



Photo: iStock.com

# 8

## Research and systematic observation

This chapter describes Finnish research on climate change and systematic observation systems. Policies, framework and financing of the research, international research cooperation and major research programmes and research organisations are presented. Studies on climate processes and systems, climatic modelling and prediction, research that supports the greenhouse gas inventory as well as research on impacts, mitigation and adaptation are also covered. Atmospheric, ocean, terrestrial and cryosphere climate observing systems are portrayed. In the end of the chapter there is a summary of the Finnish contribution to capacity building in developing countries, supplementing reporting in Chapter 7.

# 8 Research and systematic observation

## 8.1 General policy on research

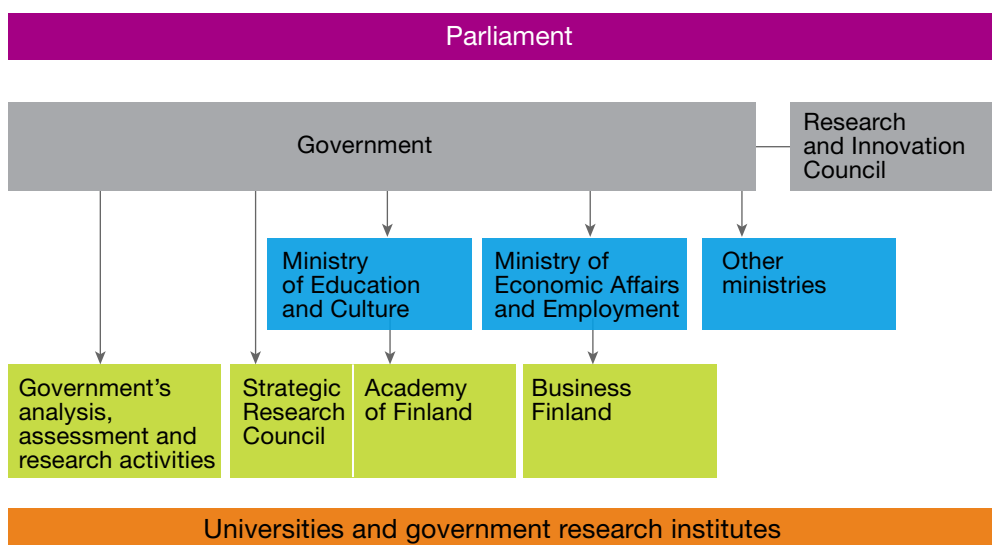
### 8.1.1 Domestic activities

In 2020, Finland’s research and development (R&D) expenditure was EUR 6,930 million, or 2.94 per cent of the country’s gross domestic product. It is a higher percentage than the average among the OECD and European Union countries. The national R&D expenditure has been rising since 2016. In 2020, 67 per cent of the R&D expenditure was in the private sector, around eight per cent in the public sector and around 25 per cent in the higher education sector. Funding of systematic observations is discussed in Section 8.3.

Regarding financing of public sector R&D, 46 per cent was financed from central government budget funds. The budget funding of this share increased by two percentage points compared to 2019. Research organisations’ own finances accounted for seven per cent. The architecture of public research funding is described in Figure 8.1. The distribution of public R&D funding in 2020 is presented in Figure 8.2.

In 2020, a total of 80,560 people worked in R&D positions, of whom 52 per cent worked in companies, 39 per cent in higher education institutions, and nine per cent in the public sector.

**Figure 8.1**  
Public research funding architecture.

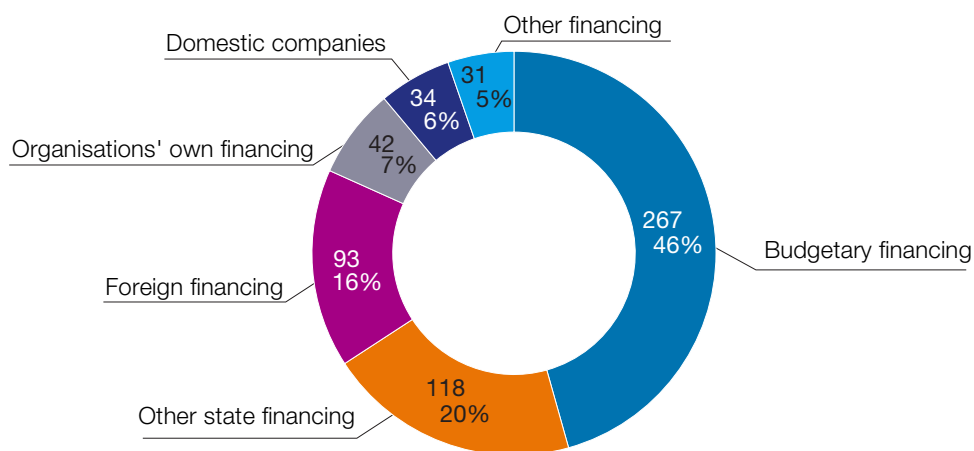


The Research and Innovation Council, chaired by the Prime Minister, supports the Government in developing and combining visionary science, technology and innovation (STI) policy. The Academy of Finland is an expert organisation in science and research within the administrative branch of the Finnish Ministry of Education, Science and Culture. It funds high-quality scientific research (EUR 469<sup>1</sup> million in 2020<sup>2</sup>). The Strategic Research Council (SRC) established within the Academy of Finland funds high-quality research of great societal relevance and impact (EUR 55 million in 2020). Business Finland is a business operator consisting of a financing centre providing internationalisation and financing services and a company carrying out customer activities. Business Finland offers funding services for research groups that cooperate with companies or want to build their research into a new business and commercialise ideas (research funding of EUR 89 million in 2020)<sup>3</sup>. The Ministries' joint analysis, assessment and research activities (VNTEAS), coordinated by the Government, generate information that supports decision making, working practices and management by knowledge (annual funding approximately EUR 10 million).

Climate change has been recognised as an important topical subject in Finnish research policy for decades. Climate change research policies are cooperatively implemented by several ministries, and climate change continues to be a priority area in many research programmes and projects (see Section 8.2 for details). Large cross-sectoral climate change programmes have aimed to increase understanding of the scientific basis of climate change, as well as the impacts and options for mitigation and adaptation, including the addressing of environmental and socioeconomic questions. Research in general has been partly shifted to concern larger views and to promote knowledge-based decision making and management. In addition, the cross-cutting nature of climate change has been integrated into many environmental, sectoral and technology research programmes and projects.

**Figure 8.2**

Public research financing in Finland in 2020 (EUR million; per cent)



1 The sum also including Strategic Research Council's 55 million, mentioned below.  
 2 By Statistics Finland. Note that there was a lot of temporary funding in the budget in 2020 because of the Covid-19 pandemic, for example.  
 3 <https://tietopankki.businessfinland.fi/anonymousextensions/MyonnettyRahoitus/MyonnettyRahoitus.html>

Finland's Government Programme (2019) strongly includes aspects of climate change and climate policy. For example, it mentions that "Climate change, declining biodiversity and the overconsumption of natural resources are among the most critical issues facing humanity". Measures in the Programme include new climate policy decisions and nearly emission-free electricity and heat production by the end of the 2030s, reducing the carbon footprint of construction, and promoting the circular economy and climate-friendly food policy. In addition, the focus of taxation will be shifted to the taxation of environmental damage.

The instrument of the Government's annual plans for joint analysis, assessment, and research activities generates information that supports decision making, working practices, and management by knowledge. Climate change related research subjects have been on the plan since its presence from 2014. Subjects are clearly linked to the information needs and topics in the Government's decision-making processes.

There has been increasing interest in research infrastructures in Finland in recent years, and more competitive funding has become available. The Academy of Finland coordinates national research infrastructure investments. It also participates in European and international research infrastructures. The role of research infrastructures in the green and digital transitions has been recognised. Indeed, responsibility and sustainable development, as well as digital platforms and data, have been named among the six strategic development areas identified in the Strategy for National Research Infrastructures, 2020 to 2030<sup>4</sup>. The Integrated Carbon Observation System (ICOS) research infrastructure has been headquartered in Finland since 2014. Finland is also leading the implementation of the ESFRI<sup>5</sup> landmark Aerosols, Clouds and Trace gases Research Infrastructure (ACTRIS). ACTRIS will be coordinated from Finland. See Section 8.1.2 for more information.

Another of the six strategic development areas identified in the Strategy for National Research Infrastructures 2020 to 2030, is open access and collaboration. This, with the objective of digital platforms and data (mentioned in Chapter 8.1.1), seeks to advance the openness and accessibility of research infrastructure services and of data produced with research infrastructures. Research Infrastructures are expected to have a publicly available Data Management Policy that outlines the location and accessibility of data.

Open science is one of the spearheads of Finnish science policy, and it is promoted throughout the scientific community (see example in Box 8.1). Universities, state research institutes and other important higher education institutions and organisations have committed to the Declaration for Open

---

4 Strategy for National Research Infrastructures in Finland, 2020 to 2030 [https://www.aka.fi/globalassets/1-tutkimusrahoitus/4-ohjelmat-ja-muut-rahoitusmuodot/4-tutkimusinfrastruktuurit/aka\\_tik\\_strategia\\_2019\\_en\\_digi\\_a.pdf](https://www.aka.fi/globalassets/1-tutkimusrahoitus/4-ohjelmat-ja-muut-rahoitusmuodot/4-tutkimusinfrastruktuurit/aka_tik_strategia_2019_en_digi_a.pdf)

5 EU's European Strategy Forum on Research Infrastructures

Science and Research, 2020 to 2025 to improve the openness of science and research. The missions of the Declaration seek to promote openness as a fundamental value throughout the research community and its activities, strengthen the societal knowledge base and innovation, and improve the quality of scientific and artistic research outputs, and the educational resources based on them, and the fluid mobility and impact of research outputs throughout society. The promotion of open science is tightly linked to developing responsible practices for researcher evaluation in Finland. In addition to the open science policy within the country, Finland has been operating extensive capacity building programmes to promote the free and open exchange of information and expertise, as well as to support endogenous capacities and capabilities in developing countries. The capacity building programmes have focused on climate observations, research, higher education cooperation relevant to climate change mitigation and adaptation, and the sustainable use of forests (see Section 8.4). Free and open international exchange of data and information has been further promoted by participation in several international research programmes, networks and data collection schemes, and databases (see Chapters 8.1.2, 8.2, and 8.3).

The Active Open science policy is a tool to overcome barriers to the free and open international exchange of data and information. Publishing research results in peer-reviewed international journals is advocated in all fields of research. Open Access (OA) has steadily gained ground in Finland. In 2020, more than 70 per cent of peer-reviewed scientific articles written in Finland were OA publications. Finnish Scholarly Journals Online has become the main platform and service for Finnish OA journals. FinELib funds various international publishing platforms that support OA and/or pre-prints. Domestic research data services support all disciplines and research organisations in opening their data when possible. Finnish research organisations participate attentively in developing the European Open Science Cloud. Finland has invested heavily in developing and maintaining both local and international research infrastructures for environment and climate research. The final reports of research projects funded by the Academy of Finland show that researchers on environmental sciences especially have adopted open data and metadata as everyday practices in their research processes.

The “avoindata” (open data) portal<sup>6</sup> provides direct links to the available open data sources throughout Finland, including research institutes, national authorities, regional councils, and municipalities (see also Box 8.1).

---

6 [https://www.avoindata.fi/data/en\\_GB/dataset](https://www.avoindata.fi/data/en_GB/dataset)

## Box 8.1

### Open Datasets Example

As an example of realising the open science objectives, the Finnish Meteorological Institute (FMI) and the Finnish Environment Institute (SYKE) have set up online services that make it possible to search for, browse, and download the Institutes' datasets in machine-readable format free of charge. The technical implementation of the online services complies with the requirements laid down in the INSPIRE Directive (2007/2/EC) for the Member States of the European Union, and the content of the service is wider than that defined in the Directive. The INSPIRE Directive requires that Member States ensure that metadata are created for the spatial datasets and the services that are needed for the establishment of the Infrastructure for Spatial Information within the European Community; this needs to be done for the purposes of Community environmental policies or activities that may have an impact on the environment. The climate and weather-related data of FMI and SYKE, including information on floods and ecosystem change, are utilised in various economic sectors in Finland, e.g. transport, natural resource management, energy, IT, and education. Access to available sources can be gained through the dedicated www pages <http://www.syke.fi/opendata> and <https://en.ilmatieteenlaitos.fi/open-data-manual> or the general portal [https://www.avoindata.fi/data/en\\_GB/dataset](https://www.avoindata.fi/data/en_GB/dataset).

Communication on new research information to decision makers, other stakeholders, and the general public is very important (see also Chapter 9). The Finnish Climate Change Panel was nominated by the Ministry of the Environment for the first time in 2011 to enhance science policy interaction between climate and energy policy, as well as public discussion. The Finnish Climate Change Panel has been an active knowledge producer and partner in the field (Box 8.2). Furthermore, several recent initiatives have fostered engagement between societal actors and research to contribute to policy needs (Box 8.3).

## Box 8.2

### The Finnish Climate Change Panel

The Finnish Climate Change Panel is an independent advisory council of top-level Finnish scholars that promotes dialogue between science and policymaking. The Panel provides scientific advice for policymaking and reinforces interdisciplinary insight in the climate action of various sectors. The Panel is tasked with assessing climate policy documents and the sufficiency of the implemented measures to respond to the challenges of climate change. The Panel produces reports to support the preparation and implementation of climate policy and legislation in Finland.

In recent years, the Panel has been advising the Finnish government on the EU Fit for 55 package. It has focused on key issues in advancing

climate action in Finland to meet the 2035 greenhouse gas neutrality target – the problem of continuous peat and peatlands use, what needs to be considered for electrification and sector integration, and how to assess and measure climate adaptation. The Panel is also in the process of producing criteria to facilitate evaluation of climate policy justice in decision-making. The Panel has also focused on working more closely with climate advisory councils around the world.

According to the Finnish Science Barometer 2019<sup>7</sup>, the public's expectations are optimistic on science and the worldview. Science is believed to be the answer to many important issues. For example, the barometer argument that “the progress of climate change is a real and serious threat, which requires efficient action from political decision-makers” is supported by a majority (73 per cent). The percentage decreased from 2016 by nine percentage points. The percentage of those who disagree has increased between 2016 and 2019 from six to 14 per cent. Although the mitigation of climate change is seen as a relatively difficult task, optimism about the solutions is relatively high. About 50 per cent of the respondents thought that science has very good or fairly good abilities to provide solutions, which is, however, less than the confidence in the ability to solve energy issues, for which the corresponding figure was nearly 70 per cent. The high confidence may reflect the fact that media coverage of climate issues and solutions has remained at a high level.

### Box 8.3

#### Interaction and Cooperation as Cornerstones of Impactful Research

A major development in the field of research is the increasing emphasis on societal impact and interaction with various societal stakeholders. It has become broadly accepted that the urgency of complex societal challenges such as climate change requires closer interaction between researchers and decision makers. Several initiatives have fostered engagement between societal actors and research to contribute to policy needs.

The Strategic Research Council (SRC) is one of the new key science policy measures on this front (see 8.2.1). Every project funded by the SRC includes resources specifically devoted to interaction with society, and the programmes that specify the topics of projects to be funded focus on developing interaction with societal stakeholders. In addition, the creation of the Government's analysis, assessment, and research activities (VNTEAS) funds research that serves policy needs as defined by the Ministries. Research on climate change has been one of the focal areas for both SRC and VNTEAS (see 8.2.1). Furthermore, research institutes and universities are

7 [http://www.tieteentiedotus.fi/files/Tiedebarometri\\_2019.pdf](http://www.tieteentiedotus.fi/files/Tiedebarometri_2019.pdf) (in Finnish) [http://www.tieteentiedotus.fi/files/Sciencebarometer\\_2019\\_23122019.pdf](http://www.tieteentiedotus.fi/files/Sciencebarometer_2019_23122019.pdf) (in English)

increasingly paying attention to social interaction, including collaboration with industry and businesses and in other partnerships such as doctoral training.

A novel initiative in research communication has been “Sofi – Science Advice Initiative of Finland”. This development project (2019 to 2021) aimed to build a permanent science policy platform and promote interaction and dialogue between researchers and decision makers. Climate change was one of the topics addressed. The Sofi project was initiated by the four Finnish science academies and funded by the Ministry of Education and Culture. The Sofi project was carried out in close collaboration with universities and research institutes and other stakeholders and included workshops and training for researchers. From 2022 onwards, Sofi’s activities will be continued under the Finnish Academy of Science and Letters.

The science policy interface has also been strengthened in legislative processes to address climate change. The Ministry of the Environment has therefore published a guide on the assessment of climate impacts in legislative proposals. It is distributed as general guidance for improving the quality of the mandatory impact assessment of legislative proposals.

In 2021, the Ministry of Education and Culture, the Academy of Finland, and the Federation of Finnish Learned Societies conducted a joint initiative, “The Year of Research-Based Knowledge”. The initiative aimed to increase awareness of research and the importance of research-based knowledge among the general public, decision makers, and the private sector. One of the core aims was to increase the visibility and accessibility of different sources of knowledge (e.g. statistics, reports, and analyses) and highlighting the fundamental nature of science and knowledge, i.e. that knowledge is constantly updated and re-evaluated as new research results emerge. The Year was an open initiative: around 20 events were devoted to climate change or energy issues, but many more addressed related topics such as the transformation of the food system. Altogether, more than 400 events or other activities by 382 different actors (e.g. higher education institutes, research organisations, the administration sector, museums, and associations) were implemented as part of the Year.

There are also many other initiatives and actors in the field. Some are more recent; some are well established. The Forum for Environmental Information is an exemplary well-established non-profit organisation in the field of environmental research that focuses on transferring scientific information to national policymaking and advances the interaction between researchers and the users of information. It organises seminars, workshops, and other events concerning timely environmental questions. It is funded by the Nessling and Kone foundations (see also Foundations in Section 8.2.1).

## 8.1.2 International activities

Finnish researchers have collaborated actively with the international research community in the form of joint projects and programmes. Finland has participated in international programmes such as World Climate Research Programme (WCRP).



These have included many Finnish research projects funded by the Academy of Finland and other funding organisations. Key partners in Finnish climate research include the other Nordic countries, the United Kingdom, Germany and the United States.

Finland has built up an archive of systematic atmospheric, oceanic, and terrestrial observations based on the regulations of corresponding international organisations. Finland is participating in the World Weather Watch at an operational level through the synoptic network of surface and upper-air stations, as well as in the Global Atmosphere Watch.

Finland has actively participated in the work of the Intergovernmental Panel on Climate Change (IPCC). Several experts from Finland served as authors for the Working Group reports and the Special reports of the IPCC Sixth Assessment Report (AR6), and many more experts participated in the review process. Due to their widespread expertise, for example, in greenhouse gas inventories and land-use issues, Finnish experts have served as authors for the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

In another major effort, Finland is overseeing the implementation of the ICOS (Integrated Carbon Observation System) organisation, which is a European distributed infrastructure for the online in-situ monitoring of greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) necessary for understanding present and future sinks and sources. The ICOS Head Office is in Helsinki. The ICOS puts the GHG observations within the global GCOS (Global Climate Observing System) and GEOSS (The Global Earth Observation System of Systems) networks in Europe into effect, and the data can be used to verify greenhouse gas inventories. The partners of ICOS Finland are the University of Helsinki, the University of Eastern Finland, and the Finnish Meteorological Institute (FMI), with the University of Oulu and the Natural Resources Institute starting as partners in 2022. Finnish funding for the ICOS will be around EUR three million annually during its operational phase (more information on ICOS in Section 8.3.1).

Finland is also leading the implementation and establishment of the ACTRIS (Aerosols, Clouds and Trace gases Research Infrastructure) organisation, which is a European distributed research infrastructure for near-surface monitoring and research on short-lived climate forcers in the atmosphere. These are the other crucial group of components (besides greenhouse gases) for determining the atmospheric component of climate warming. ACTRIS is currently in the implementation phase. ACTRIS links research, education, and innovation to promote data use, technological developments, and demonstrations related to the atmospheric components of aerosols, clouds, and trace gases. The ACTRIS Head Office will be in Helsinki, with a secondary node in Rome. The partners of ACTRIS-Finland are the FMI, the University of Helsinki, the University of Eastern Finland, and Tampere University of Technology. In addition to

the Head Office, Finland hosts several National Facilities, and a Data Centre Unit for Cloud Remote Sensing and two calibration nodes on in-situ aerosol particles and trace gases in ACTRIS. Finnish funding for ACTRIS will be around EUR five million annually during its operational phase (ACTRIS is also presented in Section 8.3.1 under atmospheric observations).

Climate change is and has been a very important priority for the Horizon 2020 framework programme and the Horizon Europe funding programme, which is the EU's key funding programme for research and innovation from 2021 to 2027.

Finnish researchers, enterprises, and other actors participated actively in climate-change-related research and innovation activities under the Horizon 2020 framework programme for research and innovation. Between 2016 and 2021, 241 projects with Finnish participant organisations were funded under the Horizon 2020 programme. Of these, a total of 39 projects were led by a Finnish coordinator.

The Technical Research Centre of Finland Ltd (VTT), the Finnish Meteorological Institute (FMI), and the University of Helsinki were involved in the largest number of projects. The total costs of Finnish participants were approximately EUR 237 million, and the total costs of the projects EUR 2,293 million. EU funding from the Horizon 2020 budget for Finnish participants was EUR 188 million, and for those 241 projects a total of EUR 1,899 million.

Horizon Europe's new generation of objective-driven and ambitious partnerships are designed to work in support of agreed EU policy objectives. Partnerships bring the European Commission and private and/or public partners together to address some of Europe's most pressing challenges through concerted research and innovation initiatives. New Partnership models help avoid the duplication of investments and contribute to reducing the fragmentation of the research and innovation landscape in the EU. Examples of new co-funded partnerships directly participating in research and innovation connected with climate change on the verge of being adopted by the European Commission, and in which the Finnish research and innovation funders are involved, are Biodiversity, Blue Economy, and Water4All. The precise amount with which Finnish participants will fund these partnerships will be determined later.

The European Commission also has a completely new approach for how to approach and solve some large societal questions and problems, and climate change is the single most important challenge. The European Commission has created five Missions which will create more impact through mission orientation and citizen participation. Research and innovation will be key to deliver on the Missions, and Horizon Europe will be a critical component for their implementation. Missions will require an entire policy toolbox (regulations, policies, investments, etc.) at European level national and local levels to succeed. The Missions have ambitious goals, and they should deliver

concrete results by 2030. From the perspective of fighting climate change, the two main missions are Adaptation to Climate Change, which supports at least 150 European regions and communities in becoming climate resilient, and 100 Climate-Neutral and Smart Cities.

Some Joint Programming Initiatives (JPIs) (such as JPI Climate, FACCE JPI and Water JPI), networks and initiatives (such as Biodiversa, LEAP-Agri, LEAP-RE) connected with climate change remain from the previous funding programme period, existing and functioning alongside the new Horizon Europe partnerships, and they will run for several years in the future. The aim of JPIs is to strengthen research and research funding cooperation in Europe in the interest of addressing specific societal challenges. Finnish researchers have also succeeded in several joint calls of these initiatives. The Academy of Finland's International co-funding activities (related to its Climate Change and Health (CLIHE) research programme) are described in 8.2.1.

The Nordic countries have together committed to ambitious climate goals towards 2050 in terms of developing energy-efficient and low-carbon societies. The Academy of Finland has participated in two Nordic collaborative programmes: the Nordic Green Growth Research and Innovation Programme (2016 to 2020) led by NordForsk, Nordic Innovation, and Nordic Energy Research. They aim to accelerate the transition to a sustainable Nordic society by promoting green economic growth, sustainability, and competitiveness. NordForsk's Nordic Bioeconomy Programme (2015 to 2022) seeks to generate new knowledge about how to promote and advance the transition to a bioeconomy-based society in the Nordic countries.

NKL (the Nordic Working Group for Climate and Air) is a working group under the Nordic Council of Ministers. It continues the work of its predecessors – for example, the NOAK working group – and supports the Nordic countries in their preparations for the UNFCCC climate negotiations. The NKL produces studies for Nordic and international climate negotiators and arranges workshops supporting the negotiations. Finland was the chair of the NKL between 2019 and 2020.

Finland is actively engaged in the work of the Arctic Monitoring and Assessment Programme (AMAP), which is one of the permanent working groups of the Arctic Council. AMAP provides reliable information on the status of and threats to the Arctic environment by collecting monitoring data and assessing levels of pollutants and their effects on the Arctic environment. Monitoring and assessing the impacts of climate change on the Arctic environment is also one of the priority areas. Based on the scientific work, AMAP provides policy-relevant information to support Arctic governments in their efforts to take remedial and preventive actions relating to contaminants and climate change. AMAP publishes scientific assessment reports with summaries for policymakers that serve the scientific community, decision makers and the general public. For example, in 2021, AMAP published the “Arctic Climate Change Update 2021:

Key Trends and Impacts” and “Impacts of Short-Lived Climate Forcers on Arctic Climate, Air Quality and Human Health” reports.

Finland is a member country and currently the chair (for 2021 to 2023) of the Barents Euro-Arctic Council (BEAC), which is a forum for intergovernmental and interregional cooperation in the Barents Region. The Barents Region consists of the 13 northern regions of Finland, Sweden, Norway, and Russia. In Finland, the regions are Lapland, Oulu, and Kainuu. The Action Plan on Climate Change for the Barents Region was adopted in the autumn of 2013. It includes several measures and projects and identifies concrete actions to be carried out by the working group for the BEAC. The BEAC Working Group on Environment (WGE) focuses on the so-called Barents Environmental Hot Spots, where enhanced environmental and cleaner production measures will lead to CO<sub>2</sub> and black carbon emission reductions, among other things. The WGE is also implementing several climate-relevant activities in the Barents Region, such as promoting regional climate strategies, enhancing the network of protected areas, and arranging conferences and projects covering climate change mitigation and adaptation themes. More details on the climate research carried out in the Arctic can be found in Box 8.4.

Capacity building in developing countries related to climate change research and systematic observation is described in Section 8.3.4.

#### **Box 8.4**

#### **Climate Research in the Arctic**

##### **Arctic Research Policy and Goals**

Finland’s Strategy for Arctic Policy<sup>8</sup> was updated in 2021 and sets out Finland’s key objectives in the Arctic region. Arctic expertise, including livelihoods and leading-edge research, is one of the four priorities the strategy identifies. With respect to research, the policy is to invest in expertise and gain knowledge of northern areas. A diverse array of Arctic research is conducted by higher education institutions and research institutes. Expertise is also possessed by many companies. Arctic research policy is cooperatively implemented by several ministries.

International cooperation is seen as very important. Finland is an active member of the Arctic Council and its Working Groups. For example, Finland has contributed significantly to the Arctic Council’s Arctic Monitoring and Assessment Programme, AMAP, and to its recent reports related to climate change.

##### **Arctic Research Funders**

Many sectoral ministries are involved in the funding and steering of Arctic research in higher education institutes and research institutes.

---

8 [https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/163247/VN\\_2021\\_55.pdf](https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/163247/VN_2021_55.pdf)

The Academy of Finland, as a national research funding agency, funds high-quality scientific research projects. The Academy of Finland is also a stakeholder in Arctic research priorities.

As part of its operations, Business Finland can provide internationalisation and financing services and carry out customer activities related to business activities and opportunities.

### **Major Arctic Research Initiatives**

The Arctic Academy Programme (ARKTIKO, 2014 to 2018) was launched to study the changing factors affecting the development of the Arctic region; the transformation process; and the dynamics of change. The programme contributed to increasing knowledge and strengthening the position of Finnish Arctic research at the top of international rankings. It promoted the identification of novel research paths and therefore new solutions. It also promoted the networking of researchers and cooperation with concurrent international projects. ARKTIKO consisted of 20 national research projects and international collaborative joint research projects.

ARKTIKO especially aimed to strengthen the transdisciplinary and multidisciplinary approach within the field of Arctic research. Specifically, the programme aimed to generate new knowledge and approaches related to the sustainable development of individuals and communities in terms of social life, health, and culture; the sustainable exploitation of Arctic environments and natural resources; and the protection of sensitive Arctic ecosystems and securing the ecosystem services they produce. The Academy of Finland's total funding for the programme was EUR 15.7 million for 2014 to 2018. The results of the ARKTIKO programme will be evaluated soon.

Joint Projects in Arctic Research (funders the Academy of Finland and the Russian Foundation of Basic Research, RFBR) (funding 1.8 million EUR, 2018 to 2020) with the following themes: Changing Arctic climate, changing diseases; Ecosystem adaptation to the rapidly changing Arctic; Information technologies for exploration and geo-monitoring in the Arctic; and Youth's coping strategies in industrial towns in the north.

Arctic Seas Programme. The primary goal of this national programme is to strengthen Finland's reputation as an internationally attractive centre of Arctic expertise.

Universities in Lapland and Oulu strategically prioritise the Arctic region. Most Finnish universities and other academic institutions have research programmes focusing on the Arctic, the North, and cold climate regions.

Arctic Centre. The Arctic Centre conducts internationally recognised and highly regarded multidisciplinary research on the Arctic region. Its emphasis on science communication and on public exhibitions improves the visibility of Finland's Arctic expertise and increases international access to Arctic information.

The Finnish Meteorological Institute's (FMI) research focuses on understanding various climate forcing mechanisms and feedbacks in the Arctic, as well as linkages between the Arctic warming and mid-latitude weather. Processes in the atmospheric boundary layer and snow and

atmosphere-sea ice-ocean interactions are studied to improve capabilities to model the weather and climate.

The Finnish Environment Institute SYKE brings expertise in research to various projects in northern areas and in the Arctic Council's work. The Institute's expertise in environmental research jointly focuses on the impacts and scenarios of climate change and ways of securing sustainable development in Arctic areas with other research organisations such as the Natural Resources Institute Luke, which has particular expertise in the use and management of renewable natural resources.

### **Arctic Research Infrastructure**

The several field stations operated by universities and research institutes are bases for field campaigns and long-term follow-up studies with an Arctic focus and in the Arctic area. The long-term continuous measurements provide unique monitoring and research material, e.g. on greenhouse gases, atmospheric aerosols, clouds, and trace gases (by FMI at Pallas, Finland, and Tiksi and Baranovo in Russia) and by University of Helsinki at Värriö, Finland. Similarly, operational observations are needed to study feedback processes like polar ozone and Arctic snow.

The Finnish National Satellite Data Centre, located in Sodankylä north of the Arctic Circle, is an excellent location for receiving data from all polar orbiting spacecraft. The centre collaboratively provides Arctic satellite data and products for international research and operational entities.

The Finnish Marine Research Infrastructure (FINMARI) supports polar oceanography and sea ice research, e.g. the ocean and sea ice processes and climate interactions in the polar oceans to support the development and improvement of forecasts and operating models and services.

R/V Aranda is an ice-reinforced research vessel (ice classification Super A1) that mostly operates in the Baltic Sea, but it has also made expeditions to the Arctic Ocean. Finland has a fleet of icebreakers, several of which are multipurpose vessels capable of offshore tasks, including serving as research platforms. Finland also has special infrastructure for large-scale laboratory studies of Arctic conditions. Aalto University operates a large-scale ice tank infrastructure which can produce sea ice at model scales. In addition, there is also a special test facility for icebreakers, operated in Helsinki by a privately owned shipyard.

## 8.2 Research

### 8.2.1 Major overarching research programmes and funding organisations

#### **Government's analysis, assessment, and research activities**

Since 2014, the Government has adopted an approach based on annual plans for analysis, assessment, and research<sup>9</sup> which underpins policy decision making and steers studies and research towards specific priority areas selected by the Government. The annual resources available for implementing the plan amount to approximately EUR 10 million. Between 2018 and 2021, there have been 17 projects whose various topics were directly related to climate change. The projects have given the required new knowledge for policymaking in the various administrative sectors. The projects have been conducted by many different organisations such as universities, research institutes, and consultants and cumulatively amount to several million euros in research funding.

#### **Academy of Finland's research funding**

The Academy of Finland is a science and research organisation within the administrative branch of the Finnish Ministry of Education and Culture. In 2020, it funded high-quality scientific research amounting to EUR 469<sup>10</sup> million and EUR 55 million for its Strategic Research Council (SRC). In addition, it provides expertise in science and science policy and strengthens the position of science and research in Finland. The provision of funding for excellent scientific research is at the core of the Academy of Finland's activities. The research is also expected to have a major scientific and social impact and follow the principles of responsible science.

There has also been a notable increase in research funding for climate-change-related topics between this and the previous reporting period. The Academy of Finland's and the Strategic Research Council's (SRC) funding for climate-change-related research together totalled more than EUR 175 million between 2017 and 2021<sup>11</sup>. Research funding allocated to climate-change-related topics by the Academy of Finland and the Strategic Research Council increased significantly, from more than EUR 95 million to more than EUR 175 million between 2013 and 2016 (four years) and between 2017 and 2021 (five years). The increase is mainly due to strategic research funding since the establishment of the SRC in 2014, especially given that many of the ongoing SRC programmes are related to climate change (see below for more details).

---

9 <https://vnk.fi/en/government-s-analysis-assessment-and-research-activities>

10 The sum also including Strategic Research Council's 55 million, mentioned below.

11 with a narrow keyword analysis and considerably more with a more inclusive analysis

The Academy of Finland's ongoing climate and energy programmes:

- The Climate Change and Health (CLIHE) research programme (funding EUR 9.7 million, duration 2020 to 2023) examines and anticipates the health risks and uncertainties caused by climate change and the social consequences of its health impacts. The programme seeks ways to combat adverse health effects and adapting to climate change. The CLIHE programme also involves international cooperation with the Belmont Forum, in which the Academy of Finland participated with EUR one million for Finnish projects, funding three consortia under the Climate, Environment and Health theme. In addition, the Academy of Finland participated in the EU Joint Programming Initiative “Connecting Climate Knowledge for Europe” (JPI Climate) for EUR 700,000.
- The C1 Value Academy Programme (funding: EUR 6 million, 2020 to 2023) seeks solutions for industrial green chemistry manufacturing from CO<sub>2</sub> emissions. The programme's research fields include synthetic chemistry and catalysis research, process engineering and systemic studies, industrial ecology and biotechnology, as well as modelling based on them.
- The Academy Programme on a biobased economy (BioFuture2025, 2017 to 2025) was launched to support the creation of a new knowledge base and promote major scientific breakthroughs through new ways of doing science. A biobased economy promises solutions that will help curb climate change and excessive natural resource consumption. Funding in the first call totalled EUR 10.3 million euros between 2017 and 2020, after which there has been few international calls that continue the programme, including ForestValue – Innovating Forest-based Bioeconomy ERANET, co-funded for EUR 1.36 million and the ForestValue Joint Call 2021 for EUR 0.75 million.
- There is special funding for system-level research into climate change mitigation and adaptation (funding EUR 10 million, 2021 to 2024) for increasing the impact of the conducted research. The aim is to examine the entirety of several subsystems (e.g. food, transport, energy, community systems) and interdependencies between the systems in terms of mitigation of and/or adaptation to climate change. It is also to provide funding for the pooling of research already carried out and based on this for conducting new research, while increasing the impact of research outside the scientific community.
- The Academy of Finland is also responsible for funding Finland's Antarctic research projects. In accordance with Finland's Antarctic Research Strategy (2014), the funding supports interactive and multidisciplinary research.

In addition, a huge number of research projects in other Academy funding schemes, with no pre-set thematic focus besides research excellency, such as Academy Projects, Postdoctoral Researchers, Academy Research Fellows,



Centres of Excellence, research infrastructures and the Finnish Flagship Programme concern climate change (for an overall estimate of the Academy of Finland's and the Strategic Research Council's funding allocated to climate change research, see above). Among them, the Atmosphere and Climate Competence Center (ACCC) Flagship (2020 to 2024, involving 450 researchers) seeks ways to mitigate CO<sub>2</sub> emission sources and reliably verify them and assess the climate neutrality of mitigation measures and air quality management actions. There are also ongoing Centres of Excellence on climate change: Tree Biology (2022 to 2029) and the Virtual Laboratory for Molecular-level Atmospheric Transformations (2022 to 2029), in addition to the recent Centre of Excellence in Atmospheric Science – From Molecular and Biological Processes to the Global Climate (2014 to 2019).

To tackle this multitude of climate change research, the Academy of Finland has recently established the Academy Programme for Climate Change and Carbon Neutrality Research (Climate-Synergy) (no additional research funding, 2022 to 2023). The Climate-Synergy coaction programme pools research on climate change and carbon neutrality funded through various Academy of Finland and Strategic Research Council (SRC) grants, incorporating it into a broad network-based programme. As its name indicates, the Climate-Synergy programme aims to create synergies and strengthen the impact of climate change and carbon neutrality research and promote the utilisation of research in society. Through the programme, the Academy seeks to increase support for high-quality, innovative and high-impact research, promote national and international research cooperation and enhance the societal impact of research in the field.

The Academy of Finland also supports the implementation of Finland's national Recovery and Resilience Plan (RRP) (see Box 8.5), part of the Sustainable Growth Programme for Finland, with EUR 25 million in 2021 to promote the twin digital and green transition. The green and digital transition will support structural changes in the economy and the development of a carbon neutral welfare society through digital solutions. The funding is provided for research that promotes solutions related to carbon neutrality and adaptation to climate change, as well as associated digital technologies. In addition, the competitive funding calls for local and national infrastructures enabled by the Recovery and Resilience Facility are expected to accelerate their twin transition.

The recently finished Academy of Finland Research programmes for climate change and energy include:

- The Arctic Academy Programme (ARKTIKO, 2014 to 2018). See Box 8.3.
- The Academy Programme New Energy (2015 to 2018) harnessed scientific methods to resolve complex issues related to the great energy transition. Several projects, including joint calls with international partners, have received funding from New Energy.

## Programmes of the Strategic Research Council

The Strategic Research Council (SRC) is an independent body that was established within the Academy of Finland in 2014. The SRC funds high-quality long-term research of great societal relevance and impact. SRC-funded research seeks concrete solutions to grand societal challenges that require multidisciplinary approaches. An important element of the strategic research is active and ongoing collaboration between producers and users of knowledge throughout the project cycle.

Each year, the SRC prepares a proposal on key strategic research themes for the next SRC programmes to be decided by the Finnish Government. SRC funding combines bottom-up and top-down elements in a rather unique manner: the SRC formulates the theme proposal through an interactive participatory process with the scientific community and knowledge users. Through the theme decision, the Government determines the research needs for the next strategic research programmes. The SRC then formulates the programmes and opens the funding calls. Although the calls are thematic, they leave it to research consortia to define what multidisciplinary approach to take to tackle the societal challenge in question. SRC programmes typically run for six years. The SRC's annual funding budget is more than EUR 55 million.

The Strategic Research Council's (SRC) ongoing programmes relevant to climate change are the following:

- Adaptation and Resilience for Sustainable Growth (ADAPT) (funding EUR 34.4 million, 2018 to 2023). The aim of the programme is to identify the best ways of supporting comprehensive resilience through using the resources of society, communities and individuals and through new ways of combining these resources. Research is also needed to identify obstacles to adaptation, such as institutional path dependencies and social and cultural practices and to develop solutions to eliminate such obstacles.
- The Towards a Sustainable, Healthy and Climate-Neutral Food System (FOOD) (funding: estimated EUR 21.3 million, 2019 to 2025) programme seeks a solution for moving towards a sustainable, healthy and climate-neutral food system. Here, “food system” refers to the complex web of multilevel connections that tie together individuals, organisations, technology, and the environment, other production factors such as infrastructure, energy, fertilisers and pesticides, and biodiversity.
- The Climate Change and Humans (CLIMATE) (funding: estimated EUR 27.2 million, 2020 to 2026) programme seeks solutions to how people can make and implement their decisions related to mitigating or adapting to climate change, and how society can facilitate this decision making sustainably and equitably.

In addition, several ongoing Strategic Research Council (SRC) programmes (2018 to 2027) include research consortia relevant to climate change. These programmes encompass themes such as the sustainable use of resources by societies, communities and individuals, the halting of biodiversity loss with research-informed solutions, and steering social development. The recently finished Strategic Research Council (SRC) programmes (2015 to 2021) with similarly relevant research consortia included topics such as energy transition and renewable energy, the use of forest resources, the circular economy of non-renewable substances, resource-efficient food production, climate and resource scenarios in relation to security risks, urbanisation, and information requirements for decision making at various levels of society.

### Box 8.5

#### Rescue and Resilience Funding also Boosted Green Research

The Rescue and Resilience Plan (RRP), including an RDI funding package, supported the green transition with EUR 192 million. Finland's RRP intended to accelerate green transition solutions to facilitate significant reductions in greenhouse gas emissions in Finland to support the national carbon neutrality target. This has also boosted green research. The green transition will require robust expertise and related investments and the design and delivery of key technologies for the low-carbon circular economy and the green transition through research, partnerships and corporate investment.

The plan also supports the green transition through investments of EUR 319 million in the decarbonisation of the energy sector, namely in energy transmission and distribution and in new energy technologies. Furthermore, EUR 156 million will be invested in low-carbon hydrogen, as well as in carbon capture, storage and recovery. In addition, the plan supports the low-carbon heating of buildings by providing funding of EUR 70 million for the replacement of oil boilers with low- or zero-carbon heating systems. Concerning green transport, EUR 40 million will be invested in supporting private and public charging points for electric cars and the gas charging and refuelling infrastructure. EUR 161 million is available for the most promising carbon-free energy investments.

### Programmes of Business Finland

Business Finland (and its predecessor Tekes) has invested significantly in the long-term development of low-carbon solutions. Business Finland financed low-carbon energy solutions with an estimated EUR 2 billion between 2006 and 2019. Renewable energy sources and energy efficiency have been key targets. The adaptation to climate change has shifted from developing individual solutions to developing systemic and sustainable solutions.

Business Finland's programmes are important instruments for combating the effects of climate change and promoting carbon neutrality. The Smart Energy programme (EUR 151 million, 2017 to) supports internationalisation and exports. It catalyses and funds energy-related ecosystems and testbeds in

Finland and abroad. Focus segments are waste-to-value, bioenergy, biofuels, smart grids, district energy, hydrogen, power-to-X, and batteries. The Bio and Circular Economy programme (EUR 171 million thus far, 2019 to) supports the development of competitive bio- and circular economy solutions and ecosystems that offer solutions to global environmental challenges and offer potential for significant global markets. The Sustainable Manufacturing Finland programme (EUR 92 million, 2020 to) focuses on renewing business models and increasing productivity, while actively seeking solutions to the challenges of climate change. Although the programme covers manufacturing industries extensively, it emphasises machine tool industries, electronics and photonics, and companies in the industrial digital transformation industry. The aims of the Smart Mobility and Batteries from Finland programme (EUR 100 million, 2020 to) are mitigating climate change and finding flexible new mobility and logistics low-emission solutions. The programme helps Finnish companies benefit from business opportunities in transport, logistics, and mobility services and create a significant Finnish battery industry.

The mission concept is a new way of working for Business Finland. Missions aim to accelerate societal systemic changes and meet global challenges. Business Finland has launched two missions, Zero Carbon Future and Digital Native Finland. The Zero Carbon Future mission focuses on creating future wellbeing by increasing the global carbon handprint. The mission focuses on the energy transition and transport and mobility sectors. A significant amount of RRF funding (EU's Recovery and Resilience Facility) will be directed through Business Finland to projects related to the green transition.

### **Climate-change-related programmes by the ministries**

Ministries channel their research funding to climate-change-related topics through the research and expert organisations in their administrative sector, such as Business Finland and others, whereas some, like the Ministry of Agriculture and Forestry and the Ministry of the Environment have also allocated funds through specific research and development programmes or calls.

Through its research and development activities, the Ministry of Agriculture and Forestry of Finland aims to proactively produce knowledge, expertise, and innovations to support decision making, promoting the competitiveness of economic activities and ensuring the sustainable use of renewable natural resources. In 2020, the ministry launched the “Catch the Carbon” package as part of the various additional measures for the land-use sector under the Government Programme. The aim of the “Catch the Carbon” package is to achieve an annual emission reduction of at least three million tonnes of carbon dioxide equivalent by 2035.

The Catch the Carbon package also includes a research and innovation programme, an information programme with projects that focus on strengthening the knowledge base for the future climate measures in the

land-use sector, as well as more practical development projects. There are around 100 Catch the Carbon projects in 2022.

The research and innovation programme aims to produce new research information that anticipates changes in the operating environment, as well as solutions for climate action in the land-use sector and the sustainable use of renewable natural resources. It comprises 15 multidisciplinary projects that focus on the reduction of GHG emissions, strengthening carbon sinks and reservoirs, and thus strengthening climate change resilience in agriculture, forestry, and other types of land use. The research and innovation programme will continue until 2024. Its volume is EUR 15 million, and the main actors in the projects are universities (e.g. University of Helsinki, University of Oulu, University of Eastern Finland) and research institutes, particularly Natural Resources Institute Finland. Several universities of applied sciences and some companies are also involved as partners. The programme emphasises close stakeholder cooperation to ensure information is effectively transmitted to serve as the basis for decision making and practical actions.

In cooperation with Business Finland, the Ministry of the Environment has prepared a programme (EUR 40 million, 2021 to 2025) to support Finnish companies and other organisations in developing low-carbon solutions related to the built environment. The aim is also to promote adaptation to climate change. The Ministry aims at proactively producing knowledge through its research and development activities. The scope is to boost the development and dissemination of products, technologies, services and practices for the built environment that mitigate climate change, promote the renewal of economic structures, and enhance the competitiveness of Finnish companies based on sustainable solutions. Funding is made available through the European Union's Recovery and Resilience Facility (RRF).

### **Sitra, the Finnish Innovation Fund**

Sitra is a future fund that collaborates with partners from different sectors to research, trial, and implement new ideas that shape the future. The aim is for Finland to be a pioneer in sustainable wellbeing. Sitra investigates, explores, and develops operating models in close cooperation with other organisations to support public administration. Sitra pursues ambitious climate and nature policies, the acceleration of a fair and competitive circular economy, and encouraging citizens to act on sustainability.

Sitra's work in promoting ambitious and cost-effective climate policy has addressed such questions as: what does a cost-effective emissions reduction pathway for Finland look like, and what kind of role could taxation, and more specifically, an environmental tax reform, play in reducing emissions and promoting economic growth and employment? From 2021 onwards, the work is also addressing the link between our economic system and nature, as well as finding solutions to halt biodiversity loss and mitigate climate change.

During the reporting period, Sitra has invested a total of approximately EUR 23.1 million in projects carried out as part of the Sustainability Solutions theme area, contributing to more than 300 projects. Sitra has also invested in several funds that promote climate change mitigation. These include a renewable energy infrastructure, energy efficiency in buildings, sustainable forestry, and new business models for a circular economy.

## Foundations

Several Finnish foundations support environmental and climate research and actively participate in the mitigation of climate change. These foundations have placed considerable emphasis on the promotion of the interaction between environmental research and society. They also support open science through these measures. The Finnish Association of Finnish Foundations has established a “Climate and Environmental Measures of Foundations” website that includes examples of the operating models and tools implemented by the active foundations. Here is an indicative but incomplete list of the biggest Finnish foundations supporting climate and environmental research: the Finnish Cultural Foundation; the Jane and Aatos Erkko Foundation; the Swedish Cultural Foundation in Finland; the Kone Foundation; the Maj and Tor Nessling Foundation; the KAUTE Foundation; the Maa- ja Vesitekniikan Tuki Foundation; the Finnish Natural Resource Research Foundation; the Weisell Foundation; the Åbo Akademi University Foundation; the Tiina and Antti Herlin Foundation; and the Walter and Andrée de Nottbeck Foundation.

### 8.2.2 Climate process and climate system studies

The Finnish Meteorological Institute, FMI, has a staff of around 200 scientists working on climate change and related problems. Regarding climate process and climate system studies, the emphasis of the programme is on:

- Climate research and services (supplying climate data, studying atmospheric radiation, analysing extreme events, performing climate modelling and scenarios, conducting impact and adaptation studies, including socioeconomic aspects, and communicating climate change);
- Greenhouse gases (measuring greenhouse gas concentrations and fluxes and interpreting the measurements using modelling tools);
- Aerosols, clouds, trace gases and climate (measuring properties of aerosols, clouds, trace gases, and their interactions both in situ and remotely, modelling aerosol dynamics and aerosol-cloud interactions).

The aerosol climate research at the FMI focuses on two main areas: the climatic influences of anthropogenic aerosols in both polluted and pristine regions; and the role of natural boreal forest aerosols in clouds and the climate. The research relies on field measurements at selected sites in Finland and international hotspots, modelling, and laboratory work and satellite retrieval.

The FMI's greenhouse gas research focuses on the high-precision concentration of GHGs and the exchange fluxes between ecosystems and the atmosphere, most typically of forests, peatlands and agricultural soils. The FMI operates both types of measurements at the Pallas-Sodankylä GAW station and on Utö island in the Baltic Sea. There are also several flux measurement sites across Finland, including a subarctic site of Kaamanen peatland, with the world's longest CO<sub>2</sub> flux time series.

The universities of Helsinki, Tampere and Eastern Finland and the FMI constitute the Atmosphere and Climate Competence Center (ACCC), the Finnish Flagship that works to address climate change and air quality issues (see also Section 8.2.1).

## Paleoclimatology

The paleoclimatological studies of Finnish universities and research institutes are primarily based on the abundant natural archives in Finland and polar areas and they contribute to international research programmes, e.g. to hemispheric and global scale reconstructions (see Box 8.6).

### Box 8.6

#### Paleoclimatology Research in Finland

At the **Environmental Change Research Unit (ECRU), University of Helsinki**, the central research theme is the development and application of empirical, computational and modelling tools to detect global climatic and environmental changes and analyse their ecological and societal impacts. ECRU focuses on centennial- to millennial-scale climatic changes especially in Arctic environments. The research is largely based on proxies stored in natural archives (peatlands, lake and marine sediments, ice cores). Research themes include carbon cycling, past climate development, and extreme events, Arctic sea-ice history and past black carbon deposition, and past peatland, lake, and marine ecosystem dynamics.

At the **Geosciences Research Unit, University of Oulu**, the objectives are to produce important threshold values in geochemical and sedimentological proxy information on past climate warming events and related loss of ice in the Arctic in time scales from hundreds to hundreds of thousands of years. The dynamics of past ice sheets, the evolution of the landscape, and high-latitude oceans are studied with modern sedimentological techniques and laser scanning imageries. The Space Climate Research Unit of the University of Oulu studies the evolution (over a few hundred years) of the Sun and the effects of solar magnetic activity. The solar wind affects the Earth's atmosphere, especially at high latitudes. Studies are related to questions like how the atmosphere is influenced, and how relevant it is to climate change.

**The Laboratory of Chronology (LC) of the Finnish Museum of Natural History** analyses the isotopic and elemental compositions of samples from environmental archives. LC has led efforts to construct radiocarbon and stable isotope chronologies from Finnish subfossil materials for the late and mid Holocene. Furthermore, abrupt climatic and environmental anomalies are tracked down by multiproxy methodologies, and the interaction between nature and people is addressed.

**Natural Resources Institute Finland (Luke)** has constructed one of the longest tree-ring chronologies in the world (5634 BCE to 2021 CE), based on living trees and mega-fossils recovered from lake bottoms and lakesides. Tree-ring material and its carbon isotope data have been used for reconstructions of past summer temperatures, cloud cover changes, and ocean-atmospheric circulation variability after the last glaciation period in cooperation with LC. Paleoclimate data are used to analyse the impacts of natural forcing factors such as solar activity and explosive volcanism.

**At the University of Turku, research in the RewarD** project focuses on the melting rapidity of the Scandinavian Ice Sheet at the end of the last Ice Age and the formation of subglacial meltwater routes in Finland. The importance of the glacial dynamics is that such glacial landforms (murtoos and related subglacial drainage routes) have yet to be properly described and determined in glaciated terrains of the Northern Hemisphere. The results will increase our understanding of how current glaciers will behave in a warming climate.

### 8.2.3 Climatic modelling and prediction

In cooperation with the University of Helsinki, the FMI contributes to climate change research by using global climate models to study the physical and chemical processes of the Earth's climate system. Global climate modelling at the FMI focuses on the use and development of the European Community Earth system model, EC-Earth, as part of a Europe-wide consortium. The main responsibility of the FMI in the development of EC-Earth lies in improving the model's global aerosol scheme. With EC-Earth, the FMI contributed to the CMIP6 climate model intercomparison project, whose combined results were used as the basis for the latest climate change projections provided in the IPCC's sixth Assessment Report. While most of the climate model development is done for EC-Earth, other global climate models such as ECHAM-HAMMOZ, NorESM, and UVic are also used for research purposes.

For example, research projects aim to better understand the ongoing climate change in the polar regions, biosphere-aerosol-cloud feedbacks, radiative transfer in the atmosphere, and the applicability of negative emissions technologies in climate change mitigation. Single components of the Earth system models, such as the atmospheric component Open-IFS, land surface component LPJ-Guess, and ocean component NEMO of the full earth system



model EC-Earth, are used and developed to address specific research goals such as ensemble predictions in weather forecasting, the role of global forests as a carbon sink, and sea-ice characteristics in the Baltic and Arctic Seas.

The FMI also develops and uses the regional climate models HARMONIE-CLIM for climate change studies in the Nordic countries. Regional climate modelling is used to produce data to evaluate the societal impacts of climate change in northern Europe, as well as to produce high-resolution projections of the changes in extreme weather-related hazards in the future.

The FMI also investigates aerosol-cloud interactions with a large eddy simulation model for aerosol-climate interactions, UCLALES-SALSA, which it has developed. The model has been used to develop new parameterisations for large scale models, improving the understanding of cloud microphysical processes and interpreting field observations.

The FMI uses and develops models (e.g. the JSBACH land surface model, the LDNDC ecosystem model, the PEcAn modelling and data assimilation platform) to study carbon sinks and sources in forests, peatlands, and agricultural lands under management and in a changing climate, as well as feedbacks between the land carbon cycle, nutrient availability, water cycle, and atmosphere. The FMI also produces information about global biospheric and anthropogenic greenhouse gas emissions in recent years by using atmospheric inverse modelling (Carbon Tracker Europe, CIF) with atmospheric GHG data from satellites and in situ measurements. The FMI participates in joint international GHG modelling efforts like the GCP (Global Carbon Project) which feed into IPCC work.

#### 8.2.4 Research in support of the national greenhouse gas inventory

Research in support of the national greenhouse gas inventory has aimed to develop methodologies and emission factors or other parameters to improve the accuracy and reduce the uncertainties of the greenhouse gas inventory. This research has been largely funded by the Ministry of the Environment and the Ministry of Agriculture and Forestry. Funding has also been provided by various consortiums, including other ministries, national funding organisations such as the Academy of Finland, and the private sector.

In recent years, the focus of research in supporting the greenhouse gas inventory has been on developing and improving methods and national parameters for estimating carbon stock changes, in soils in particular, in the land-use, land-use change and forestry (LULUCF) and agriculture sectors. The Finnish Yasso model for estimating carbon stock changes in soils (developed by the European Forest Institute, the Finnish Environment Institute, Natural Resources Institute Finland (Luke) and the Finnish Meteorological Institute has been acknowledged internationally and is also used in inventory

preparation in other countries. A recent example of Yasso model-related research that yielded an improvement in the estimate of the carbon stock changes in croplands is a project that studied the chemical composition of different soil amendments. Based on the results, the effect of cover crops is now included in the estimate of cropland CO<sub>2</sub> and N<sub>2</sub>O emissions in the national greenhouse gas inventory.

Several research projects conducted by universities and research institutes have provided emission factors and research results to estimate CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub> emissions from organic soils and peat extraction. For example, the effects of paludiculture and continuous cover forestry are actively studied to facilitate the reporting of the potential GHG mitigation resulting from novel management options.

A development project on the Finnish normative manure system provided material to update the Nitrogen Mass Flow Model, which is used to calculate nitrous oxide emissions from manure management (the Finnish Environmental Institute and the Natural Resources Institute Finland). Furthermore, an ongoing project with the Finnish Environment Institute (SYKE) as the Finnish partner, funded by the Nordic Council of Ministers, aims to improve the F-gas inventories in the Nordic countries through joint comparison and verification of the emission estimation methodologies, emission factors, and other parameters and assumptions used in different countries.

Efforts to disseminate the results of the research have been made to support other countries in their inventory preparation efforts. In addition to publishing the results in international journals and experts' participation in the preparation of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, emission factors and parameters have been provided to the IPCC Emission Factor Database (EFDB), which is a key source of information for developing countries in particular.

### 8.2.5 Research on the impacts of climate change, adaptation, and mitigation

This sub-chapter mainly focuses on research performed since the publication of the Seventh National Communication. The text aims to provide an overview and the descriptions are not exhaustive. More information on the research activities is available at the websites of the research institutes and universities (see the list at the end of Chapter 8).

Many research institutes and universities carry out research on climate change impacts, adaptation and mitigation in Finland. Several research organisations have set up their own climate-change-related programmes or research units. Close cooperation among research organisations is a characteristic feature of Finnish research on climate change impacts, adaptation and mitigation.

National research programmes (see Section 8.2.1) have provided funding and common goals for the research.

Taking as an example the Academy of Finland's and the Strategic Research Council's funding for climate change related research which totalled in 2017 to 2021 more than EUR 175 million (see 8.2.1). The funding is allocated broadly; more than 30 organisations served as grant holders during the research period.

The Ministry of Agriculture and Forestry and the Ministry of the Environment were funding the Research Programme for Environmental impacts of agriculture (MATO) during 2016 to 2020. One of the aims of the MATO programme was to enhance adaptation and mitigation. The Ministry of Agriculture and Forestry also runs a development fund for agriculture and forestry that grants R&D funds for activities that benefit the agri-food sector across a broad front. The main focus is on research concerning the sustainable development of the profitability and competitiveness of livelihoods. The funded projects also include adaptation theme.

In research on climate change, natural sciences no longer dominate and economics, law, social sciences and humanities are increasingly contributing to the knowledge that is needed for tackling climate change in terms of mitigation or adaptation. For example, issues of justice and a fair transition to a resilient low carbon society as well as energy security have become important research topics.

An overall objective of the research on climate change is to be able to understand better complex interactions between a wide range of climate change impacts and adaptation and mitigation measures. Active research on possible measures to address climate change has emerged. The interactions between mitigation and adaptation actions are also increasingly recognised. Inter- and transdisciplinary approaches are more and more employed to deal with the complexity of the challenges. In addition, active participation of practitioners is required; for example, practitioners such as farmers contribute with important practical knowledge in the development of verification system for carbon sequestration in arable lands.

Climate change research is also closely connected to other themes, such as bioeconomy and circular economy, resilience, studies of societal transitions, energy research, transport research, consumer studies and also ecological research. Education and training of experts are an integral part of the research activities.

## **Research on climate change impacts and adaptation**

Research on climate change impacts and adaptation has become a recognised topic in the Finnish R&D activities. Most of the research is based on project funding ranging from short-term studies to long-term research projects. Finnish

research organisations and researchers participate actively also in European research projects.

Key themes of the research include

- the impacts of climate change in different sectors and areas (for example, agriculture, forestry, health, buildings and other infrastructure, hydropower, ecosystems, the Arctic);
- scenario development, including the use and downscaling of global and European scenarios based on the Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSP);
- risk assessments, including the analysis of exposure and vulnerability at a national, regional or local scale; analysis of the costs of inaction in the face of changing climate;
- adaptation and resilience, including the use of nature-based solutions for, for example, flood or storm water management;
- cross-border impacts of climate change and relevant policy responses.

The Ministry of Agriculture and Forestry has carried out a systematic review of past and ongoing research projects in Finland with a focus on adaptation to climate change in different sectors.<sup>12</sup> The research has provided a base for the updating of the National Adaptation Plan and for regional and local roadmaps and strategies for adaptation to climate change.

## **Research on climate change mitigation, including technologies**

As with research on climate change impacts and adaptation, studies on mitigation, as well as analyses of mitigation policies are carried by many research organisations. Key themes include

- identifying, developing and assessing technological solutions for mitigating climate change in different sectors, including renewable energy production and power-to-X solutions;
- energy efficiency in different sectors (e.g. industry, buildings, transport), energy storage and demand-side management;
- socio-economic analyses of energy transitions, in particular the shift to low carbon futures and climate neutrality at different levels of governance and managing intermittent energy sources;

---

<sup>12</sup> Ministry of Agriculture and Forestry (forthcoming) Report on the state of the research supporting adaptation to the climate change in 2021

- developing and analysing scenarios for emission reductions, including technological and economic modelling;
- examining ways to maintain and increase sinks, including carbon capture;
- developing, analysing and evaluating policy instruments for reaching energy and climate goals;
- the exploration of links between mitigation, resource efficiency and biodiversity conservation.

The overall goal is to strengthen the knowledge base for systemic transitions to a low carbon, resource efficient and resilient society. An increasing number of studies have assessed climate change problems from a transdisciplinary perspective and integrated socio-economic aspects. For example, the Strategic Research Council has funded large consortia, in which research institutes, universities and other actors, including the private sector, join forces in dealing with technology and energy disruptions and resource efficiency. Other broad inter- and transdisciplinary research efforts have addressed the mitigation of emissions from the land use sector and dealt with opportunities to increase sinks in forests and forestry and agriculture.

Funding from Business Finland plays an important role for technology developers who are seeking business opportunities in mitigation technologies. The EU's Integrated Life Projects have supported demonstration projects for upscaling. One example is the support for Carbon Neutral Municipalities and Regions (Canemure).

Some actors in the field of mitigation research and examples of their research are presented here below:

Research, development and innovation (RDI) in both Universities and Universities of Applied Sciences combine multidisciplinary expertise with the needs of co-operative partners and the society. New solutions are widely sought to help society and businesses in their sustainable renewal e.g. by supporting the transition towards a carbon-neutral society in all sectors.

Co-operation and co-creation with both companies and the public sector enhance also long lasting partnerships. Funding is provided by the European Social Fund (ESF), European Regional Development Fund (ERDF) as well as ministries' programmes and Business Finland in many cases, while the financing from the municipalities and companies plays a significant role too.

VTT Technical Research Centre of Finland Ltd (VTT) is conducting applied research in areas that are crucial to solve in order to reach a carbon neutral economy and society. These areas are carbon-neutral process industry, low-carbon and smart mobility, sustainable and smart built environment,

sustainable food system, carbon neutral and flexible energy system, and hydrogen for future society.

Some examples on achievements include that VTT has established innovation ecosystems in smart energy and smart transportation, where companies, research actors, public sector and citizens can co-create and pilot new technologies and services. It has also led development in sustainable fuels, and their utilization in various forms of mobile and stationary applications. Research on alternative proteins with lower carbon footprint has resulted in four start-ups. VTT has also been working on development of a small modular nuclear reactor for residential heating. In addition, it has supported ministries to formulate medium and long term climate and energy scenarios and carried out assessment of impacts of national climate and energy policies and measures in collaboration with other research institutes.

The Finnish Environment Institute (SYKE) carries out research on climate change mitigation by analysing the economics and management of renewable intermittent energy sources, the legal base for low carbon transitions, the practices of low carbon consumption and business development, and by developing methods and processes for estimating and analysing consumption-based greenhouse gas emissions as a complement to area-based estimates that SYKE has produced for all municipalities in Finland. SYKE also carries out research on the security aspects of the energy transition.

The Natural Resources Institute Finland (Luke) has organized its research activities into four programmes, namely Profitable and responsible primary production, Circular bioeconomy, Climate smart carbon cycle and Adaptive and resilient bioeconomy. All of these have climate change mitigation and adaptation as an integral, inherent theme. Furthermore, The Natural Resources Institute Finland also has a programme for Statutory and expert services which is responsible for e.g. the greenhouse gas inventory for agriculture and land use, land-use change and forestry sectors.

## **Research on assessing, evaluating and monitoring climate action**

Policies and other societal actions to strengthen mitigation and adaptation are regularly reported to the UNFCCC and the EU (Chapter 4), but, in addition dedicated research aims at creating more systematic and better quality controlled information on the contribution of policies to transformative societal change. Such assessments and evaluations of policies have in particular been initiated by the Strategic Research Council (SRC) and the dedicated Government's analysis, assessment and research activities (VNTEAS). The latter have, for example, included research-based assessment of the Government's Climate and Energy Strategy and a research-based evaluation

of the national Climate Change Adaptation Plan 2015–2022<sup>13</sup>. These operational studies for policy development have been linked with more strategic research on climate and energy issues through studies focusing on technological disruption in energy. New projects under the SRC Climate Programme deepen the understanding further, for example by analysing the perceived legitimacy and fairness of current and potential policy instruments. They have evaluated current systems and also provided assessments of alternative future pathways.

### **Climate justice and just transition related research**

Climate justice and just transition related research have been increasing in recent years. Currently the Climate Change Panel is in the process of creating a support tool to assess justice-aspects in climate policy. The Legitimacy 2035 research project assesses legitimacy issues in the context of climate legislation and policy. In addition, there are thematic research projects related to, for example, just and sustainable food system transition. Furthermore, Ministry of the Environment has made new type of research cooperation with research groups from the University of Turku: A specific Citizens' Jury on Climate Actions was convened to support the assessment of the legitimacy of the Government's Medium-term Climate Change Policy Plan and was run by the researchers. The Citizens' Jury on Climate Actions discussed 14 policy measures and assessed, that during the implementation of the measures factors such as income and geographical location should be taken into account. The Ministry of the Environment has cooperated also with other research groups in relation to use of new participatory methods, for example in participation of the youth<sup>14</sup>.

## **8.3 Systematic observations**

The routine surface and upper air weather observations made by the FMI are the primary source of atmospheric observations relevant to climate change, including atmospheric composition. The FMI also carries out physical marine observations.

SYKE conducts or coordinates climate-related observations of hydrology and the chemical and biological state of inland and marine waters, as well as of terrestrial biodiversity. Climate-related observations of forests, agricultural areas, and fisheries are made by the Natural Resources Institute, Luke. Several universities also have activities in this area. The data collected compiled by the Finnish Museum of Natural History (Luomus) provides data for understanding long-term changes in the biota.

---

13 KOKOSOPU project, Hilden et al. 2022, <https://tietokayttoon.fi/julkaisu?pubid=42102>

14 ALL-YOUTH ([allyouthstn.fi](http://allyouthstn.fi))

Most of the systematic long-term observational activities depend on regular budgetary funding, but many important data series on biota (birds, insects) are collected by amateur observers. In addition, observations carried out as part of research projects are funded to a significant degree by external R&D funding. The total funding for systematic observations related to climate change is difficult to determine, because most of the observations are primarily made for other monitoring purposes (such as resource management), although the observations are also applicable to tracking climate change. Budgetary funding for some of these monitoring programmes has partly been reduced, and some data series may therefore suffer. There is also a need to invest in both virtual and physical infrastructure to ensure the maintenance and accessibility of the long-term data that prove important in understanding the gradual effects of climate change.

The sections below present the atmospheric, ocean, terrestrial and cryosphere observation systems. The observation systems covered are those providing climate observations, as well as other observations relevant for research on climate change impacts, adaptation, and mitigation.

### 8.3.1 Atmospheric observing systems

The FMI's meteorological observation network is comprised of 83 manual precipitation stations and 185 automatic weather stations (AWS), of which two include upper-air observations. AWSs offer a comprehensive set of parameters essential for climate studies (e.g. temperature, pressure, relative humidity, precipitation, wind, solar radiation). Observation records are mainly distributed as synoptic weather messages every ten minutes, and hourly via the Global Telecommunication System. The FMI has been responsible for the aviation weather observations of Finnish airports since 2012. A dual polarisation Doppler radar network provides comprehensive coverage of Finland, offering a wide range of climate and operative applications for society.

The FMI participates in the Global Climate Observing System (GCOS) Surface Network (GSN) with three stations. One station (Sodankylä) is also part of the GCOS Upper-Air Network and the GCOS Reference Upper-Air Network (GUAN and GRUAN). Since 2013, the FMI's datasets have been free for public use via an online service (see 8.1.1 and Box 8.1).

For example, Finnish climate observations have been included in the European Climate Assessment & Dataset (ECA&D), which is a European collection of reliable long-term climatic observations for climate change research. In addition, daily precipitation data are in use at the Global Precipitation Climatology Centre (GPCC).

The FMI has maintained a climatological database since 1959, including data from climatological normal values to near-real-time values for certain observations. In addition to the electrical data records, a significant amount of



climatological data dating back nearly 200 years in time is still in paper format and being digitised.

The FMI is actively participating in the activities of the network of European Meteorological Services (EIG EUMETNET). The activities of the EUMETNET include observing systems, data processing, basic forecasting products, research and development, and training.

Finland is a participant in the Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO), the purpose of which is to observe greenhouse gas concentrations and the long-range transport of pollutants in the atmosphere. Greenhouse gas measurements are made available at the World Data Centre for Greenhouse Gases (WDCGG) at the Japan Meteorological Agency and other global and European data banks.

The FMI maintains a GAW station at Pallas-Sodankylä in Lapland, where greenhouse gas concentrations are measured on a mountaintop in a national park. Carbon dioxide, methane, nitrous oxide, ozone, air pollutants, and aerosols are measured continuously at the station. Continuous measurements of carbon dioxide started in 1996 and of methane in 2004.

Finland is participating in the Integrated Carbon Observation System (ICOS) (see also Sections 8.1.1 and 8.1.2), which is a European research infrastructure for quantifying and understanding the greenhouse gas balance of the European continent and adjacent regions. Both atmospheric concentrations and fluxes over different ecosystems are measured, with measurements taken over oceans and the Baltic Sea.

The mission of ICOS is:

- To provide the long-term atmospheric and flux observations required to understand the present state and predict the future behaviour of the global carbon cycle and greenhouse gas emissions.
- To monitor and assess the effectiveness of carbon sequestration or greenhouse gas emission reduction activities on global atmospheric composition levels, including the attribution of sources and sinks by region and sector.
- To set new standards for research instrumentation, measuring protocols, and data processing.

The ICOS Finland network maintains four atmospheric stations at Hyytiälä SMEAR II, Pallas, Puijo, and Utö which continuously measure the high-accuracy concentrations of carbon dioxide, methane, and carbon monoxide. Weekly sampling will include a broader selection of species similar to that of the GAW programme. The host institutes of ICOS Finland (the FMI, the University of Helsinki, the University of Eastern Finland) also maintain

nine ICOS ecosystem stations that measure greenhouse gas fluxes above forest, wetland, lake, and urban environments. The Stations Measuring Ecosystem-Atmosphere Relationship (SMEAR) in the boreal climate zone support research on biosphere-aerosol-cloud-climate interactions and the biogeochemical cycles of carbon, nitrogen, sulphur, and water. Several SMEAR sites contribute to atmospheric and environmental research infrastructures such as ICOS, ACTRIS and eLTER, allowing synergistic data interpretation (see also 8.3.3). The national station network now consists of a total of 13 atmospheric and ecosystem stations that are part of ICOS. From 2022, Natural Resources Institute Finland and the University of Oulu have joined ICOS Finland and are preparing to add their flux stations to the ICOS network.

For ACTRIS, the Finnish site selection (called National Facilities) includes the FMI Pallas and Utö sites, the University of Helsinki INAR sites in Hyytiälä, Värriö, and Helsinki, and a University of Eastern Finland site in Puijo. In addition, the FMI operates overseas ACTRIS stations in Marambio (Antarctica) and Tiksi (Siberia). However, the Tiksi station is currently (2022) inactive. The ACTRIS sites contribute to aerosol, trace gas, and cloud in-situ observations, as well as to the cloud remote sensing components of ACTRIS.

Furthermore, the FMI is leading the preparation of part of the ACTRIS Data Centre (CloudDataNet). The University of Helsinki is contributing to ACTRIS central calibration facilities in aerosol in-situ and trace gases. The University of Helsinki and FMI are establishing the ACTRIS Head Office to provide effective access for a wide user community to resources and services to facilitate high-quality Earth System Research (see Section 8.1.2).

Additional climate-related observational activities carried out at the FMI are as follows:

- The FMI is responsible for national background air quality monitoring. The monitoring network consists of about twenty measurement stations. Most of the measurements are part of international monitoring and research programmes.
- Background air quality monitoring started at the beginning of the 1970s. Today, the measurements include major ions, polycyclic aromatic hydrocarbons (PAHs), heavy metals and mercury in the air and in precipitation, ozone, sulphur oxides, nitrogen oxides, volatile organic compounds, and fine particles.
- The FMI has also assisted in establishing and enhancing measurements of atmospheric composition at stations in India, China, South Africa, and on polar research cruises.
- The Integrated Monitoring programme, which is coordinated by the United Nations Economic Commission for Europe (UNECE), refers to the simultaneous measurements of the physical, chemical, and biological

properties of an ecosystem over time and across compartments at the same location (stations in Kotinen and Hietajärvi). The objective of HELCOM (Baltic Marine Environment Protection Commission, or the “Helsinki Commission”) is to protect the marine environment of the Baltic Sea (station at Hailuoto).

- The FMI also maintains a monitoring and warning system for tropospheric ozone concentrations in accordance with the European Union’s Ozone Directive. Air quality issues in the EU are coordinated by the European Environment Agency and the European Topic Centre on Air Quality.

Finland is a member of the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). The FMI hosts the EUMETSAT’s Satellite Application Facility on Ozone & Atmospheric Chemistry Monitoring, O3SAF.

### 8.3.2 Ocean observing systems

Finnish research institutes with significant marine components have started a national marine research infrastructure consortium (FINMARI) coordinated by the Finnish Environment Institute SYKE. The aim is to facilitate efficient international and national use of the marine infrastructure. This is done in close cooperation with other international and national infrastructures and ESFRIs<sup>15</sup> such as ICOS, EMBRC, and EURO-ARGO.

The infrastructure includes the research infrastructures of four Finnish research institutes and three university field stations. FINMARI is a distributed infrastructure, consisting of field stations, research vessels, laboratory facilities, FerryBoxes, gliders, fixed measurement platforms, and profiling buoys in the Northern Baltic Sea. FINMARI is listed as a nationally essential research infrastructure in the Finnish national infrastructure roadmap for 2021 to 2024. FINMARI is a hub for the ocean observing system in Finland and provides access to both the infrastructure and the data it produces.

SYKE participates in the joint Baltic Sea environmental monitoring programme (HELCOM COMBINE), which has produced long-term data on the state of the Baltic Sea since 1979. The operative state monitoring of offshore sea areas in the Gulfs of Bothnia and Finland, as well as the northern Baltic Proper is carried out by SYKE (chemical and biological parameters, contaminants) and the FMI (physical parameters). Monitoring is conducted at about 55 sampling stations during four annual cruises with R/V Aranda. Offshore monitoring is undertaken in cooperation with the Swedish Meteorological and Hydrological Institute (SMHI), and with Estonian and Russian research institutes. The monitoring of coastal waters is carried out by regional environmental authorities with SYKE. For example, the marine monitoring data serve the national implementation of the EU Marine Strategy Framework Directive and the Water

---

15 EU’s European Strategy Forum on Research Infrastructures

Framework Directive and the work of HELCOM. The open data have also been utilised e.g. in evaluating the observed climate change effects in the Baltic Sea. Data are also delivered e.g. to the databases of the International Council for the Exploration of the Sea (ICES), the European Environment Agency (EEA), and EMODnet/ DG MARE.

SYKE also delivers near-real-time information from several million datapoints annually on the state of the Baltic Sea through the Alg@line, which serves research, the general public, the media and the authorities. Alg@line utilises the Ship-of-Opportunity (SOOP) monitoring system, which uses merchant ships as operating platforms on which measurements are taken using autonomous flow-through systems. The Alg@line project is a pioneer in the field of unattended SOOP monitoring, forming a state-of-the-art environmental monitoring system ranging from data collection and assimilation to Internet applications and products.

The FMI is responsible for monitoring the physical properties of the Baltic Sea. The FMI's operational measurement network includes 14 tide gauges, five wave buoys, Argo floats (TS/O<sub>2</sub>) in four of the Baltic Sea basins, and several surface temperature buoys along the coast. Regular temperature and salinity soundings are also made in coastal monitoring stations. In addition to the abovementioned ICES, EEA, and EMODnet databases, operational measurements are also provided to the Copernicus Marine Service database.

The FMI also contributes to the global Argo programme by providing floats for the Nordic Seas in addition to the Baltic Sea via the Euro-Argo Research Infrastructure. For enhanced climate, marine, and ecosystem research in the Baltic Sea, the FMI has established with SYKE the Utö Atmospheric and Marine Research Station (part of FINMARI), which provides high time-resolution data on marine ecosystem atmosphere feedback processes and the carbon cycle.

### 8.3.3 Terrestrial observing systems

In the following, the terrestrial observing systems in Finland also includes a description of inland waters and hydrology. The observing systems of greenhouse gas measurements over different terrestrial ecosystems and of the interaction of terrestrial ecosystems and atmosphere are described in Section 8.3.1 above.

SYKE is the national centre coordinating and supervising the monitoring of the water resources, hydrological cycle, and chemical and biological state, including data management, quality control, and the assessment of the chemical and ecological quality of inland waters. Many hydrological data series are unique for their temporal duration (longer than 100 years), particularly those related to the freezing and break-up of rivers and lakes and the water levels of some large lakes.

Flood forecasting at SYKE is based on the Watershed Simulation and Forecasting System. Its main component is a model that simulates the entire hydrological cycle and water balance in catchment areas. The forecasts are made several times a day from more than 500 water-level and discharge observation points and are available on the webpage providing national information about the water situation in Finland ([vesi.fi](http://vesi.fi)). Simulated hydrological data with more than 20 variables from 1962 to the present are available from the system's user interface. The modelling system is used extensively in research projects on climate change impacts in hydrological cycle and water resources in Finland. The climate-change-related data and simulations are produced on demand, and some information and maps are also available on the national webpages, [vesi.fi](http://vesi.fi) and [ilmasto-opas.fi](http://ilmasto-opas.fi). The hydrological simulation system also includes a nutrient simulation model (VEMALA), which can be used to simulate extensive water quality data, including source apportionment. The loading projections can be provided for historical periods, as well as for the future climate change scenarios on demand.

The water quality data acquired and hosted by SYKE cover the country and important watersheds, as well as special small-scale watersheds for baseline monitoring. All data are subject to systematic quality control, including the use of standardised methods for analysis.

Finland reports terrestrial climate observations to several international databases. For example, runoff data are reported to the Global Runoff Data Centre in Germany and the Nordic Runoff Data Centre in Sweden. Finland has reported lake water temperatures to a global project coordinated by the University of Nebraska.

SYKE also carries out monitoring using data from Earth Observation (EO) satellites<sup>16</sup>. These include water quality and temperature in the Baltic Sea, snow extent, and lake ice, which are currently monitored operationally (i.e. products are generated when new data become available, in practice, almost every day for the moderate resolution satellites such as Sentinel 3). For inland lakes, the operating methods are under development. Land cover, land-use, and phenology products are generated more slowly: one per year for every six years<sup>17</sup>. Land and cryosphere products are SYKE's contribution to the EU's Copernicus services. Operational processing of EO data is carried out in cooperation with the Finnish Meteorological Institute at the National Satellite Data Centre.

In addition to inland water observations, the monitoring of terrestrial ecosystems aids the detection of changes induced by climate change. Integrated monitoring has indeed become an important approach in environmental

---

16 [www.syke.fi/earthobservation](http://www.syke.fi/earthobservation)

17 For details, see ([https://www.syke.fi/en-US/Open\\_information/Open\\_web\\_services/EO\\_web\\_map\\_services/](https://www.syke.fi/en-US/Open_information/Open_web_services/EO_web_map_services)).

sciences. At SYKE, the multidisciplinary International Cooperative Programme on Integrated Monitoring (UNECE ICP IM) is one of the activities established under the Convention on Long-range Transboundary Air Pollution (CLRTAP) to develop the necessary international cooperation for assessing pollutant effects and emission reductions. The key aim is to quantify the integrated effects of air pollution and climate change on the environment through monitoring, modelling, and scientific review using data from catchments or plots in natural or semi-natural forested areas with minimal disturbance. SYKE further participates in the UNECE ICP Waters and ICP Modelling & Mapping (ICP M&M) activities, which also cover the monitoring and assessment of climate change effects.

The Finnish Long-Term Socio-Ecological network (LTER Finland) is coordinated by the University of Helsinki and brings together the Finnish research sites and scientists conducting research on long-term socio-ecological processes and problems in a coordinated Finnish research infrastructure. The LTER also belongs to the Europe-LTER and international LTER (ILTER) networks. LTER Finland currently consists of nine highly instrumented sites/research platforms, representing the main ecosystems (marine, terrestrial, lake, subarctic, urban) in Finland, which provide a national infrastructure for long-term site-based ecosystem and biodiversity research in Finland, including climate change impacts.

Currently, about 60 national monitoring schemes or projects provide data concerning biodiversity in Finland. This monitoring work involves three research institutes: the Finnish Museum of Natural History; Natural Resources Institute Finland Luke; and SYKE. This work includes collecting information on the changes taking place in ecosystems and habitats, species and species communities, and genes and genotypes. Monitoring data dealing with changes in biodiversity and habitats are compiled on a website. SYKE organises national butterfly (since 1999) and moth (since 1993) monitoring schemes, providing information about the effects of climate change on species occurrences. SYKE is also coordinating the research infrastructure project FinBIF (Finnish Biodiversity Information Facility).

Monitoring of disease vectors and zoonoses that can be connected to climate change is performed by the Finnish Food Authority and the Finnish Institute for Health and Welfare.

Luke performs national forest inventories (NFIs), which produce reliable information on the land use, forest resources, growth, condition and biodiversity of forests. NFIs are based on statistical sampling. The most recent NFI was undertaken between 2014 and 2018 and the 13th NFI is ongoing (2019 to 2023). Twelve NFIs have been completed since the 1920s, providing internationally unique time series on the development of land use and forest resources.

Luke participates in UNECE ICP Forests Level II intensive monitoring, which is the key for providing an insight into causes affecting the condition of forest ecosystems and the effects of various stress factors, including climate change. The results are reported annually. The forest damage advisory service at Luke is responsible for monitoring forest pests and diseases and the damage they cause. The service supports the decision making of forest owners and administrators by answering enquiries and producing diagnoses and prognoses about forest pests and diseases. Luke also collects information on the phenology of tree and forest berries. The extent of climatic warming can thus be assessed based on the time series for the bud burst of different tree species.

Finland is a member in the Sustaining Arctic Observing Networks (SAON) and the vice-chair currently comes from Finland. The SAON was established on the initiative of the Arctic Council and the International Arctic Science Committee (IASC). The purpose of the SAON is to support and strengthen the development of multinational engagement for sustained and coordinated pan-Arctic observing and data sharing. The SAON has two committees: the Arctic Data Committee and the Committee on Observations and Networks. The vision of the SAON is to sustain a comprehensive observing system for the Arctic and that users should have access to free, open and high-quality data that will realise pan-Arctic and global value-added services and provide societal benefits. The EUR 15 million Arctic Passion EU project with parallel actions in the US and Canada are supporting strongly SAON to facilitate the ROADS process<sup>18</sup> with a key goal to establish Shared Arctic Variables (SAV) to broaden observation practitioners to local and indigenous communities. Ongoing projects also include an atmospheric observations initiative and participation in the EU PolarNet project for the optimisation of existing monitoring and modelling programmes. The prime Finnish site in SAON is the Pallas Supersite<sup>19</sup>, which is a versatile research infrastructure for monitoring and studying the atmosphere, ecosystems and their interactions.

The surveillance system of invasive alien species has been developed to collect and record data on the occurrence of invasive alien species, estimate how their populations have increased or shifted location, and measure the effectiveness of the management measures. The work is mostly done by integrating new elements into the existing inventories and monitoring systems. Citizens can also report their observations of alien species to an internet portal<sup>20</sup>, which includes geospatial information.

### 8.3.4 Cryosphere observing systems

Except for sea ice monitoring, the cryosphere observing system in Finland is organised as part of the hydrological monitoring system. Monitored cryosphere

---

18 <https://helda.helsinki.fi/handle/10138/341820>

19 <https://en.ilmatieteenlaitos.fi/pallas-atmosphere-ecosystem-supersite>

20 <https://vieraslajit.fi/>

variables include snow water equivalent, ice cover duration and thickness in lakes and rivers, and seasonal soil frost thickness. This monitoring programme is coordinated by SYKE. Data storage and data quality control, as well as making data available to the public, are done on SYKE's premises. All monitoring data can be accessed through the webpage providing the national information of the water situation in Finland<sup>21</sup>. Field measurements are carried out by the local authorities or citizen observers. The monitoring network consists of more than 200 cryosphere monitoring stations where data are collected fortnightly or more frequently during the winter, and the stations are spread all over Finland. Earth Observation (EO) satellite products are used to operationally monitor snow extent and lake ice. The international data availability will be developed in the Arctic PASSION project ("Pan-Arctic Observing System of Systems: Implementing Observations for Societal Needs"), in which the FMI and SYKE are partners. Cryospheric data are also reported to the National Snow and Ice Data Center (NSIDC) in the United States.

Based on satellite observations and ground measurements, the FMI has developed methodology to reliably estimate the amount of annual snow mass and changes in snow cover in the Northern Hemisphere<sup>22</sup>. These accurate data, starting in 1980, are a significant improvement to the Essential Climate Variables of the WMO's Global Climate Observing System.

Sea ice monitoring in the Baltic Sea is carried out by the FMI, which has about 20 people observing ice along the Finnish coastline. They observe the ice situation visually and measure the thickness of the ice weekly, providing pointwise in-situ information. The data are available from the FMI. To cover the whole Baltic Sea, the most important source for ice observations is satellites. They provide information on the ice extent and type, concentration, ice ridges and leads, for example. Both in-situ and satellite measurements provide an input to model the structure, thermodynamics and drift of sea ice. The FMI also provides a long time series of the maximum annual extent of ice cover in the Baltic Sea that starts in the winter of 1720/1721.

### 8.3.5 Support for developing countries in strengthening systematic observations

Climate change and the intensification of extreme weather phenomena will increase the demand for development projects, especially in countries that lack the capacity to develop the required systematic observations themselves. The strengthening of atmospheric and terrestrial observing systems provides basic information for adaptation to changes in climate and environmental conditions.

---

21 <https://www.vesi.fi/>

22 Pulliainen, J., Luojus, K., Derksen, C. et al. Patterns and trends of Northern Hemisphere snow mass from 1980 to 2018. *Nature* 581, 294–298 (2020).  
<https://doi.org/10.1038/s41586-020-2258-0>



Finland finances the Systematic Observations Financing Facility (SOFF), launched in 2022, that supports Least Developed Countries (LDC) and Small Island Developing States (SIDS) to generate and exchange basic surface-based observational data critical for improved weather forecasts and climate services. Finland also finances the Climate Risk and Early Warning Systems (CREWS) initiative that funds Least Developed Countries (LDC) and Small Island Developing States (SIDS) for risk informed early warning systems. Furthermore, many other organizations and funds that Finland finances, such as the Adaptation Fund, Green Climate Fund and Nordic Development Fund, implement projects that strengthen the capacities of developing countries to assess climate risks, develop early warning systems and take anticipatory action.

Projects that support the development of observation systems and are funded by the Finnish Government are described in Section 8.4. The research institutes SYKE, Luke, GTK, and FMI provide expertise in the planning and implementation of projects, including work to improve monitoring systems and their use in climate change adaptation. The FMI also leads and provides expertise to projects funded by the World Bank, the Asian Development Bank and the EU.

## 8.4 Capacity building in developing countries

As it has for many years, Finland continues to finance and operate extensive capacity building programmes around the world concerning climate observations, research and higher education relevant to climate change mitigation and adaptation, meteorology, and the sustainable management of forests, water and other natural resources.

The programmes have increased the endogenous capacities and capabilities of developing countries to tackle these issues through improved technological means and human resources. Thanks to the momentum of the cooperation and higher visibility through the programmes, this has also led to increased national funding and support. Furthermore, the programmes have identified opportunities for and supported actions to overcome barriers to the free and open international exchange of data and information. From 2017 to 2021, more than 70 institutions in 25 developing countries have benefitted from capacity building provided by their Finnish counterparts.

The main instruments to support capacity building in developing countries are the Institutional Cooperation Instrument (ICI), the Higher Education Institutions Institutional Cooperation Instrument (HEI-ICI), and the Academy Programme for Development Research (DEVELOP). Furthermore, many other development cooperation programmes, funded through bilateral cooperation or through multilateral channels, include elements to increase the endogenous capacities of partners in developing countries.

**In transboundary water cooperation**, critical for climate change adaptation, Finland has supported the drafting of the UNECE Water Convention handbook on the effective, equitable and sustainable transboundary water allocation intended for global use, and a review of solutions and investments in the water-food-energy-ecosystems nexus in transboundary basins. Finland has also played an active role in developing international water diplomacy activities in collaboration with partners, including UNICEF and the OSCE, emphasising the potential of water cooperation in conflict prevention and in confidence-building measures. The Finnish approach builds on joint analyses, training and mentoring, bringing together technical water expertise with peace mediation.

**The Institutional Cooperation Instrument (ICI)** supports projects between public sector institutions. The projects respond to the capacity development needs of the public sector institutions of developing countries with the expertise available in Finnish governmental authorities and agencies. The objective of the projects is to strengthen the capacities and knowledge of the institutions and their staff. The projects are funded by the Ministry for Foreign Affairs and implemented by Finnish public sector institutions with their corresponding counterpart institutions in developing countries. Between 2017 and 2021, four Finnish public sector agencies have provided climate-related capacity building through ICI projects.

The Finnish Meteorological Institute (FMI) is among the world's leading national hydrometeorological institutes and has provided capacity-building and technical assistance to national meteorological and hydrological services (NMHS) to develop weather, climate, and early warning services through development cooperation projects worldwide. It has implemented the following ICI projects since 2017:

- Improving the Adaptation to Climate Change by Enhancing Weather and Climate Services in Kenya, Rwanda, and Tanzania. Partners: Kenya Meteorological Department, Rwanda Meteorology Agency, Rwanda Environmental Management Authority, and Tanzania Meteorology Authority. 2022, ongoing
- Capacity Building in the Field of Meteorology, FMI-Uzhydromet Meteorology Project. Partner: Centre of Hydrometeorological Service of the Republic of Uzbekistan (Uzhydromet). 2022, ongoing
- Meteorology cooperation in Ukraine, UHMC-FMI Meteorology Project. Partner: Ukrainian Hydrometeorological Center (UHMC). 2022, ongoing
- Improving the Adaptation to Climate Change by Enhancing Weather and Climate Services in Sudan. Partner: Sudan Meteorological Authority. 2020, ongoing

- Promoting the Modernisation of Hydrometeorological Services in Vietnam. Partner: Meteorological and Hydrological Administration of Viet Nam. 2019, ongoing
- Finnish-Nepalese Project for Improved Capability of the Government of Nepal to Respond to the Increased Risks Related to the Weather-related Natural Disasters Caused by Climate Change. Partner: Department of Meteorology and Hydrology (DHM). 2018, ongoing
- Capacity Building in the Field of Meteorology, Finnish-Kyrgyzstan Meteorology Project. Partner: The Agency on hydrometeorology under the State Committee on Ecology and Climate of the Kyrgyz Republic (Kyrgyzhydromet). 2018 to 2021
- Capacity Building in the Field of Meteorology, Finnish-Tajikistan Meteorology Project. Partner: The Agency on Hydrometeorology of the Committee of Environment Protection under the Government of the Republic of Tajikistan (Tajikhydromet). 2017 to 2021
- Promoting Adaptation to Climate Change by Reducing Weather and Climate-Related Losses through Improved Services in Sudan and South Sudan. Partners: Sudan Meteorological Authority (SMA) and South Sudan Meteorological Department (SSMD). 2016 to 2019.

*Natural Resources Institute Finland (Luke)* is a research and expert organisation with expertise in renewable natural resources and sustainable food production. It has implemented the following ICI projects since 2017:

- Institutionalising National Forest Monitoring in Myanmar. Partners: Myanmar Forest Research Institute and University of Forestry, Yezin. 2017 to 2021
- Implementation support of results and data of the first National Forest Resources Monitoring and Assessment at regional and local level in Tanzania. Partners: Tanzania Forest Services (TFS), Tanzanian Forest Research Institute (TAFORI) and Sokoine Agricultural University (SUA). 2016 to 2020
- Capacity building on novel approaches in sustainable management of forest and wood resources in Mozambique. Partners: Agrarian Research Institute of Mozambique (IIAM) and the Faculty of Agronomy and Forest Engineering of Eduardo Mondlane University (UEM-FAEF). 2016 to 2020.

*The Geological Survey of Finland (GTK)* is a geoscience research agency operating under the Ministry of Economic Affairs and Employment, specialising in the assessment and sustainable use of geological resources. It has been implementing the following climate-related ICI projects since 2017:

- Strengthening the Mastering of Natural Resources for National Welfare in Tajikistan. Partner: Main Department of Geology under the Government of the Republic of Tajikistan (MDG). 2022, ongoing
- Strengthening the Mastering of Natural Resources for National Welfare in Uzbekistan. Partner: State Committee of the Republic of Uzbekistan on Geology and Mineral Resources (GOSCOMGEOLOGY). 2022, ongoing
- Strengthening the Mastering of Natural Resources for National Welfare in the Kyrgyz Republic. Partner: State Committee of Industry, Energy and Subsoil Use of the Kyrgyz Republic (SCIESU). 2020, ongoing
- Managed Aquifer Recharge to Ensure Sustainable Groundwater Availability and Quality under Ongoing Climate Change and Fast Economic Development in Vietnam. Partners: The Sub-Institute of HydroMeteorology and Climate Change (SIHYMECC) and the Center for Water Resources Warning and Forecast (CEWAFO). 2018, ongoing.

*The Finnish Environment Institute (SYKE)* is a multidisciplinary research and expert institute, committed to solving society's most burning issues that have an impact on the environment. It has implemented the following ICI projects since 2017:

- Building Capacity of the Kyrgyz Republic on assessing the environmentally sustainable development of the Lake Son Kul. Partner: State Agency of Environmental Protection and Forestry of the Kyrgyz Republic (SAEPF). 2016 to 2018
- Marine Spatial Data Infrastructure (MSDI), Integrated Coastal Zone Management (ICZM) and Maritime Spatial Planning (MSP) in Zanzibar. Partner: Department of Urban and Rural Planning (DoURP) of Zanzibar. 2016 to 2018
- Formation of decision-making system aimed at ecological and economic development of Issyk-Kul lake's territory, based on the results of environmental monitoring. Partner: State Agency of Environmental Protection and Forestry of the Kyrgyz Republic (SAEPF). 2014 to 2018.

**The Higher Education Institutions Institutional Cooperation Instrument (HEI-ICI)** supports collaborative projects between higher education institutions, with the objective of strengthening the provision of higher education and developing the subject-specific, methodological, educational, and administrative capacities of the participating institutions in developing countries. The programme is funded by the Ministry for Foreign Affairs and administered by the Finnish National Agency for Education.

The ongoing climate-related HEI-ICI programmes during the funding period between 2020 and 2024 are:

- Strengthening Climate Change Education for Sustainable Development in Myanmar and Vietnam (CLIDEV). The partner institutions are the University of Helsinki and Laurea University of Applied Sciences in Finland, Yezin Agricultural University and the University of Forestry and Environmental Sciences in Myanmar, and Hue University and the Vietnam National University of Forestry in Vietnam. The associate partners are the Food and Agricultural Organization of the United Nations Regional Office, the Joint IUFRO-IFSA task force on Forest Education and the Center for People and Forests (RECOFTC).
- Problem-based-learning bioeconomy entrepreneurship and capacity building programme in Africa (PBL-BioAfrica). The partner institutions are the Häme University of Applied Sciences and Aalto University in Finland, Egerton University, the University of Nairobi, and South Eastern Kenya University in Kenya, Mulungushi University, and the University of Zambia in Zambia. The associate partners are the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), the Finnish University Partnership for International Development (UniPID), the Accelerated Growth for SMEs in Zambia Programme (AGS), as well as local associate partners in Kenya and Zambia.

During the funding period between 2017 and 2020, the following climate related HEI-ICI programmes were implemented:

- Promoting education and research on energy-efficient lighting and renewable energy for sustainable development (EARLI). The partner institutions are Aalto University in Finland, the University of Dar es Salaam (UDS) in Tanzania, Eduardo Mondlane University (UEM) in Mozambique, and Addis Abeba University (AAU) in Ethiopia. The affiliate partners are the Fundo de Energia (FUNAE), Electricidade de Moçambique (EDM), Empresa Nacional de Parques e Ciência e Tecnologia and Empresa Publica – ENPCT in Mozambique, and the Ethiopian Energy Authority in Ethiopia.
- Capacity Building in Fisheries and Aquaculture Education in the Kyrgyz Republic (FishEDU). The partner institutions are the University of Eastern Finland and the Kyrgyz National Agrarian University in the Kyrgyz Republic. The affiliate partners are the UN World Food Programme (Kyrgyz Republic Country Office), the UN Food and Agriculture Organization (Kyrgyz Republic Country Office), the Regional Central Asian and Caucasus Fisheries and Aquaculture Commission, the Department of Fisheries at the Ministry of Agriculture of the Kyrgyz Republic, and Aqua Service Ltd. in the Kyrgyz Republic, as well as Natural Resources Institute Finland, Stimulator Ltd., and Raisioagro Ltd. in Finland.

- Geospatial and ICT Capacities in Tanzanian Higher Education Institutions (Geo-ICT). The partner institutions are the University of Turku in Finland, the University of Dar es Salaam (UDSM), Ardhi University (ARU), the State University of Sansibar (SUZA), and Sokoine University of Agriculture (SUA) in Tanzania.
- Partnership for Forestry Higher Education Cooperation in Mekong Region (PARFORM). The partner institutions are the Viikki Tropical Research Institute (VITRI) of the University of Helsinki in Finland, Savannakhet University (SKU), the National University of Laos (NUoL) and Souphanouvong University (SU) in Laos, the University of Forestry in Yezin, Myanmar, and Kasetsart University (KUFF) in Thailand.
- Native Crops for Innovative and Sustainable Food Futures in Peru and Colombia (PECOLO). The partner institutions are the Finland Futures Research Centre and the Functional Foods Forum and Department of Biochemistry at the University of Turku in Finland, Universidad El Bosque in Colombia, and Universidad Agraria La Molina in Peru.
- Sustainable Management of Natural Resources in Mozambique (SuMNatuRe). The partner institutions are the University of Jyväskylä in Finland and the Eduardo Mondlane University and Zambeze University in Mozambique, as well as the University of Eastern Finland as an affiliate partner.
- Improving capacity, quality, and access of Geoinformatics Teaching, Research and Daily Application in Taita Taveta County, Kenya (TAITAGIS). The partner institutions are the Department of Geosciences and Geography at the University of Helsinki in Finland and the Taita Taveta University (TTU) in Kenya.

**The Academy Programme for Development Research (DEVELOP)** is funded by the Academy of Finland and the Ministry for Foreign Affairs of Finland. It provides funding to multidisciplinary, problem-based research that targets global development issues, helps boost development and capacities in developing countries and makes good use of Finnish knowledge and expertise in the field. The programme's themes are based on Finland's development policy objectives and the Agenda 2030/Sustainable Development Goals. The programme provides funding for four-year research projects.

The ongoing climate-related research programmes under DEVELOP from 2018 to 2022 are:

- Water and vulnerability in fragile societies (WATVUL). The partner institutions are the University of Helsinki and Aalto University in Finland, the Royal University of Phnom Penh and the Cambodian Institute for Technology (ITC) in Cambodia, the University of Gadjah Mada

in Indonesia, and Centro de Investigaciones y Estudios Superiores en Antropología Social (CIECAS) and Colegio de la Frontera Sur (ECOSUR) in Mexico.

- Environmental sensing of ecosystem services for developing climate smart landscape framework to improve food security in East Africa (SMARTLAND). The partner institutions are the University of Helsinki in Finland, Taita Taveta University, Jomo Kenyatta University of Agriculture and Technology, the Kenya Forest Research Institute, the Kenya Wildlife Service, the Kenya Forest Service, the Ministry of Agriculture of Kenya, Duke University, the Swedish University of Agricultural Sciences, and the International Livestock Research Institute.
- Sustainable Livelihoods and Politics at the Margins: Environmental Displacement in South Asia. The partner institutions are the University of Helsinki in Finland and Shahjalal University of Science and Technology, Sylhet, in Bangladesh.
- Cuban Energy Transformation, Integration of Renewable Intermittent Sources in the Power Systems (IRIS). The partner institutions are the University of Turku and Tampere University in Finland, Universidad de Oriente, Santiago de Cuba Instituto Superior Politécnico Jose Antonio Echeverria, the Technical University of Havana, CUJAE CUBAENERGIA, and Centro de Investigacion de Energia Solar (CIES) in Cuba.
- Superior Grain Safety with Designed Mycotoxin Binding Properties (POWERGRAIN). The partner institutions are the University of Helsinki, the Department of Food and Nutrition Science (FAN) in Finland, and IRSAT DTA (Institut de Recherche en Sciences Appliquées et Technologies) in Burkina Faso.

## Literature and internet links

Aalto University ice tank, <https://www.aalto.fi/en/research-and-learning-infrastructures/aalto-ice-and-wave-tank>

Academy of Finland research programmes, <https://www.aka.fi/en/research-funding/programmes-and-other-funding-schemes/academy-programmes/>

ACTRIS - The European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gas, <http://www.actris.eu/>

Algaline, <https://www.finmari-infrastructure.fi/ferrybox/>

Arctic Centre at the University of Lapland, <https://www.arcticcentre.org/EN>

Arctic Monitoring and Assessment Programme (AMAP), <http://www.amap.no/>

Business Finland, <https://www.businessfinland.fi/en>

Declaration for Open Science and Research (Finland) 2020–2025

<https://avointiede.fi/en/policies/declaration-open-science-and-research-2020-2025>

Environmental monitoring at the Finnish Environment Institute (SYKE) and the environment administration, including National environment monitoring strategy & development program MONITOR 2020

[http://www.syke.fi/en-US/Research\\_Development/Production\\_of\\_environmental\\_information](http://www.syke.fi/en-US/Research_Development/Production_of_environmental_information)

<http://www.ymparisto.fi/en-US/Envibase>

[http://www.syke.fi/en-US/Research\\_Development/Research\\_and\\_development\\_projects/Projects/National\\_environment\\_monitoring\\_strategy\\_development\\_program\\_MONITOR\\_2020](http://www.syke.fi/en-US/Research_Development/Research_and_development_projects/Projects/National_environment_monitoring_strategy_development_program_MONITOR_2020)

The Finnish Association of Finnish Foundations: Climate and Environmental Measures of Foundations <https://saatiotrahastot.fi/en/climate-and-environment/>

Finnish Climate Change Panel, [www.ilmastopaneeli.fi](http://www.ilmastopaneeli.fi)

Finnish Environment Institute (SYKE), <http://www.syke.fi/en-US>

Finnish Food Authority (Ruokavirasto), <https://www.ruokavirasto.fi/en/>

The Finnish Institute for Health and Welfare, <https://thl.fi/en/web/thlfi-en>

The Finnish Institute of International Affairs, <http://www.fiia.fi/en/home/#tab1>

The Finnish Institute of Occupational Health, <https://www.ttl.fi/en/>

Finnish Marine Research Infrastructure – FINMARI, <https://www.finmari-infrastructure.fi/>

Finnish Meteorological Institute (FMI) – research, <http://en.ilmatieteenlaitos.fi/research>

Finnish National Report on Systematic Observations for Climate. National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan (2013) Finnish Meteorological Institute. [https://library.wmo.int/doc\\_num.php?explnum\\_id=3618](https://library.wmo.int/doc_num.php?explnum_id=3618)

Finnish Scholarly Journals Online, <http://pro.tsv.fi/tisci/index.php?lang=en>

Finnish Science Barometer 2019 by the Finnish Society for Scientific Information, [http://www.tieteentiedotus.fi/files/Tiedebarometri\\_2019.pdf](http://www.tieteentiedotus.fi/files/Tiedebarometri_2019.pdf) (in Finnish) [http://www.tieteentiedotus.fi/files/Sciencebarometer\\_2019\\_23122019.pdf](http://www.tieteentiedotus.fi/files/Sciencebarometer_2019_23122019.pdf) (in English)

Geological Survey of Finland, <https://www.gtk.fi/en/>

Global Atmosphere Watch (GAW),

<https://public.wmo.int/en/programmes/global-atmosphere-watch-programme>

Government Institute for Economic Research (VATT) – research,

<http://www.vatt.fi/en/research/>

Government's annual plan and projects for joint analysis, assessment and research activities,

<http://vnk.fi/en/government-s-analysis-assessment-and-research-activities>

Hildén, M., Berninger, K., Halonen, J.I., Käyhkö, J., Mettiäinen, I., Tikkakoski, P., Tuomenvirta, H., Gregow, H. & Tynkkynen, O. (2022) How to strengthen Finland's capacity to adapt to climate change? Article Series of Government's analysis, assessment and research activities 26/2022. <https://tietokayttoon.fi/julkaisu?pubid=42102>



ICOS Finland, [http://www.icos-infrastructure.fi/index.php?option=com\\_content&view=article&id=3&Itemid=1](http://www.icos-infrastructure.fi/index.php?option=com_content&view=article&id=3&Itemid=1)

IPCC Emission Factor Data Base, <http://www.ipcc-nggip.iges.or.jp/EFDB/main.php>

Natural Resources Institute Finland (Luke), <http://www.luke.fi>

Nordic Working Group for Climate and Air (NKL), <https://www.norden.org/en/noak>

Open data - The portal “avoindata” (open data). Direct links to available open data sources throughout Finland, including research institutes, national authorities, regional councils and municipalities  
[https://www.avoindata.fi/data/en\\_GB/dataset](https://www.avoindata.fi/data/en_GB/dataset)

Piironen, T., Leskinen, O. & Saastamoinen, U. (2021) Climate Impact Assessment Guide for Legislative Proposals. Publications of the Ministry of the Environment 2021:15 (In Finnish, with abstract in English) <http://urn.fi/URN:ISBN:978-952-361-245-7>

The Research Institute of the Finnish Economy (Etna), <https://www.etla.fi/en/>

Strategic Research Council research programmes  
<https://www.aka.fi/en/strategic-research/strategic-research/strategic-research-in-a-nutshell/programmes-and-projects/>

Strategy for National Research Infrastructures in Finland 2020–2030  
<https://www.aka.fi/en/about-us/decision-making-bodies/firi-committee/strategy-for-national-research-infrastructures-in-finland-20202030/>

SAON – Sustaining Arctic Observation Networks, <http://www.arcticobserving.org/>

Sitra, The Finnish Innovation Fund, <https://www.sitra.fi/en/#>

Top-Level Research Initiative, a Nordic research and innovation initiative on climate, energy and environment, <http://www.toppforskningsinitiativet.org/en>

Universities – list of Finnish Universities, <http://minedu.fi/en/universities>

Universities of Applied Sciences in Finland – list, <http://minedu.fi/en/universities-of-applied-sciences>

VTT Technical Research Centre of Finland Ltd – research, <http://www.vtt.fi/research/?lang=en>

