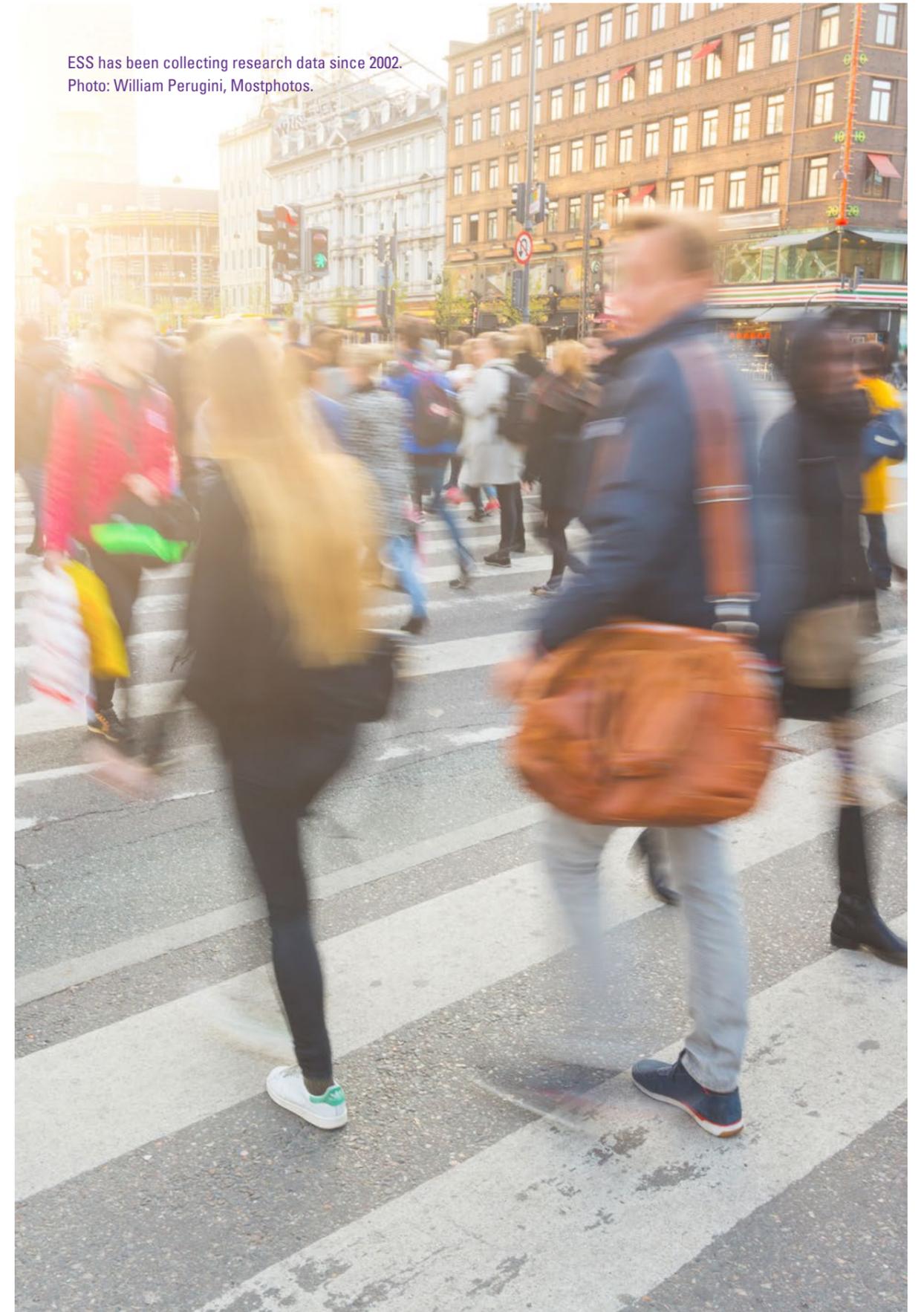
Finnish Research Infrastructure on Population Based Surveys

Height measurements at FIRI-PBS.
Photo: Hanna Tolonen.

FIRI-PBS is a distributed research infrastructure owned jointly by the partners of the consortium. Its preparation phase focuses on information from population-based health surveys. Population-based survey data means data on health and its determinants collected through questionnaires and objective health measurements, and linking these to administrative data sources.

Currently, most of the existing datasets and expertise are spread across different organisations that have over the years conducted these surveys and established further cross-sectional, cohort and intervention studies tied with them. There is no central portal where a summary of available data and knowledge and expertise could be accessed. This hampers effective secondary use of existing data leading to situations where new data collection is initiated even though required data would already exist. Even though Finland has a newly established health data permission authority, FINDATA, to support secondary use of health and social data, its mandate does not cover all Finnish data owners such as universities or all data sources within the covered organisations, leaving out many research data sources.

Combinations of different data sources provide an extensive database which allows for a holistic, multidisciplinary approach to examine health and its determinants, develop prevention and treatment innovations and support evidence-informed policy decisions.

The mission of this research infrastructure is

- to enhance active use of existing and newly collected population-based survey data in both national and international research initiatives and multidisciplinary collaborations
- to increase knowledge and use of common standardised tools for
- collection of new survey data
- to enhance data quality and cost-effective collection of new data.

The aim of this research infrastructure is to provide support for researchers and research groups

- in accessing and using the existing survey data by supporting the FAIR (Findable, Accessible, Interoperable, Reusable) principle, i.e. enhancing the secondary use of existing data
- in preparing a new survey by facilitating the use of standardised and validated methods and instruments to enhance comparability of the outcomes/results between studies and over time.
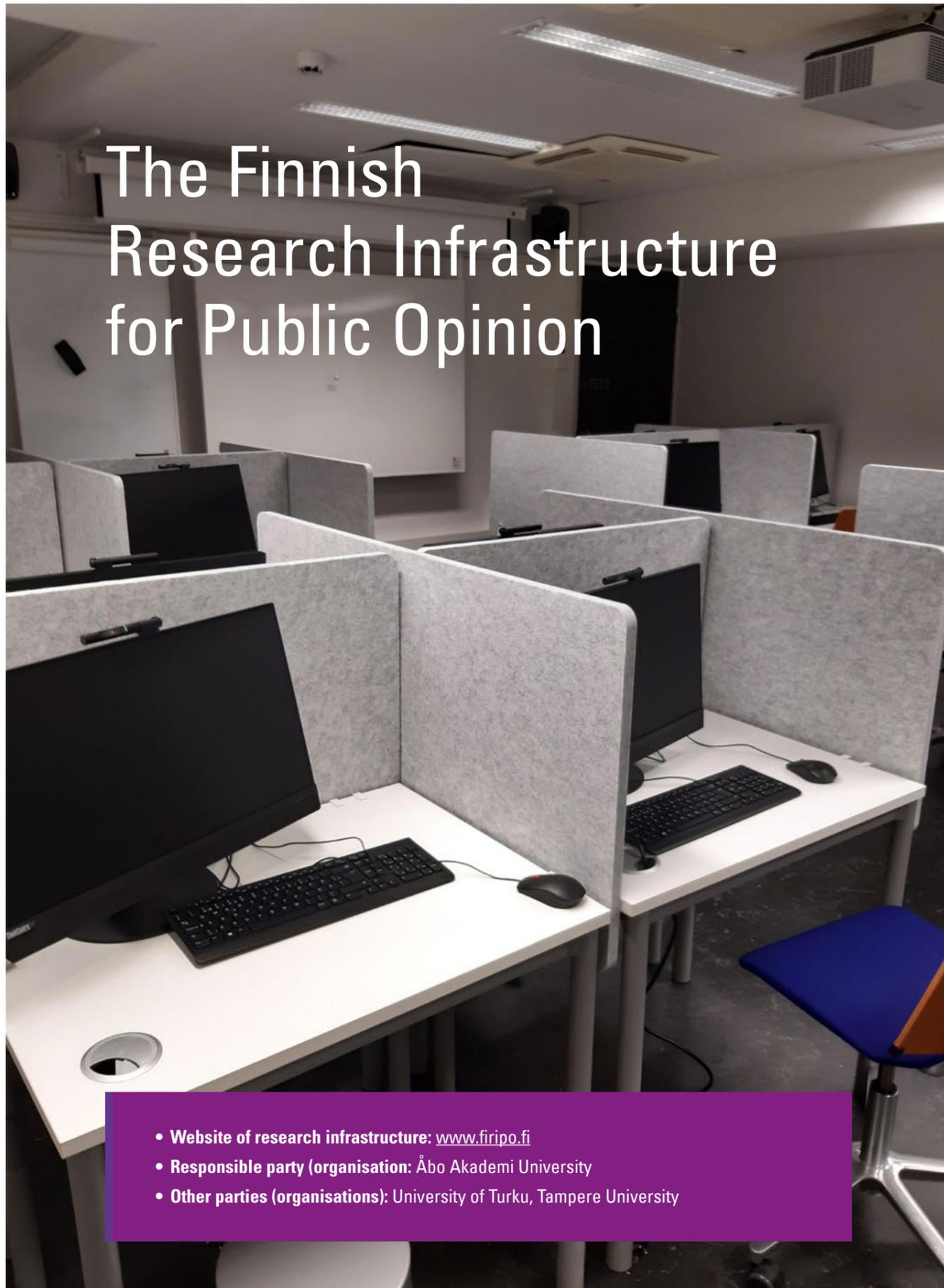
Services offered by research infrastructure

The following services and tools will be established for FIRI-PBS in a stepwise approach, that is, not all services will be available from the beginning.

- The focal point for the services will be the information portal, a one-stop-shop for researchers and other stakeholders. Through this portal they can access information about:
- Description of the RI partners and their competences, a catalogue of experts in Finland in the field of population-based health surveys.
- A searchable data catalogue will include information, in a standardised format, about existing datasets owned by the consortium partners. Information will include target population, timing of the data collection and details of the collected information. Also, information about derived and post-harmonised variables, and coverage of the ethical approval and informed consent. Supports the FAIR principle, that is, also includes information about access to the listed datasets.
- The population-based survey methods catalogue will include information about existing and used standardised questionnaire modules and other survey methods such as physical health measurement protocols, translation of questions into different languages, information about possible validation of questionnaire modules/measurement protocols and post-harmonisation protocols/rules established for available data collections.
- ELSI and FAIR guidelines including generic examples of the information material and informed consents fulfilling GDPR requirements while ensuring as broad a use of collected data as possible and required record linkage to other data sources.
- A toolbox will include a collection of guidelines, program codes and other practical tools. Guidelines would include topics such as record linkage and survey non-response management. Program codes would be for example R codes used for data cleaning. Practical tools would support management of the informed consent and participants' right to check collected personal information as well as remote data access and analysis system.
- Capacity building, training possibilities, e-learning materials, webinars, etc. about use and collection of population-based health survey data will be organised.

- **Website of research infrastructure:** www.firi-pbs.fi
- **Responsible party (organisation):** Finnish Institute for Health and Welfare
- **Other parties (organisations):** Finnish Institute of Occupational Health, University of Eastern Finland, University of Helsinki, Tampere University, University of Turku, University of Oulu

The Finnish Research Infrastructure for Public Opinion

The Finnish Research Infrastructure for Public Opinion (FIRIPO) is a multidisciplinary collaboration for the study of public opinion, attitude formation and choice behaviour. FIRIPO serves a broad spectrum of various academic disciplines and scholars around the world. FIRIPO will also inform societal actors, especially decision-makers and the media.
Through large-scale panel data design, FIRIPO is able to track developments in public opinion and also to quickly respond to any needs concerning public opinion in current political issues. FIRIPO also facilitates laboratories for experimental research.

As a research infrastructure, FIRIPO has three central aims:

- JSystematise and coordinate scientific research on public opinion in Finland
- Learn, develop and share (new) methods in public opinion research
- Facilitate an open-access platform for survey research and experimental research on public opinion and choice behaviour.

FIRIPO is currently in its first funding period and still in a construction phase. At the end of this period, the plan is to consolidate the services under the FIRIPO portal, so that access to all parts of the infrastructure is easily available via a single gateway.

- **Website of research infrastructure:** www.firipo.fi
- **Responsible party (organisation:** Åbo Akademi University
- **Other parties (organisations):** University of Turku, Tampere University

Services offered by research infrastructure

- Citizen panel, a public opinion survey pool of respondents for online surveys (current n=4,250) www.kansalaismielipide.fi
- Politician panel, a pool of local politicians for online surveys (current n=1,000)
- Swedish-language Barometer, public opinion survey pool of Swedish-speaking respondents for online surveys (current n=4,700) www.barometern.fi
- Decision-making labs
  - Tampere University https://webpages.tuni.fi/dmlab/public
  - University of Turku, https://pcrclab.utu.fi
- Deliberation Labs being built at Åbo Akademi University (operational as of January 2022)
- Ethnic minority panel (as of autumn 2022)
- Visiting scholars' programme (fully operational as of autumn 2021, after the reopening of societies).

Data archive.
Photo: Outi Törnblom.

The Finnish Social Science Data Archive (FSD) archives and disseminates digital research data collected to study Finnish society, people and cultural phenomena, and preserves the data in the long term. Most of the archived data comprise quantitative survey data and qualitative textual data. The data in FSD holdings have usually been collected for research purposes. The FSD actively acquires new data for archiving and supports the re-use of data in various ways.

The archived datasets are mainly disseminated for research, teaching and learning purposes. Some datasets are freely available for any purpose. The data at the FSD are suitable, among others, for research, teaching and study in the fields of social sciences, humanities, education and health sciences. The FSD also has data depositors and users from several other fields and disciplines.

The FSD is a national resource centre that acts as a service provider in the Consortium of European Social Science Data Archives, CESSDA ERIC. In addition, it coordinates the Finnish data collection of two international comparative survey programmes and the Finnish membership in the Inter-university Consortium for Political and Social Research, ICPSR, based in the USA.

The FSD is an expert organisation with skilled employees working on both the archival content and the technical infrastructure. They maintain existing services and develop and produce new ones in cooperation with national and international partners. The FSD was established in 1999 to fulfil a task appointed to the University of Tampere by the then Ministry of Education. FSD operations are funded by the Ministry of Education, Science and Culture, Tampere University and so-called external funders, the most notable of which is the Academy of Finland.

Services offered by research infrastructure

- Aila Data Service (research data deposit and download for re-use)
- data archiving services
- information services
- Data Management Guidelines
- Research Methods Guidebook
- textual data collection tool Penna
- Finnish Party Agenda Database Pohtiva
- FNESdata Longitudinal Survey Metadata Portal
- Tietomilli survey data comparison tool
- KUHA2 software for harvesting metadata
- provision of data descriptions for harvesting by joint data catalogues.

The Finnish Social Science Data Archive

- **Website of research infrastructure:** www.fsd.tuni.fi
- **Responsible party (organisation):** Tampere University

Earth-space research ecosystem

The Earth-Space Research Ecosystem (E2S) examines interactions between space and the atmosphere and the impact of natural phenomena occurring in these on our daily lives. The impacts of natural phenomena and their changes in near-Earth space and outer space are reflected in the topmost layers of the atmosphere, and eventually all the way to Earth. The conditions in space and the atmosphere are constantly changing, and the effects of these changes are evident in the cyclically variable thickness of the ozone layer, as geomagnetic activity and radio interference and in climate change, including the effects on the carbon cycle.

E2S monitors the transformation of space and northern environments from one season, year, decade and century to another. In our increasingly technology-driven and space-dependent society, the impacts of the changes must be taken into account so that established functions of society can be guaranteed in the future (incl. positioning, navigation, space security and satellite communications). Changes in the magnetic and particle and radio environment are often the result of events in near-Earth space and, in particular, of disturbances caused by solar storms. The effects of these disturbances extend to different parts of the atmos-

phere, from which they can be monitored by long-term, high-quality measurements.

E2S covers observations from the large-scale measurement areas at Tähtelä and Metsähovi. Both of these megasites are among the world's most diverse research areas. The Tähtelä space campus in Sodankylä and the Metsähovi Radio Observatory together form an internationally unique infrastructure that covers measurements and expertise from distant and near-Earth space to the atmosphere and the surface of the Earth. The measuring equipment is capable of extensively monitoring with a frequency coverage of MHz–GHz and the relevant shorter wavelength bands (UV, VIS, NIR, IR). The measurements collected over the past 150 years enable a versatile examination of the conditions in the Arctic region and space.

The comprehensive measurements of the E2S infrastructure monitor the situation of space and the Arctic region throughout the year, at all times of the day. The measurements are made on the surface of the Earth using magnetometers, all-sky cameras, radio telescopes and antennae, riometers, radars, VLF sensors, satellite signal reception stations,

satellite lasers and spectrometers of different wavelengths, as well as drones and space satellites. The E2S infrastructure includes self-built measuring devices based on its own inventions and customised sensor systems.

E2S enables solutions to research issues affecting our everyday lives and facilitates a versatile understanding of our living environment. The infrastructure looks for answers to, among other things, the best way to distinguish between natural and artificial positioning disturbances, how different natural threats affect our lives and shape our living environment, how precisely and within what time frame the impacts of climate and geo threats can be predicted, what needs to be taken into account in the planning of society's activities and how best to protect against extreme effects.

Snow-clearing at a FinnRef station.
Photo: Topi Rikkinen.

Services offered by research infrastructure

- Observatory-level continuous measurements since 1914 and individual periods from previous decades; meteorological measurements, atmospheric scans and long-term 24/7 monitoring of changes and disturbances in the magnetic and radio environment.
- Comprehensive monitoring of environmental disturbances and natural hazards in the MHz–GHz frequency band and in the frequency bands of visible light, UV and infrared radiation.
- Identification of natural radio interference, separating it from artificial radio interference, and expertise in near-Earth and outer space radio interference.
- Monitoring solar activity and solar storms as well as new solar activity indicators.
- Knowledge and browser-based quick-look images of disturbances in the magnetic environment, space air and space weather, including the pulsation and auroral oval.
- Continuous monitoring of relevant in situ quantities related to carbon and water cycle in different ecosystems (carbon flux, snow cover, soil moisture and ground frost, vegetation physiology) as well as campaign measurements and expertise.
- Customised drones, drone measurement platforms and drone solutions for the mapping of challenging measuring sites and campaign measurements.
- Reception of satellite-based measurements and satellite communication services as well as CAL-VAL methods for calibrating and validating satellite data.
- Tähtelä and Metsähovi science days in alternate years as well as intensive education, field courses and a platform for international research visits, including technical support and accommodation facilities.

- **Website of research infrastructure:** www.oulu.fi/sgo/e2s
- **Responsible party (organisation):** Sodankylä Geophysical Observatory (University of Oulu)
- **Other parties (organisations):** Metsähovi Radio Observatory (Aalto University), Finnish Meteorological Institute, National Land Survey of Finland

Digitisation at the Finnish Biodiversity Information Facility (FinBIF). Photo: Leif Schulman.

Services offered by research infrastructure

- Provision of biodiversity data on the Laji.fi portal. Through compiling a consolidated body of big data, FinBIF enables researchers to identify past, current and rapidly evolving biodiversity patterns, and facilitates their analysis together with explanatory variables.

- A reference library of DNA barcodes of Finnish species created by the Finnish Barcode of Life project and distributed through FinBIF. This enables the identification of species based on DNA.

- Imaging of specimens. Researchers and teachers may acquire high-resolution images or 3D scans of specimens for analysis and for illustrations in publications or teaching material.

- Data management services. A Collection Management System has been developed and provided to all Finnish natural history collection institutions. Tailor-made entry and management platforms for observational data are created for research and standardised data-gathering projects. Advice on data management is given to research groups.

- Educational services. An e-learning environment of the University of Helsinki is integrated with FinBIF's IT systems and data resources. FinBIF hosts iNaturalist Finland, which can be used for training in species identification.

- Research use services. FinBIF designs tools for the visualisation and analysis of the data delivered at its portal. A data dashboard and an R programming language interface to the FinBIF API are provided, several analysis tools are under planning.

Finnish Biodiversity Information Facility

The research infrastructure (RI) FinBIF was established to accelerate the digitisation, mobilisation and open-access distribution of biodiversity data, and to boost its use in research, decision-making, education and business.

FinBIF is a distributed but integrated e-infrastructure. It includes multi-source data mobilisation, ICT development for data management and distribution, data management and analysis services, and a cross-sectoral network of data providers and users. Data providers and data-generating processes feed data to existing or FinBIF-made databases from which they go through a standardisation and annotation process into FinBIF's data warehouse to form one fit-for-use data mass controlled for legal use restrictions. The open data and services are provided through a one-stop-shop portal at https://laji.fi/. A small share of the data is restricted-use data provided to authorised officials through a parallel portal, but also to researchers, on a discretionary basis, through a data request service.

FinBIF is in an operational stage but service development for additional research areas continues.

FinBIF's core national partners are the country's five largest natural history collection (NHC) institutions: the Finnish Museum of Natural History (Luomus) of the University of Helsinki, the Biodiversity Units of the Universities of Oulu and Turku, and the NHCs of Jyväskylä University and the City of Kuopio. In the ongoing development cycle (ends in 2022), also Natural Resources Institute Finland takes part, and the Finnish Environment Institute (SYKE) joined the core consortium in 2021.

FinBIF is the national node of the Global Biodiversity Information Facility (GBIF), of which Finland is a member. FinBIF core partners also form the national node of the Distributed System of Scientific Collections (DiSSCo), an ESFRI roadmap RI.

- **Website of research infrastructure:** www.laji.fi
- **Responsible party (organisation):** Finnish Museum of Natural History Luomus, University of Helsinki
- **Other parties (organisations):** Biodiversity Unit, University of Oulu; Biodiversity Unit, University of Turku; Jyväskylä University Museum, Kuopio Natural Science Museum; Finnish Environment Institute (SYKE)

European Plate Observing System FIN-EPOS

Equipment of the FIN-EPOS research infrastructure.
Photo: FIN-EPOS.

The European Plate Observing System EPOS (www.epos-eu.org) is a multidisciplinary distributed ESFRI landmark research infrastructure that facilitates the integrated use of data, data products and facilities from the solid Earth science community in Europe. EPOS brings together Earth scientists, national research infrastructures, information and communication technology experts, decision-makers and the general public to develop new concepts and tools for accurate, durable and sustainable answers to societal questions concerning geo-hazards and those geodynamic phenomena (including geo-resources) relevant to the environment and human welfare. EPOS will simplify and speed up the process of combining information from different fields of geophysics, and it aims to be the principal source of open access geoscientific data and tools in Europe.

FIN-EPOS is a coordination consortium and the Finnish national node of EPOS. FIN-EPOS partners own and operate Earth science observatories, laboratories and data centres in Finland that will be delivering data to eight out of ten EPOS thematic core services – TCSs: Seismology, GNSS Data and Products, Geomagnetic Observations, Anthropogenic Hazards, Multi-scale Laboratories, Geological Information and Modelling, Satellite Data, and Geo-Energy Test Beds for Low Carbon Energy.

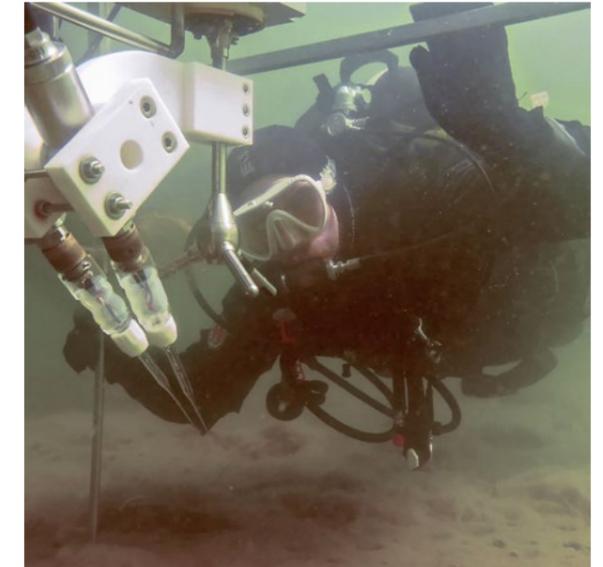FIN-EPOS is in many ways like a mini-EPOS and, thus, it has components at planning, implementation and operational phases. FIN-EPOS has a coordination office at the Institute of Seismology of the University of Helsinki and a council that is responsible for setting a long-term national Solid Earth Sciences RI plan, monitoring the data delivery to EPOS TCSs, transnational access and usage of mobile instrument pool. It is also responsible for enhancing Finnish participation in European and Nordic-level initiatives related to EPOS and for increasing the user base of EPOS data. Finland is due to become a full member of EPOS ERIC in 2022.

Services offered by research infrastructure

- EPOS aims to develop a holistic, sustainable and multidisciplinary research platform that provides coordinated access to harmonised and quality-controlled data from diverse Earth science disciplines together with tools for their use in analysis and modelling.

- EPOS will ensure that new data products are accessible to both researchers and users across the wider society.

- FIN-EPOS partners offer online open access to their data, data products as well as transnational access to laboratories and observatories.

- The FIN-EPOS website offers information on EPOS and FIN-EPOS partners' services for large variety of stakeholders such as Finnish academia, students, decision-makers, industry, media and citizens.

- The FIN-EPOS web platform will offer open access to multidisciplinary datasets, online activities, software, computing and imaging facilities.

- **Website of research infrastructure:** www2.helsinki.fi/fi/infrastruktuurit/fin-epos

- **Responsible party (organisation):** University of Helsinki

- **Other parties (organisations):** Aalto University, CSC – IT Center for Science Ltd, Finnish Geospatial Research Institute, Finnish Meteorological Institute, Geological Survey of Finland, VTT Technical Research Centre of Finland Ltd, University of Oulu

Finnish Marine Research Infrastructure

FINMARI, the Finnish Marine Research Infrastructure, combines all major components of the Finnish marine research community. It is a distributed infrastructure network of field stations, research vessels, gliders, laboratory facilities, ferryboxes, fixed measurement platforms, profiling buoys and multiple autonomous platforms, providing a unique hub for observational and experimental marine research facilities.

FINMARI has developed a strategic, long-term approach to utilise the specific strengths of the partnership in addressing multiscale variability of the marine environment. This is done through synergetic integration of the research foci and RI competence profiles of the partnership (marine ecology, geology, physics, chemistry, biology, fisheries, blue economy, societal impacts). The approach emphasises next-generation survey tools, necessary to address the physical dynamics of the system and the embedded chemical and biological processes. In parallel, novel automated experimental facilities are a priority, targeting especially biodiversity and ecosystem function research, organism traits, climate change experimentation, and facilitation of Blue Growth potential of coastal seas.

FINMARI is evolving towards a cutting-edge, integrated marine RI, openly accessible for research and education, delivering comprehensive, sustainable and high-quality open-access data from the marine environment and facilitating excellence in marine research across disciplines. It excels from basic sciences to highly applied topics, impacting widely the society through data provision, novel services, and collaborative actions. Through wide collaboration at the European scale, FINMARI strengthens the impact of Finnish marine research on the leading international level.

Marine research diver at work.
Photo: Alf Norkko.

Services offered by research infrastructure

- data, data-driven products and information
  - real-time or near-real-time operational oceanographic data
  - observational data with delayed mode availability
  - project-based field observations
  - data from experimental field or laboratory setups
- physical access to infrastructures
- remote access to infrastructures
- access to biological and physical materials
- services related to sensor maintenance, method validation and calibration
- coordinated provision of best practices and open source code

- **Website of research infrastructure:** www.finmari-infrastructure.fi
- **Responsible party (organisation):** Finnish Environment Institute (SYKE)
- **Other parties (organisations):** University of Helsinki/Tvärminne Zoological Station, University of Turku/Archipelago Research Institute, Åbo Akademi University/Husö Biological Station, Finnish Meteorological Institute, Geological Survey of Finland, Natural Resources Institute Finland

Pallas Research Station.
Photo: Juha Hatakka.

Integrated Atmospheric and Earth System Research Infrastructure

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- **Website of research infrastructure:** www2.helsinki.fi/en/inar-institute-for-atmospheric-and-earth-system-research/infrastructure/national-research-infrastructures
- **Responsible party (organisation):** University of Helsinki
- **Other parties (organisations):** Finnish Meteorological Institute, University of Eastern Finland, Tampere University, Natural Resources Institute Finland, Finnish Environment Institute, CSC – IT Center for Science Ltd, University of Oulu, University of Turku, University of Jyväskylä

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The INAR RI coordinates the Finnish national contributions to four ESFRI (European Strategy Forum on Research Infrastructures) RIs: ICOS (Integrated Carbon Observation System), ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure), eLTER (Integrated European Long-Term Ecosystem, Critical Zone & Socio-Ecological Research Infrastructure) and AnaEE (Infrastructure for Analysis and Experimentation on Ecosystems).

The INAR RI integrates the nationally operated sites and platforms into a benchmarking RI in the atmosphere-ecosystem domain both nationally and internationally. The key strength of the INAR RI is the comprehensive and multidisciplinary scientific understanding, with continuous long-term observations, extensive field and laboratory experiments, use of remotely observed data, and advanced modelling, leading to groundbreaking insights into different atmosphere-ecosystem processes, and to innovative method and instrument development at co-located sites and platforms. Long-term integrated observations in the atmosphere-ecosystem domain will help societies to respond and find best practices related to climate change mitigation and adaptation, land-use change, environmental degradation and poor air quality.

The INAR RI facilities currently include 30 sites (17 co-located), eleven laboratories and mobile units and two data infrastructures. The cornerstones of the INAR RI are the highly instrumented core stations such as the SMEAR stations (Stations for Measuring Earth Surface-Atmosphere Relations) and Pallas-Sodankylä GAW (Global Atmosphere Watch), which provide co-location of measurements for the four environmental ESFRI RIs.

Each INAR RI sister RI is proceeding in different phases at European level and therefore some INAR RI components are already established while others are still under development. However, the national parts of INAR RI are in operation and delivering data. In the next years, the INAR RI community will continue to work towards integrating the environmental measurements, upgrading the existing observational sites and exploratory platforms to guarantee and improve the representativeness and quality of the measurements, establish new measurement sites and develop services. In addition, the INAR RI continues to be active on the European level. Outside Europe, it coordinates and supports the building of the global SMEAR station network.

Services offered by research infrastructure

- The INAR RI provides a wide set of services and its user groups are diverse including local and global scientific communities, policymakers, public authorities, the private sector, students, non-governmental organisations (NGOs) and civil society.
- INAR RI services include open access to comprehensive multidisciplinary long-term atmosphere-ecosystem observation data, quality-controlled data products, data-model interfaces, physical and remote access to the measurement stations and experimental platforms, staff training, hands-on training and support for activities at the sites, help in troubleshooting instrument malfunctions, state-of-the-art instrument development, in-depth calibration, and development and benchmarking new technologies.

Forest ecosystem research with equipment of the Scan4est research infrastructure. Photo: Harri Kaartinen.

Measuring Spatiotemporal Changes in Forest Ecosystem

The long-term vision is that the knowledge and experiences gained using the Measuring Spatiotemporal Changes in Forest Ecosystem Research Infrastructure (Scan4est RI) will help to

- understand spatiotemporal forest structure and functions,
- understand processes and events affecting them and

- create a mobile technology that allows highly automatised monitoring of single trees growing in varied forest environments and building of a digital replication of the monitored trees, tree communities and forested landscapes.

Then, for each tree, essential characteristics, such as health, structural and functional development, wood proper-

ties and their variation can be linked, allowing scientists to answer important research questions, build new scientific knowledge and support multidimensional societal decision-making at varying resolutions of space and time.

Understanding complex forest ecosystems requires long time series of repeated measurements, as the process of cyclic forest growth can last centuries while having variation at diurnal and annual scales. The main scientific challenges this research infrastructure (RI) is aimed at, but not limited to, are the unexplored and open problems relating to tree-growth allocation and wood-formation processes that are important for leading scientists in this field globally.

The foundations of the RI consist of the following elements:

- Laser-scanning change monitoring infrastructure (incl. elements for terrestrial and airborne laser scanning)
- Experimental and automated laser-scanning infrastructure for tree characterisation
- X-ray microdensitometer for measuring wood properties
- Test site and key characteristics of trees.

The RI consists of detailed measurements from some 10,000 trees growing in varying environmental conditions at the Evo test site in southern Finland. A 30-year time series with annual measurements will be collected using various laser-scanning sensors for investigating single tree growth processes and forest dynamics. In addition to scientific challenges, Scan4est RI aims to solve a global technological forest measurement challenge and develop disruptive forest monitoring solutions based on laser scanning and point cloud processing technologies that can be used

to collect detailed time series from trees and tree communities with a fraction of the cost and set up in varying forest conditions for supporting science, business and societies as a whole. New positioning technologies, new concepts and point cloud processing algorithms to derive structural and functional characteristics of trees will be tested in the RI.

In addition to its contribution to science and multiple use of forests, Scan4est is the only RI serving the R&D needs of the forest industry and many small and medium enterprises operating in the field of natural resources. The PIs have been using and building some of the RI elements since 2007. Scan4est is the key RI for the UNITE Flagship and 16 other scientific projects that are currently running. The RI is in the construction phase (2020–2026), but it is expected that the first datasets will be available in 2021.

- **Website of research infrastructure:** www.scanforest.fi
- **Responsible party (organisation)/Other parties (organisations):**
  Finnish Geospatial Research Institute, University of Eastern Finland

Services offered by research infrastructure

- Detected individual trees for the whole Evo forest.
- Multitemporal monitoring plots and their point clouds.
- Experimental datasets for method developers.
- Site environmental conditions.

7. Links

- **Act on the Academy of Finland (20.11.2009/922)**
  [https://www.finlex.fi/fi/laki/kaannokset/2009/en20090922.pdf]

- **Strategy for National Research Infrastructures in Finland 2020–2030**
  [https://www.aka.fi/globalassets/1-tutkimusrahoitus/4-ohjelmat-ja-muut-rahoitusmu-odot/4-tutkimusinfrastruktuurit/aka_tik_strategia_2019_en_digi_a.pdf]

- **FIRI Committee policy: Characteristics of the administrative ownership of national research infrastructures (in Finnish)**
  [https://www.aka.fi/globalassets/1-tutkimusrahoitus/4-ohjelmat-ja-muut-rahoitusmu-odot/4-tutkimusinfrastruktuurit/tik-linjaus-kansallisten-tutkimusinfrastruktuurien-hal-linnollisen.pdf]

- **FIRI Committee policy: Characteristics of funding for research infrastructures (in Finnish)**
  [https://www.aka.fi/globalassets/1-tutkimusrahoitus/4-ohjelmat-ja-muut-rahoitusmu-odot/4-tutkimusinfrastruktuurit/tik-linjaus-tutkimusinfrastruktuurien-rahoituksen-tun-nusmerkit.pdf]

- **National roadmap for research, development and innovation**
  [https://okm.fi/en/rdi-roadmap]

8. Appendices

Appendix 1. Members of the Finnish Research Infrastructure Committee from 1 July 2019 to 30 June 2022

Chair	**Vice President for Research Riitta Maijala**, Academy of Finland
1st Vice Chair	**Director Erja Heikkinen, Ministry of Education**, opetus- ja kulttuuriministeriö
2nd Vice Chair	**Vice President for Administration Ossi Malmberg**, Academy of Finland
Members	**President and CEO Johanna Buchert**, Natural Resources Institute Finland
	President and CEO Johanna Buchert, Natural Resources Institute Finland Anni Huhtala, Associate Research Professor, VATT Institute for Economic Research
	Professor Juha Hämäläinen, Research Council for Culture and Society, Academy of Finland
	Rector Keijo Hämäläinen, University of Jyväskylä
	Rector Jukka Mönkkönen, University of Eastern Finland
	Rector Ilkka Niemelä, Aalto University
	Senior Director Arto Pussinen, Business Finland
	Rector Riitta Rissanen, Lapland University of Applied Sciences
	Professor Mika Rämet, Research Council for Biosciences, Health and the Environment, Academy of Finland
	Vice-rector Hanna Snellman, University of Helsinki
	CEO Antti Vasara, VTT Technical Research Centre of Finland
	Professor Minnamari Vippola, Research Council for Natural Sciences and Engineering, Academy of Finland
	Rector Mari Walls, University of Tampere
Permanent expert	**Counsellor of Education Petteri Kauppinen**, Ministry of Education, Science and Culture
Secretariat	**Senior Science Adviser Merja Särkioja**, Academy of Finland
	Science Adviser Paula Leskinen, Academy of Finland
	Science Adviser Marjut Kaukolehto, Academy of Finland (from 1 February 2022)
	Coordinator Tiina Ilo, Academy of Finland

Abbreviations

AALTO	Aalto University	FCCI	Finnish Computing Competence Infrastructure
ACTRIS	Aerosol, Clouds and Trace Gases Research Infrastructure	FINBB	Finnish Biobank Cooperative
ALD center	Research infrastructure for atomic layer deposition and etching	FinBIF	Finnish Biodiversity Information Facility
AnaEE ERIC	Infrastructure for Analysis and Experimentation on Ecosystems	FINMARI	Finnish Marine Research Infrastructure
BBMRI	Biobanking and Biomolecular Resources Research Infrastructure	FinnLight	Finnish National Infrastructure for Light-Based Technologies
BF	Biocenter Finland	FinStruct	Integrated Structural Biology Infrastructure Instruct-ERIC Centre Finland
BIOECONOMY RI	Bioeconomy research infrastructure	FiQCI	Finnish Quantum Computing Infrastructure
CERN	European Organization for Nuclear Research	FIRI	Finnish Research Infrastructure
CESSDA	Consortium of European Social Science Data Archives	FIRI Committee	Finnish Research Infrastructure Committee
CLARIAH	Social sciences and humanities research infrastructure consortium combining FIN-CLARIN and DARIAH-FI	FIRI-PBS	Finnish Research Infrastructure on Population Based Surveys
CLARIN	Common Language Resources and Technology Infrastructure	FIRIPO	The Finnish Research Infrastructure for Public Opinion
CSC	IT Center for Science Ltd.	FUWIRI	Research Infrastructure for Future Wireless Communication Networks
E2S	Earth-space research ecosystem	GBIF	Global Biodiversity Information Facility
EATRIS	European Advanced Translational Research Infrastructure	GL	Finnish Geodetic Institute
EFDA-JET	European Fusion Development Agreement, Joint European Torus	GTK	Geological Survey of Finland
EISCAT	European Incoherent Scatter Association	HUS	Helsinki and Uusimaa Hospital District
ELIXIR	European Life-Science Infrastructure for Biological Information	HY	University of Helsinki
EMBC	European Molecular Biology Conference	HYKS	Helsinki University Central Hospital
EMBL	European Molecular Biology Laboratory	ICDP	International Continental, Scientific Drilling Program
EPOS	European Plate Observing System	ICOS	Integrated carbon Observation System
ERIC	European Research Infrastructure Consortium	IL	Finnish Meteorological Institute
ESA	European Space Agency	IML	Institute Mittag-Leffler
ESFRI	European Strategic Forum on Research Infrastructures	INAR RI	Integrated Atmospheric and Earth System Research Infrastructure
ESO	European Southern Observatory	INFRAFRONTIER	The European Research Infrastructure for the generation, phenotyping, archiving and distribution of model mammalian genomes
ESRF	European Synchrotron Radiation Facility	INSTRUCT	Integrated Structural Biology Infrastructure
ESS	European Social Survey	IODP	Integrated Ocean Drilling Program
EU-OPENSCREEN	European Infrastructure of Screening Platforms for Chemical Biology EU-OS Finland	ISY	University of Eastern Finland
EURO-ARGO	European contribution to the ARGO Program	ITER	International Thermonuclear Experimental Reactor
Euro-BioImaging	European Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences	JHR MTR	Jules Horowitz Materials Testing Reactor
EuroHPC	European High Performance Computing Research Infrastructure	JY	University of Jyväskylä
FAIR	Facility for Antiproton and Ion Research	JYFL-ACCLAB	Finnish Accelerator Centre and Technology Hub

KA	The National Archives of Finland	TIN	Research and Innovation Council
KOTUS	Institute for the Languages of Finland	TK	Statistics Finland
KSSHP	Central Finland Hospital District	TTL	Finnish Institute of Occupational Health
KYS	Kuopio University Hospital	TTY	Tampere University of Technology
LUKE	Natural Resources Institute Finland	TY	University of Turku
LUMI	Supercomputer LUMI	TYKS	Turku University Hospital
LUT	Lappeenranta-Lahti University of Technology	VTT	VTT Technical Research Centre of Finland Ltd
LVM	Ministry of Transport and Communications	VY	University of Vaasa
MAX IV	Synchrotron Radiation Facility	ÅA	Åbo Akademi University
MML	National Land Survey of Finland		
NeIC	Nordic e-Infrastructure Collaboration		
OKM	Ministry of Education, Science and Culture		
OtaNano	Otaniemi Micro- and Nanotechnology Research Infrastructure		
OY	University of Oulu		
OYS	Oulu University Hospital		
PII	Printed Intelligence Infrastructure		
PPSHP	North Ostrobothnia Hospital District		
PRACE	Partnership for Advanced Computing in Europe		
RAMI	Circular Raw Materials Research Infrastructure		
RDI	Research, development and innovation		
RRF	Recovery and Resilience Fund		
RRP	Recovery and Resilience Plan		
Scan4est	Measuring Spatiotemporal Changes in Forest Ecosystem		
SPR	Finnish Red Cross		
STM	Ministry of Social Affairs and Health		
SYKE	Finnish Environment Institute		
TAU	Tampere University		
TAY	University of Tampere		
TAYS	Tampere University Hospital		
TEM	Ministry of Economic Affairs and Employment		
THL	Finnish Institute for Health and Welfare		

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