



8

RESEARCH AND SYSTEMATIC OBSERVATION

This chapter describes Finnish research on climate change: international research cooperation, major research programmes, studies on climate process and system, climatic modelling and prediction, research that supports the greenhouse gas inventory as well as research on impacts, mitigation and adaptation. It is followed by a portrayal of atmospheric, ocean and terrestrial climate observing systems. In the end of the chapter there is an outline of the Finnish contribution to capacity building in relation to research and systematic observation in developing countries.

8 RESEARCH AND SYSTEMATIC OBSERVATION

8.1 General policy on research

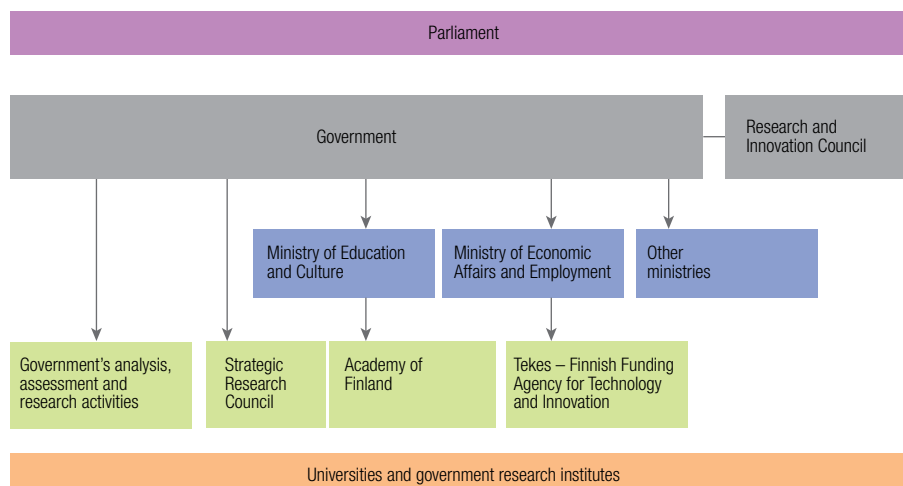
8.1.1 Domestic activities

In 2015, Finland's research and development (R&D) expenditure was EUR 6,100 million, or 2.9 per cent of the country's gross domestic product. Although national R&D expenditure has been declining since 2011, it is still a higher percentage than the average among the OECD countries. In 2015, around 67 per cent of the R&D expenditure was by the private sector, nine per cent by the public sector and 24 per cent by the higher education sector.

Of R&D funding, 53 per cent was from the private sector, 21 per cent from the public sector, 12 per cent from the higher education sector, and 14 per cent from foreign funding. The architecture of public research funding is described in Figure 8.1. The distribution of public R&D funding in 2011 is presented in Figure 8.2.

In recent years, the number of R&D personnel has decreased slightly and it is at around 76,000 (2015). The decrease since 2011 has been a few per cent. The number of R&D personnel with a doctoral degree has more than tripled since 1995.

Figure 8.1
Architecture of public research funding in Finland.

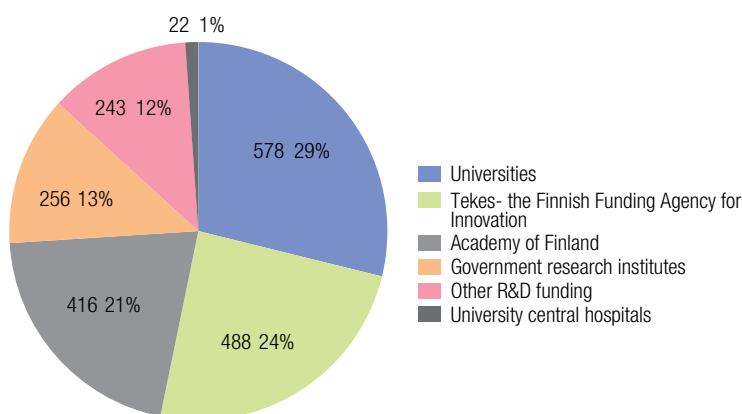


The Research and Innovation Council, chaired by the Prime Minister, supports the Government in developing and combining visionary science, technology and innovation (STI) policy. The Academy of Finland is the umbrella of the national Research

Councils, and it finances high-quality scientific and strategic research (EUR 415 million in 2015, including Strategic Research Council's part of EUR 55 million). Tekes – the Finnish Funding Agency for Innovation provides innovation funding for companies, research organisations, and public sector service providers (EUR 488 million in 2015). The Ministries' joint analysis, assessment and research activities, coordinated by the Government, generate information that supports decision-making, working practices and management by knowledge.

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 at increasing an understanding of the scientific basis of climate change, as well as the impacts and options for mitigation and adaptation, including addressing of environmental and socio-economic 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 funding in Finland in 2015 (EUR million; per cent)



Finland's Government Programme (2015) has five strategic priorities composed of 26 key projects. Climate change is related to the priority of Bioeconomy and clean solutions, and its key project of Towards carbon-free, clean and renewable energy cost-efficiently.

The new instrument of the Government's annual plan 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.

Focus on research infrastructures has grown in recent years in Finland. The Academy of Finland coordinates national research infrastructure investments, as well as participates in European and international research infrastructures. As an international example, Finland is a member of the Integrated Carbon Observation System (ICOS) network. The ICOS network is headquartered in Finland since 2014. Finland is also leading the implementation of the Aerosols, Clouds and Trace gases Research Infrastructure (ACTRIS), which is scheduled to be operational in 2020, and the statutory seat of ACTRIS will be in Finland. See Section 8.1.2 for more information.

Box 8.1

OPEN DATA SETS 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' data sets 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), 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 data sets 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. FMI Open Data Service usage has been growing annually, currently there is about 10,000 registered software developers and users and over 440,000 data downloads per day (5.2 req/s). Data is utilised in various economic sectors in Finland, e.g. Public, Energy, IT and Education. SYKE's open data policy applies to its data and register assets. SYKE's open data includes versatile information on water resources, surface and ground waters, the Baltic Sea, environmental load and distractions, the valuable natural environment, land cover and the built environment. SYKE's open data can be found at <http://www.syke.fi/opendata>. ■

Open science is one of the spearheads of Finnish science policy and it is promoted by all means necessary (see an example in Box 8.1). The Ministry of Education and Culture has outlined that Finland will become one of the leading countries in open science and research by 2017. Operating models should contain a variety of premises for openness, such as to meet the requirements for digital preservation to serve open research and science. The objective is to have open access to all scientific publications by 2020. In the future, Statistics Finland will be preparing annual impact reports on Open Data to Finnish society.

In addition to the open science policy within the country, Finland has been operating extensive capacity building programmes to promote the exchange of information and know-how 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 Chapter 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). Publishing research results in peer-reviewed international journals is advocated in all fields of research. A thorough window to the Finnish open access journals is available at www.journal.fi. Furthermore, there are scientific open access journals with a climate and ecosystems related focus, published by the Finnish research institutes, societies and universities, such as Boreal Environment Research and Silva Fennica that promote free international access to research results for their part.

The new instrument of the Strategic Research Council (SRC) at the Academy of Finland was founded in 2014 as a new research funding body. It funds high-quality research in areas of high societal significance. The research aims at finding concrete solutions to grand challenges that require multidisciplinary approaches. An important element of such research is active collaboration between those who produce new knowledge and those who use it. The SRC prepares approximately yearly a proposal on key strategic research themes and priorities to be approved by the Finnish Government.

Communication on new research information to decision-makers, other stakeholders and the general public is very important (see 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).

According to the Finnish Science Barometer 2016 the public's expectations are optimistic on science and the world view. Science is believed to be the answer to many important issues. As an 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 the majority (84%). The percentage of those who disagree is almost marginal (6%). Although the mitigation of climate change is seen as a relatively difficult task, optimism about the solutions has increased. One reason for this could be the Paris Agreement resulting from international climate negotiations, and its good media coverage.

Box 8.2

THE FINNISH CLIMATE CHANGE PANEL

The Finnish Climate Change Panel was nominated by the Ministry of the Environment in December 2011. The 12-member Panel was tasked to strengthen the interaction between research and policy making. The panel served two approximately two year terms and published reports on several topics relevant to climate policy making (e.g. The Climate Change Act, Energy system and emission reduction measures, Carbon neutrality, Black carbon, Environmentally and socially sustainable climate policy in agriculture, Climate education, Adaptation to climate change, risks, responsibilities and costs). The mid-term evaluation of the Panel recommended that the panel should make more effort in communicating its messages, and relevant action was taken accordingly.

The legal base for the Finnish Climate Change Panel was established when the Climate Change Act came into force in summer 2015. The Panel is appointed as an independent body to support planning and decision-making of climate policy. The Government nominated the Panel in January 2016. The policy advisory role of the Panel has become stronger. Panellists have e.g. been invited to comment on the 2016 Energy and Climate Strategy in relevant committee hearings in the Finnish Parliament. The Panel's advice has also been sought during the preparation of the Government's first Mid-term Climate Change Policy Plan. The Panel has continued its work with LULUCF related issues, and has published a report on Cleantech. ■

8.1.2 International activities

Finland has participated in the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP). 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 to 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 IPCC Fifth Assessment Report (AR5) and many more experts participated in the review pro-

cess. Due to their widespread expertise in greenhouse gas inventories and land-use issues, quite a few Finnish experts served as authors for the supplementary guidance material on methodologies for estimating anthropogenic greenhouse gas emissions by source and removals by sinks resulting from land use, land-use change and forestry: '2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol' and '2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands'. Finnish experts will participate as authors in the preparation of the IPCC Special Report on 1.5 °C Global Warming and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories starting in 2017.

In another major effort, Finland is overseeing the implementation of the ICOS (Integrated Carbon Observation System) organisation, which is a European distributed infrastructure for online, in-situ monitoring of greenhouse gases (CO_2 , CH_4 and N_2O) necessary for understanding present-state and future sinks and sources. In November 2015, the European Commission officially launched ICOS ERIC, the Integrated Carbon Observation System European Research Infrastructure Consortium. The ICOS links research, education and innovation to promote technological developments and demonstrations related to greenhouse gases. The ICOS Head Office is located in Helsinki. The ICOS puts into effect the GHG observations within the global GCOS (Global Climate Observing System) and GEOSS (The Global Earth Observation System of Systems) networks in Europe, 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). 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 a preparatory phase, and is scheduled to be operational starting from 2020. ACTRIS links research, education and innovation to promote data use, technological developments and demonstrations related to atmospheric components; aerosols, clouds and trace gases. The ACTRIS Head Office is planned to be located in Helsinki, with a secondary node in Rome, Italy. The partners of ACTRIS-Finland are the FMI, the University of Helsinki, the University of Eastern Finland and Tampere University of Technology. Finnish funding for ACTRIS will be around EUR five million annually during its operational phase (ACTRIS is presented in more detail in Section 8.3.1).

Joint Programming is a European scheme that involves building a new approach with the aim of strengthening research and research funding cooperation in Europe in the interests of addressing certain specific societal challenges. Several currently ongoing Joint Programming Initiatives (JPIs) touch upon climate change themes, principally the Agriculture, Food Security and Climate Change (FACCE JPI), Connecting Climate Knowledge for Europe (JPI Climate) and Water Challenges for a Changing World (Water JPI). There are also several ERA-NETs, some of them under the umbrellas of JPIs, which touch upon the climate change issues. Examples of these include WaterWorks2014 and WaterWorks2015 (under Water JPI), ERA-NET Plus on Climate Smart Agriculture (under FACCE-JPI), ERAfrica, BiodivERsA and ERA-NET Cofund for climate services (ERA4CS). Finnish representatives are involved in the governance of these initiatives and there are national support groups as well. Finnish researchers have also succeeded in several joint calls of these initiatives. Finnish researchers have actively participated in climate-change related research under Horizon 2020 Work Programmes 2014 to 2016. By

March 2017, more than 56 projects with Finnish participant organisations were being funded, under six activities of the Work Programmes of the European Commission. The Technical Research Centre of Finland Ltd (VTT) and the Finnish Meteorological Institute (FMI) were involved in the largest number of projects. The total cost of the projects was approximately EUR 502 million. Five projects are led by a Finnish coordinator.

From 2008 until 2016, Finland was a member of the Top-level Research Initiative (TRI), a major Nordic venture for climate, energy and the environment. TRI comprised six programmes, each of which have launched thematic calls using appropriate funding instruments. Types of calls launched included Centres of Excellence in research and top-level research networks. TRI initiative has not only generated considerable new knowledge about climate change, it has also educated a large generation of young climate researchers.

NOAK (the Nordic Working Group for Global Climate Negotiations) is a working group under the Nordic Council of Ministers. It was established in 2007 as part of the prime ministers' globalisation initiative and its aim was first to support the preparations for the UNFCCC climate negotiations in Copenhagen in 2009. After Copenhagen, the group received a permanent status and its mandate was widened to contribute to an ambitious and effective implementation of the UNFCCC and its Paris Agreement, with a Nordic perspective. NOAK produces studies for Nordic and international climate negotiators and arranges workshops supporting the negotiations. Finland was the chair of NOAK in years 2011–2014 and has been the coordinator of NOAK since 2011.

Finland is a participant in the Arctic Monitoring and Assessment Programme (AMAP), which is an intergovernmental monitoring and research programme under the Arctic Council. The main goal of AMAP is to provide reliable and sufficient information on the status of, and threats to, the Arctic environment, and to provide scientific advice on actions to be taken in order to support Arctic governments in their efforts to take remedial and preventive actions relating to contaminants. AMAP monitors and assesses levels of pollutants and their effects on the Arctic environment. Assessing the impacts of climate change on the Arctic environment is one of the priority areas. AMAP publishes non-technical assessment reports for decision-makers and the general public and also more scientific reports. For example in 2016, AMAP published jointly with the WCRP Climate and Cryosphere (CliC) Project, and the International Arctic Science Committee (IASC) 'The Arctic Freshwater System in a Changing Climate' and in 2015, the AMAP Assessment: Human Health in the Arctic, which deals extensively with climate change related issues. AMAP's latest climate change related report was an updated report on Snow, Water, Ice and Permafrost in the Arctic (SWIPA 2017). The report serves as an arctic contribution to the IPCC special report on 'Oceans and Cryosphere' (due in 2019) and the Assessment Report 6 (due in 2021). Relating to adaptation to climate change and other drivers of change, AMAP produced three regional Adaptation Actions for a Changing Arctic Report including the Barents area (2017). Finland chaired the AMAP Working Group in 2015 to 2017 and Finland is currently chairing the Arctic Council (2017–2019). During this period, Finland will lead the Arctic Council Expert Group on Black Carbon and Methane that aims to improve circumpolar knowledge of the emissions and mitigation actions.

Finland is a member country of the Barents Euro-Arctic Council, 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 autumn 2013 and includes a number of 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 CO₂ and black carbon emission reductions, among other things. In addition, the WGE is 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 8.3.

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

Box 8.3

CLIMATE RESEARCH IN THE ARCTIC

Arctic Research Policy and Goals

Finland's Strategy for the Arctic Region defines objectives for Finland's Arctic policy. With respect to research, the policy is to invest in expertise and to gain knowledge of northern areas. A diversified array of Arctic research is conducted by higher education institutions and by 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 in the Arctic Council and its Working Groups. Finland has, for example, contributed significantly in 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 funding and steering of Arctic research in higher education institutes and research institutes.

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.

Tekes – the Finnish Funding Agency for Innovation offers funding for research and development conducted by Finnish companies, research organisations, and public sector service providers.

Major Arctic Research Initiatives

ARKTIKO. The national research programme ARKTIKO (2014 to 2018) aims to study and understand the changing factors that affect the development of the Arctic region, the process of transformation, and the dynamics of change.

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

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, snow and atmosphere-sea ice-ocean interactions are studied to improve capabilities to model 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 focuses in particular on impacts and scenarios of climate change and ways of securing sustainable development in arctic areas jointly with other research organisations, such as the Natural Resources Institute LUKE, that 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 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). 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 developing and improving of forecasts and operative models and services.

R/V Aranda is an ice-reinforced research vessel (ice classification Super A1) mostly operating in the Baltic Sea but it has also made expeditions to the Arctic Ocean. Finland has a fleet of icebreakers of which several 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. The Aalto University operates a large-scale ice tank infrastructure, which can produce sea ice at model scales. In addition, there is 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 plan for analysis, assessment and research

In 2014, the Government adopted an approach based on annual plans for analysis, assessment and research which underpins policy decision making and steers studies and research towards specific priority areas selected by the Government. The resources available for implementing the plan amount approximately to EUR 10 million. During 2014 to 2017 there are several projects relating to climate change (see Table 8.1), altogether about EUR 2.3 million. The projects have been conducted by many different organisations: Universities, research institutes and consultants.

Programmes of the Academy of Finland

The recently finished Finnish Research Programme on Climate Change (FICCA, 2011 to 2014), by the Academy of Finland, was launched to respond to the scientific challenges posed by climate change on a broad front. One of the principles underlying the FICCA programme was to support the type of multidisciplinary research that addresses both social and environmental areas — with the objective being a systemic approach to research problems. In the first call for applications in 2010, eleven research projects were granted funding for 2011 to 2014. In 2011, international joint calls were launched with Chinese and Russian funding partners and, eventually, six international joint projects were funded for 2012 to 2014. In the 2012 call, researchers were invited to submit applications for development research projects targeted at climate change research, and as a result, the Ministry for Foreign Affairs of Finland and the Academy of Finland co-funded seven research projects for 2013 to 2014. The total funding of the

Table 8.1

Climate change related projects in the Government plan for analysis, assessment and research in 2014 to 2017.

Projects, themes	Duration	EUR	Decision making process
EU 2030; several projects, themes: <ul style="list-style-type: none"> • Effects of the EU's climate and energy targets for 2030. • Which policy measures and other measures are effective in achieving the targets set in the 2030 Energy and Climate Package of the EU? • Impact of the amendments to the Emissions Trading Directive on Finnish industry, energy production and economy 	2014 to 2017	1,500,000	Support for: <ul style="list-style-type: none"> • EU 2030 policy • Preparation and evaluation of Energy and Climate Strategy
Climate negotiations, themes: <ul style="list-style-type: none"> • How should Finland prepare for the obligations imposed by the international climate agreement? 	2016	150,000	Support for international climate negotiations
Adaptation; several projects, themes: <ul style="list-style-type: none"> • Adaptation actions for a changing Arctic • Proactive management of weather and climate related risks • Assessment of risks and vulnerability to climate change 	2014 to 2017	650,000	Support for: <ul style="list-style-type: none"> • Adaptation strategies and such • Arctic cooperation, strategic work

FICCA research projects was around EUR 17 million, of which approximately one-half was granted to universities and the other half to research institutes.

Sustainable Governance of Aquatic Resources (AKVA, 2012 to 2016) aimed to tackle the scientific challenges related to water. The Nordic climate and environment was one of the programme's major challenges specified by the Academy Board. Several projects, including joint calls with international partners, have received funding from AKVA.

The Academy of Finland has three ongoing Programmes related to climate and energy:

The Academy Programme on a biobased economy (BioFuture2025, 2017 to 2020) was launched in order to support the creation of a new knowledge base and to promote major scientific breakthroughs through new ways of doing science. A biobased economy is evolving alongside the fossil-fuelled economy, promising solutions that will help curb climate change and excessive natural resource consumption. In the first call for applications in 2016, ten research consortium projects were granted funding for 2017 to 2020.

The Arctic Academy Programme (ARKTIKO, 2014 to 2018) aims to study and understand the change factors affecting the development of the Arctic region, the transformation process, and the dynamics of change. The programme has four themes: Good quality of life in the north, Economic activity and infrastructure in Arctic conditions, The northern climate and environment, and Cross-border Arctic policy. ARKTIKO has funded 20 extensive international research projects and two international joint projects.

The Academy Programme New Energy (2015 to 2018) harnesses 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.

The Strategic Research Council (SRC) at the Academy of Finland provides funding for long-term and programme-based research to produce knowledge to solve society's grand challenges that require multidisciplinary approaches. The SRC prepares approximately yearly a proposal on key strategic research themes and priorities to be approved by the Finnish Government. An important element of such research is active collaboration between those who produce new knowledge and those who use it.

The Government decides on the research needs to be explored and decides the final themes, which the SRC then formulates into research programmes and funding calls. SRC programmes run for three to six years. Programmes that include projects of particular relevance for climate change are the following:

- Disruptive Technologies and Changing Institutions (Energy transition and renewable energy)
- A Climate-Neutral and Resource-Scarce Finland (Energy transitions, use of forest resources, off shore wind, circular economy of non-renewable substances, resource efficient food production).
- Security in a Networked World (Climate and resource scenarios)
- Urbanising Society (Urban form, smart cities)

Programmes of Tekes

The Finnish Funding Agency for Innovation (Tekes) has coordinated major research and development programmes on the mitigation of climate change. The BioRefine – New Biomass Products Programme (2008 to 2011) developed business related to new value-adding products or new process or business concepts that utilise biomass in a variety of forms, as well as technologies, equipment production and services. The Green Mining Programme's main objective was to make Finland a global leader of the sustainable mineral industry by 2020. Green Growth (2011 to 2015) and Groove – Growth from Renewables (2010 to 2014), generally had a wider scope, but their topics were also relevant for climate change mitigation. The aim of the Green Growth programme was to support the generation of innovations enabling significant leaps in energy and material efficiency and to create a foundation for developing new value networks based on green growth. The Groove – Growth from Renewables programme enhanced the business capabilities of Finnish small and medium-sized enterprises working with renewable energy by improving their international competitiveness and by developing networks together with the financier network. Ongoing programmes CleanWeb (2016 to 2018) and BioNets (2016 to 2018) have connections to the mitigation of climate change. The objective of CleanWeb is to create rapidly scalable cleantech businesses and accelerate access to the markets. This involves leveraging digitalisation and new innovations and practices to transform the cleantech sector into a reformed, competitive growth industry. The aim of the BioNets programme is to advance Finland's bio and circular economy by generating innovative and international business ecosystems, new business development platforms and new bioeconomy solutions, services and actors. The goal is to pilot solutions at an early stage together with customers. Basically all of the 756 ongoing or finished projects and their volume of EUR 290 million (2011 to 2017) contribute to climate change mitigation either by providing more knowledge through research or by supporting the business capabilities of renewable energy companies.

Sitra, the Finnish Innovation Fund

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 responsible operators to support public administration.

One of Sitra's three theme areas is promoting a resource-wise and carbon-neutral society. The aim is to make Finland a trailblazer for a new society based on a sustainable economy by 2019. The process of drawing up Finland's road map for a circular economy was led by Sitra. The road map was published in autumn 2016. The first trials of this road

map – the key projects and pilots – have already been launched. Between 2013 and 2016, practical tools were developed to help companies make their businesses carbon neutral.

Sitra has invested a total of approximately EUR 16.2 million in projects carried out as part of the Resource-wise and Carbon-neutral Society theme area, contributing to over 150 projects. In addition, Sitra has invested in several companies and funds and on 31 December 2016, had investments in six companies and eight international funds in the field. The current projects and fund investments of Sitra include themes that promote climate change mitigation, such as the circular economy.

Foundations

Several foundations have given considerable emphasis to climate change studies and environmental studies. An indicative but not a complete list of those foundations is: the Atmosmare Foundation, the Finnish Cultural Foundation, the John Nurminen Foundation, the Kalevi Sorsa Foundation, the KAUTE Foundation, the Kone Foundation, the Lammi Biological Station Environmental Studies Foundation, the Maa- ja Vesitekniiikan Tuki Foundation, the Maj and Tor Nessling Foundation, the Marjatta and Eino Kolli Foundation, the Metsämiesten Säätiö Foundation, the Swedish Cultural Foundation in Finland, the Tiina and Antti Herlin Foundation, the Walter and Andrée de Nottbeck Foundation, and the Väinö Tanner Foundation.

8.2.2 Climate process and climate system studies

The Finnish Meteorological Institute FMI has a staff of around 80 scientists working with climate change and related problems. With regard to 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, doing impact and adaptation studies, including socio-economic 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 concentrates 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 the aerosol-climate system. It relies on field measurements, modelling, and laboratory work and satellite retrieval. The focus is on investigating:

- Aerosol-cloud interactions
- Aerosol optical properties
- Radiative forcing by atmospheric aerosols
- Atmospheric aerosol formation
- Climatic effects of absorbing aerosols into the atmosphere and snow and ice surfaces.

The FMI operates five stations in Finland that continuously measure climatically important aerosol, cloud and trace gas properties. The most advanced of these is the Pallas-Sodankylä GAW station in northern Finland, where aerosol measurements were started in 1996. Other stations are located in Utö (Baltic Sea, since 2003), Virolahti (eastern Finland, since 2005), Kuopio (central Finland, since 2006) and Helsinki (since 2004). The

FMI has also assisted in establishing and enhancing aerosol measurements at stations in India, China, South Africa, Antarctica and Russia, and on polar research cruises.

The research aims to improve the treatment of aerosol processes in climate models and investigate future aerosol emission scenarios. The FMI is using and developing a number of aerosol process models for atmospheric applications. It also has facilities to conduct aerosol laboratory experiments, develop instruments and conduct chemical analyses. In addition, algorithms for retrieving aerosol data from satellites have been developed.

The Universities of Helsinki and Eastern Finland and the FMI host the Finnish Centre of Excellence (CoE) in Physics, Chemistry, Biology and Meteorology of Atmospheric Composition and Climate Change (CoE status in 2002 to 2007, 2008 to 2013, and 2014 to 2020). Its main objective is to reduce scientific uncertainties concerning global climate change issues, particularly those related to aerosols and clouds. Its research aims to create a deep understanding of the dynamics of aerosol particles and ion and neutral clusters in the lower atmosphere, with an emphasis on biogenic formation mechanisms and their linkage to biosphere-atmosphere interaction processes, biogeochemical cycles and trace gases. The latest measurement techniques, as well as modelling approaches are developed and utilised at the centre. The core activities include conducting continuous measurements and maintaining a database on atmospheric and ecological mass fluxes, as well as conducting focused experiments and modelling to understand the observed patterns.

Paleoclimatology

Finnish universities and research institutes have extensive activities in paleoclimatology and they cooperate in several research areas. Studies are mostly based on good natural archives in Finland and polar areas.

At the Environmental Change Research Unit (ECRU) of the 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. The ECRU is particularly interested in centennial to millennial-scale climatic changes with a focus on Arctic environments. The research is largely based on proxies stored in natural archives (peatlands, lake and marine sediments, ice cores). Specific research themes include carbon cycling, climate development and extreme climatic events, past black carbon deposition in the European Arctic, Arctic sea ice history, past peatland and lake dynamics. Intensive data handling and data compilations are a key element of research at ECRU. The research of the ECRU is also a part of wider international research programs.

The Department of Geosciences and Geography at the University of Helsinki works on climate reconstructions based on biological indicators in lake sediments. The Geological Survey of Finland studies varved sediments, with an emphasis on their physical properties.

At the Geoscience Research Unit of the University of Oulu, the objectives under paleoceanographic and -climatological research are to produce important threshold values in geochemical (incl. isotopic fingerprint) and sedimentological proxy information on past climate warming events and related loss of ice in the North in time scales from hundreds to hundreds of thousands of years. Polar marine sediment records (e.g. Central Arctic Ocean and Prydz Bay and Wilkes Land in Antarctica), as well as terrestrial glacial-interstadial deposits in the Eurasian Arctic also document transitions between different climate states well, including abrupt events on timescales of decades to a few centuries. The research is conducted under international research programmes. The Space Climate Research Unit of the University of Oulu studies the long-term (up to a few hundred years) evolution of the Sun and the effects of solar magnetic activity to the space around the Sun, including the Earth. All possible long-term series of observations made by satellite and ground-based instruments to study solar effects to the Earth's atmosphere and climate

are in use. The solar wind affects the climate and atmosphere, especially at high latitudes. Studies are related to questions like how these mechanisms influence the atmosphere and how relevant they are to climate change.

The Natural Resources Institute Finland (Luke; previously the Finnish Forest Research Institute Metla) has constructed the longest annual pine tree-ring chronology in the world (5634 BC to AD 2016s) based on megafossil trees recovered from lake bottoms. This chronology has been used for reconstructions of past summer temperature changes and variability in the northern climate after the last glaciation period. In general, the paleoclimate research conducted at the Natural Resources Institute Finland is focussed on constructing tree-ring chronologies for reconstructions of past temperature and precipitation variability in Finland and adjacent areas and for contributing to the efforts of reconstructing the past climate variability at Hemispheric and global scales in international cooperation. Tree-ring chronologies and the paleoclimate reconstructions are used for analysing the impacts of natural forcing factors (solar activity and explosive volcanism) and the effects of ocean-atmospheric circulation on climate variability. The paleoclimate expertise of Luke contains the fieldwork and laboratory work with subfossil wood materials (tree-ring dating, blue intensity/latewood maximum density, wood anatomy) needed to build the long tree-ring chronologies.

The Laboratory of Chronology (LC) of the Finnish Museum of Natural History analyses the isotopic and elemental compositions of samples from different environmental archives. The LC has led efforts to construct radiocarbon and stable isotope chronologies from Finnish subfossil materials for the late and mid Holocene times. The aim is to constrain the temperature-cloud-irradiance interrelationships and their dependence of North Atlantic variability in the ocean-atmospheric circulation. Furthermore, abrupt climatic and environmental anomalies are tracked down by multiproxy methodologies and the interaction between nature and people is addressed.

8.2.3 Climatic modelling and prediction

The FMI studies climate change using climate models that describe the physical and chemical processes of the Earth's climate system. The modelling is based on participation in the EC-Earth earth system model collaboration. The FMI is also continuing to use the ECHAM global climate model family. ECHAM is a global climate model developed by the Max Planck Institute for Meteorology. The FMI also develops and uses the regional climate models HARMONIE-Climate and REMO. Regional climate modelling is used to produce data for evaluating the societal impacts of climate change in northern Europe.

The model development at FMI includes aerosol and cloud parameterisation and related radiative transfer effects as well as atmospheric chemistry greenhouse gas exchanges. The FMI has in-house high performance computing (HPC) facilities for modelling.

For ocean climate research, the FMI utilises a regional set-up based on the NEMO-LIM3 model for estimating climate change and variability in the Baltic Sea and a global set-up for the Arctic Ocean and southern ocean research. A particular interest of the FMI is to develop sea ice dynamics and an ice thickness distribution model.

8.2.4 Research in support of the national greenhouse gas inventory

Research in support of the national greenhouse gas inventory has aimed at developing methodologies and emission factors or other parameters to improve the accuracy and reduce the uncertainties of the greenhouse gas inventory. This research has been funded to a large extent by the Ministry of the Environment and the Ministry of Agriculture and For-

estry. 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 to support the greenhouse gas inventory has been on developing and improving methods and national parameters for estimating the 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 and the Finnish Forest Research Institute, currently the Natural Resources Institute Finland (Luke)) has been acknowledged internationally and is used in inventory preparation in other countries, too. Several national and international projects have enabled the current use of Yasso in estimating carbon stock changes of most land use classes in Finland. Several research projects conducted by universities and research institutes have provided more accurate emission factors for CO₂, N₂O and CH₄ emissions from organic soils and peat extraction.

In addition, a recent project at the Natural Resources Institute (Luke) on harvested wood products estimated carbon content of different domestic products and allocated harvests since 1990 to different forest-related activities under the Kyoto Protocol, i.e. to afforestation and reforestation, deforestation and forest management. Methodology for identification of land use and land use change has also been further developed. An ongoing development project on the Finnish normative manure system will provide an updated Nitrogen mass flow model to calculate nitrous oxide emissions from manure management (the Finnish Environmental Institute and the Natural Resources Institute Finland).

Furthermore, an ongoing project at the Finnish Environment Institute (SYKE) funded by the Nordic Council of Ministers aims to improve the F-gas inventories in the Nordic countries by joint comparison and verification of the emission estimation methodologies, emission factors and other parameters and assumptions used in different countries. The project will also provide estimates of the strengths and weaknesses of the inventories and, e.g. the applicability of the national emission factors and other parameters to other 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, the national 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 Sixth 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).

In research on climate change, the focus has gradually shifted from dominantly natural sciences to more comprehensive approaches that include socio-economic studies and inter- and transdisciplinary approaches. The aim 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

A large number of 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. Climate change research is 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.

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 funding for climate change research in 2013 to 2016, which totalled more than EUR 59 million, nearly 20 organisations served as grant holders during the research period. Of these, the foremost research performer is the University of Helsinki; it is involved in over 40 projects. Of the other universities, the University of Eastern Finland, the University of Oulu, and the Universities of Turku are runner-ups with several climate change projects each. In addition, Aalto University, the University of Jyväskylä, the University of Tampere, Åbo Akademi University, Tampere University of Technology and Lappeenranta University of Technology have one or a few projects each. Research institutes are also active: the Academy of Finland's scientific research funding has been granted to the FMI (almost 30 projects), the Natural Resources Institute Finland (Luke) including former Metla and MTT, the Finnish Environment Institute (SYKE), the Geological Survey of Finland (GTK), VTT Technical Research Centre of Finland, the National Institute for Health and Welfare (THL) and the International Institute for Applied Systems Analysis.

The Ministry of Agriculture and Forestry and the Ministry of the Environment are funding the Research Programme for Environmental impacts of agriculture (MATO) during 2016 to 2020. One of the aims of the MATO programme is to enhance adaptation and mitigation. For example, one project is aiming at modelling the carbon sequestration potential of soil amendments in agricultural soils.

Finnish research organisations (for instance SYKE, VTT, FMI) have also been active in adaptation and mitigation research in the European context. Several studies on adaptation have been funded/launched within the EU's framework programme. Finnish research partners are also active in several ERA-Net -programmes initiated under the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI). The Natural Resource Institute Finland (Luke) is among the coordinators of the Knowledge Hub FACCE MACSUR, which brings together the excellence of research in modelling grasslands, livestock, crops, farms, and agricultural trade in order to improve the modelling of climate change impacts on European agriculture and in order to illustrate to political decision-makers how climate will affect regional farming systems and food production in Europe. The five-year project started in June 2012. SYKE leads the working group on effects under the COST Action Innovations in Climate Governance (INOGOV) that explores social science solutions for addressing climate change.

Research on impacts and adaptation

Examples on how the projects of the Government plan for analysis, assessment and research instruments have been able to enhance multidisciplinary research are the projects ELASTINEN and SIETO (see also table 8.1). ELASTINEN was a joint project by the Finnish Meteorological Institute, the University of Helsinki, the Finnish Environment Institute SYKE, the Natural Resources Institute Finland Luke, the Finnish National Institute for Health and Welfare and Gaia Consulting Oy, examining the state of weather and climate risk management in Finland and assessing ways to manage risks and the role

of a range of parties. The SIETO project aims at improved weather and climate risk assessment and operational models merging expertise from both natural and environmental, as well as human and socio-economic sciences.

The objective of ELASTINEN was also to decrease the vulnerability of Finnish society and increase its adaptive capacity to changing climate, enhancing the implementation of the National Climate Change Adaptation Plan

Several studies on the impacts of climate change and adaptation on forestry and agriculture have been carried out in the Natural Research Institute Finland Luke. In 2016, a detailed vulnerability and risk assessment for agriculture, forestry, fisheries, game management and reindeer husbandry was carried out. Other relevant, ongoing research projects and programmes include the Forests and Water Research and Development Programme (H2O), 2013 to 2017, aiming to increase the understanding of the effects of climatic factors and their temporal changes on forests, to investigate the effects of forests and forest management on the water cycle and water quality, to find new methods for preventing detrimental impacts, and to develop and provide new methods and planning tools for the conservation of waters and soils. Research on the adaptation of agriculture to climate change has focused, for example, on scenario analysis, adaptation of the food sector and related socio-economic impacts, and forage production in a changing climate.

Research on the impacts of climate change on inland waters, sea areas, water resources, land ecosystems and biodiversity has been carried out at SYKE. SYKE has also carried out studies of climate impacts, vulnerabilities and risks at different spatial and temporal scales, including analyses of adaptation to climate change as a societal process and studies of scenarios for climate change impacts. Examples include Marine Spatial Planning in a Changing Climate (MARISPLAN) and Pathways Linking Uncertainties in Model Projections of Climate and its Effects (PLUMES) funded by the Academy of Finland.

Impacts and adaptation in the Arctic are intensively studied at the Arctic Centre at the University of Lapland which is the northernmost university in the European Union. The research focuses on global change, sustainable development, anthropology and governance, including an international glaciology group specialised in climate change and modelling the impacts of climate change on Arctic and Antarctic ice masses, extreme events and global sea level.

Adaptation in the urban environment and questions related to the living environment and climate change have been studied. Extreme weather events, such as flood risks, are topical issues for urban planning and construction, and the interconnections between mitigation and adaptation activities are also important aspects of the research.

Assessments of climate change related risks take place in several of the above-mentioned research streams. The FMI provides expertise and cooperation in several such studies.

The National Institute for Health and Welfare studies the health and welfare impacts of climate change with special focus on inequalities, especially vulnerable population groups and measures that should be taken to enhance resilience and preparedness to changes.

A study by the Climate Change Panel (Box 8.2 on the Climate Change Panel) in 2016 examined the risks, costs and responsibilities of the climate change using crop and flood damages as case studies.

Research on climate change mitigation

Systemic and modelling studies on mitigation, as well as analyses of mitigation policies are carried out at several sectoral research institutions. An increasing number of studies have assessed climate change problems from a transdisciplinary perspective and integrated various socio-economic aspects. The Strategic Research Council has funded large consortia, where research institutes, universities and other actors, including the private

sector, join forces in dealing with technology and energy disruptions and resource efficiency. Tekes funding has been important for technology developers who are seeking business opportunities in cleantech.

VTT Technical Research Centre of Finland has a central role in analysing and developing solutions for mitigation. Research efforts range across key sectors, such as the energy industry, transport and the building sector, including system analysis on climate impact of the different technologies, assessments on greenhouse gas impacts, as well as developing renewable and other CO₂ neutral energy production options. One of VTT's key areas is work on scenarios and comprehensive assessments of energy policies.

Climate change policies and measures and their implementation and impacts are also extensively studied at SYKE. Specific topics include the environmental impacts of climate policies and measures, including their effects on carbon sinks and air quality. Life cycle analyses are extensively used in the work. SYKE further analyses energy and other transitions aiming for a low carbon society and the renewal of manufacturing. Studies of energy policy explore ways of managing the increasing share of renewables in the energy mix. Transition studies explore how industrial renewal can contribute to mitigation and how policies influence innovation. The economics of climate change mitigation has been explored by, for example, the Government Institute for Economic Research (VATT), that has shown that subsidies for energy intensive industries are inefficient use of public funds, the University of Oulu, that together with VATT and SYKE has explored the economics of intermittent energy use, VTT, which runs models of the energy system and Luke, that has developed a combined forestry and energy model.

An emerging field of research is the study of 'mitigation experiments', often focusing on local or regional solutions for reducing greenhouse gas emissions, switching to renewable energy resources or improving energy efficiency. These studies explore the potential of 'bottom up' solutions that can contribute to more ambitious mitigation goals at local or regional level than those set at national or EU levels. The studies examine both technical and governance aspects of the experiments. Special research focus has been devoted to the 'carbon neutral municipalities' (Hinku) that have become an expanding municipality and private actor driven network testing out and scaling up innovative solutions for climate change mitigation. The Finnish Environment Institute has provided research-based support for the network.

The Natural Resources Institute Finland studies mitigation measures in the agriculture and forest sectors. Examples of research topics include the enhancement of sinks in agriculture and horticulture, the impacts of changes in climate and energy policy on agriculture, and multi-level integrated modelling and analysis of agricultural systems. In the forest sector, the climate and energy research focuses on the interaction and coherence of different policies that have an impact on the management and use of forests. Special emphasis is put on numerical modelling that combines economic behaviour, policy options and a description of forest resources. As a project example, researchers from the Natural Resources Institute Finland (Luke) and FMI explore the possibilities of optimising forest management for timber production and climate change mitigation, accounting for the trade-offs between carbon and albedo, and climate policy and the economic objectives of forest utilisation in the Academy of Finland funded OPTICA project. In addition, the feasibility, impact and business opportunities of various policy measures promoting carbon sequestration are being examined at a national level.

Developing technology in carbon capture and storage is mostly done commercially in Finland. Applying CCS technology is still in demonstration state. Related research is conducted for instance at Aalto University and Åbo Akademi University. From Finland's point of view, especially interesting is so called bio-CCS (BECCS) that would be used in energy plants utilising biomass or forest industry waste. VTT Technical Research

Centre of Finland has developed CLC (Chemical Looping Combustion) technology on bio-CCS together with other Nordic partners. Carbon capture and use (CCU) is also an emerging technology. VTT together with Lappeenranta University of Technology (LUT) have a project (NeoCarbon) aiming at producing synthetic biofuel by extracting CO₂ from air or combustion gas.

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, there is dedicated research aiming 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. The latter have, for example, included research-based assessment of the Government's Energy and Climate Strategy (see Table 8.1). These operational studies for policy development are linked with more strategic research on climate and energy issues through studies focusing on technological disruption in energy, such as the projects BC-DC focusing on intermittent energy, SET analysing energy transitions, and EL-TRAN examining the required changes in the electricity system. These projects evaluate current systems and also provide assessments of alternative future pathways.

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.

Climate-related observation on hydrology and the chemical and biological state of inland and marine waters, as well as terrestrial biodiversity is carried out or coordinated by SYKE. Climate-related observations on forests, agricultural areas and fisheries are made by the Natural Resources Institute Luke. Several universities also have activities in this area.

Most of the systematic, long-term observational activities are carried out by budgetary funding. However, ongoing, more experimental observations carried out as a part of research projects are, to a significant degree, funded through external R&D funding and they may serve as basis for new systematic observations in the future.

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

8.3.1 Atmospheric observing systems

The meteorological observation network of the FMI is comprised of 86 manual precipitation stations and 180 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 (liquid and solid), wind, solar radiation). Observation records are distributed as synoptic weather messages mainly every 10 minute and via Global Telecommunication System hourly. The FMI has been responsible of aviation weather observations of Finnish airports since 2012. A dual polarisation

Doppler radar network gives comprehensive coverage over Finland offering a wide range of climate and operative applications for the 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, respectively). Since 2013, the FMI's data sets have been free for public use via an online service (see 8.1.1).

Finnish climate observations have been included in, for example, 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.

The FMI maintains a GAW station at Pallas-Sodankylä in Lapland, where greenhouse gas concentrations are measured on a mountain top 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.

- Flask samples are collected weekly at Pallas. The Earth System Research Laboratory in Boulder, Colorado analyses them for CO₂, CH₄, CO, H₂, N₂O and SF₆ concentrations, and the Stable Isotope Laboratory of the University of Colorado in Boulder analyses them for concentrations of the stable isotopes of CO₂ and CH₄. At Sodankylä, ozone soundings in the troposphere and stratosphere are conducted weekly. Regular ozone soundings have also been performed at Marambio in Antarctica since 1988.
- Global data integration and earth system modelling are essential for assessing global trends and regional sources and sinks. The data from the station in Lapland is sent to relevant data banks, including the World Data Centre for Greenhouse Gases in Japan and European data banks, ICOS in particular.

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 of adjacent regions. Both atmospheric concentrations and fluxes over different ecosystems are measured together 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 FMI maintains three atmospheric stations at Pallas, Puijo and Utö, which continuously measure carbon dioxide, methane and carbon monoxide. Weekly sampling will include a broader selection of species similar to that of the GAW programme. The FMI also maintains five ICOS ecosystem stations that measure greenhouse gas fluxes above forest and wetland ecosystems. Altogether, the national station network now consists of 14 atmospheric and ecosystem stations that are ready to join the ICOS.

Finland is leading the implementation of Aerosols, Clouds and Trace Gases Research Infrastructure (ACTRIS), and will be participating in it once it will be ready (2020 onwards). ACTRIS provides high quality data on atmospheric components, and other services for supporting scientific research and science-based policy making. ACTRIS consists of national observing stations, international central facilities focused on data flows and calibration services for different types of instruments, and a top-level organisation, which is coordinating the infrastructure.

ACTRIS provides:

- Advanced facilities for national and international atmospheric science research programmes, enabling a leading role for Europe and member countries. This lowers the barrier for new and innovative environmental science projects.
- Long-term calibrated and reliable reference observations of key atmospheric parameters; aerosols, clouds and trace gases, providing comprehensive comparison data for improvement of air quality, pollutant dispersion, satellite retrievals, and weather and climate forecast models.
- Standardisation and development of new observational methods in atmospheric science to meet future needs; establishment of a common and globally competitive research framework.

The Finnish site selection for ACTRIS is not yet done, but the preliminary list of FMI sites includes Pallas, Puijo and Utö. Furthermore, the FMI is leading the preparation of part of the ACTRIS Data Centre (CloudDataNet) and the setting up of the ACTRIS Head Office.

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. Nowadays, 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 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.

Aerosols have both direct and indirect effects on the atmosphere. The magnitude of these effects in terms of warming or cooling remains one of the most significant sources of uncertainty in climate models. As a part of the WMO's GAW programme, the scattering, backscattering, absorption and size distribution of aerosols are measured at Pallas. Aerosol optical depth is measured at the Pallas-Sodankylä GAW station, Kuopio, Hyytiälä and Helsinki, as well as at the Argentinian Marambio Antarctic station. The results are regularly submitted to the World Data Centre for Aerosols and AERONET database (NASA).

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 international and national use of experimental resources efficiently. This is done in close cooperation with other international and national infrastructures and ESFRI's such as ICOS, EMBRC and EURO-ARGO.

The infrastructure includes research infrastructures of three Finnish research institutes, three universities, and a state-owned shipping company. The infrastructure network consists of several field stations, research vessels and multi-purpose icebreakers, laboratory facilities, ferryboxes, fixed measurement platforms and buoys in the Northern Baltic Sea. FINMARI is listed as a nationally essential research infrastructure on 'Finland's Strategy and Roadmap for Research Infrastructures 2014–2020' by the Finnish government. FINMARI provides a hub for the ocean observing system in Finland and through the hub, access can be gained to both the infrastructure and the data that it produces.

SYKE participates in the joint Baltic Sea environmental monitoring programme (HELCOM Combine), which produces long-term data on the Baltic Sea ecosystem. The operative state monitoring of off-shore sea areas is carried out by SYKE (chemical and biological parameters, contaminants) and FMI (physical parameters). The monitoring network covers the Gulfs of Bothnia and Finland, as well as the northern Baltic Proper. Physical and chemical monitoring is conducted at about 60 sampling stations during three annual cruises with R/V Aranda. In addition, e.g. phyto- and zooplankton and benthic macrofauna are monitored at some of the stations and cruises. In the Gulf of Bothnia and the northern Baltic Proper, the off-shore monitoring is arranged in coordination with the Swedish Meteorological and Hydrological Institute (SMHI), and in the Gulf of Finland in cooperation with Estonian and Russian research institutes. The monitoring of in-shore and coastal waters is carried out by regional environmental authorities together with SYKE. The marine monitoring data serves, for example, the national implementation of EU/ Marine Strategy Framework Directive and Water Framework Directive and the work of HELCOM. The open data set stored in SYKE's databases has been utilised also, e.g. in evaluating the observed climate change effects in

the Baltic Sea. Additionally, data is 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 on the state of the Baltic Sea through Algaline that serves research, the general public, media and authorities. Algaline utilises the so-called Ship-of-Opportunity (SOOP) monitoring system, which uses merchant ships as operating platforms. The data collection and water sampling for analytical measurements are carried out using autonomous flow-through measuring systems. The Algaline project is a forerunner in the field of unattended SOOP monitoring. It currently forms 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 physical properties of the Baltic Sea. The FMI network includes 14 water level stations at the coast, as well as regular temperature and salinity sounding stations and wave buoys in the open sea areas of the Baltic Sea. For the sea ice monitoring, FMI conducts sea ice and snow thickness measurements in the fast ice areas and utilises sea ice observations from several satellites.

FMI is contributing to the global Argo program by providing float to the Baltic Sea and North Atlantic monitoring via the Euro-Argo Research Infrastructure. For enhancing climate research and monitoring in the Baltic Sea, FMI together with the other partners of the Finnish Marine Infrastructure Consortium FINMARI has established the Utö Atmospheric and Marine Research Station.

8.3.3 Terrestrial observing systems

SYKE is the national centre for monitoring the physical, chemical and biological state of inland waters. Many hydrological data series are quite long, particularly those related to the freezing and break-up of water bodies 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 hydrological model representing the cycle and balance of water in a catchment. The forecasts are made daily from more than 500 water level and discharge observation points. Simulated hydrological data with over 20 variables from 1962 up to the present are available from the user interface of the system. Access to historical data is based on a yearly maintenance fee. The modelling system is extensively used in climate change research projects. The climate change related data and simulations are produced on demand. The hydrological simulation system also includes a nutrient simulation component by which quite extensive water quality related information (concentration and loads of N, P and sediments) that provides historical data series, and climate change simulation data can be produced on demand.

SYKE water quality data covers 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 to the Nordic Runoff Data Centre in Sweden. Finland has reported cryospheric data to the National Snow and Ice Data Center (NSIDC) in the United States and lake water temperatures to a global project coordinated by the University of Nebraska.

In addition to inland water observations, the monitoring of terrestrial ecosystems aids in detecting changes induced by climate change. Integrated monitoring has indeed become an important approach in environmental sciences. At SYKE, the multidisciplinary International Cooperative Programme on Integrated Monitoring (UNECE ICP IM) is one of the activities set up 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 located in natural or semi-natural forested areas with minimal disturbance. The international Programme Centre of the ICP IM is located at SYKE. SYKE further participates in the UNECE ICP Waters and ICP Modelling & Mapping (ICP M&M) activities, which also cover monitoring and assessment of climate change effects.

SYKE acts as a coordinating body for the Finnish Long-Term Socio-Ecological network (FinLTSER), which brings together the Finnish research sites and scientists that conduct research on long-term socio-ecological processes and problems in a coordinated Finnish research infrastructure. The FinLTSER also belongs to the Europe-LTER and international LTER (ILTER) networks. The FinLTSER presently consists of nine highly instrumented sites/research platforms, representing the main ecosystems (marine, terrestrial, lake, sub-arctic, 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, 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.

Luke performs national forest inventories (NFIs), which produce reliable information on land use, forest resources, growth, condition and biodiversity of forests. NFIs are based on statistical sampling. The most recent NFI was done in the 2009 to 2013 and consisted of approximately 60,000 sample points. Eleven NFIs have been completed since the 1920s, providing internationally unique time series on the development of land use and forest resources. The twelfth NFI was started in 2014 and the field work will be completed in 2018.

The forest damage advisory service at Luke is responsible for monitoring forest pests and diseases and the damage they make. The service supports the decision making of forest owners and administrators by answering inquiries and making diagnosis and prognosis about forest pests and diseases. A report on the forest damage situation is published each year. Luke also collects information on the phenology of tree and forest berries. The extent of climatic warming can thus be assessed on the basis of the time series for the bud burst of different tree species.

Luke participates in UNECE ICP Forests Level II intensive monitoring, which is the key for providing insight into causes affecting the condition of forest ecosystems and into effects of different stress factors, including climate change. The results are reported on an annual basis.

Finland participates in the Sustaining Arctic Observing Networks (SAON). 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. In 2014, the SAON established two committees: the Arctic Data Committee and the Committee on Observations and Networks. The vision of the SAON is 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 ongo-

ing projects include an atmospheric observations initiative and participation in the EU project PolarNet for optimisation of existing monitoring and modelling programmes.

SYKE monitors the environment of Finland and the surrounding areas using data from Earth Observation (EO) satellites. Water quality and temperature in the Baltic Sea, snow extent, and lake ice are currently monitored operationally (i.e. products are generated when new data become available, practically almost every day as to the moderate resolution satellites such as Sentinel 3). For inland lakes, the operational methods are under development. Land cover, land use and phenology products are generated at a slower pace (one per year to every six years). Land and cryosphere products are SYKE's contribution to the Copernicus services. Operational processing of EO data is carried out in cooperation with the Finnish Meteorological Institute at the National Satellite Data Centre. At the moment, SYKE's EO R&D concentrates on algorithm development for EU's Sentinel 1, 2 and 3 satellite series.

The surveillance system of invasive alien species has been developed to collect and record data on the occurrence of invasive alien species, to estimate how their populations have increased or shifted location but also to measure the effectiveness of the management measures. The work is mostly done by integrating new elements to the existing inventories and monitoring systems. Also, citizens can report their observations of alien species to the Vieraslajit.fi internet portal including geospatial information.

8.4 Capacity building in developing countries

For many years, Finland has been operating extensive capacity building programmes around the world concerning climate observations, research, higher education cooperation relevant to climate change mitigation and adaptation, and the sustainable use of forests. The programmes have increased the endogenous capacities of developing countries to tackle these issues through improved technological means and human resources. In many instances national funding and support have also increased thanks to the momentum of the cooperation and an increased visibility through the programmes.

Climate data management systems have been implemented in several developing countries through Finnish development agencies and with considerable financial and personnel support. Institutional support for the capacity building programmes has mainly been channelled through technical aid to strengthen the meteorological observing networks and weather services, as well as climatological databases, expert services and training programmes. Since the early 1970s, the Ministry for Foreign Affairs has financially supported the strengthening of the WMO's Global Observing System.

The FMI is engaged in several projects for the Finnish Ministry for Foreign Affairs, the European Union, the World Bank and other partners to develop the institutional capacities of national meteorological and hydrological services (NMHSs) in developing countries through various activities. In all countries, the national weather service is the de facto official responsible for dealing with weather and climate risks and disseminating warnings and forecasts to the general public. Increasing the capacity of these services to carry out their increasingly demanding tasks provides benefits to society through the delivery of more timely and accurate weather and climate services to the public.

Many of the FMI's projects represent a continuation of earlier activities (see the Sixth National Communication). The ongoing FMI capacity building activities include:

- Complementary Project to the SIDS- Caribbean Project and SHOCS I and II (COPS), 2010 to 2011 and 2013 to 2015: Improving the operational capacity of

the NMHSs in the Caribbean Region to provide weather and climate services; and enhancing the role of the Association of Caribbean States, and improving the capacity of the NHMSs and Disaster Management Agencies for the governance of the early warning process.

- Pacific SIDS 2009 to 2011 and 2013 to 2017: increasing the capacity of Pacific Small Island Developing States to produce and deliver weather and climate services tailored for the needs of the most vulnerable communities, improving regional coordination for developing early warning systems, improving cooperation with local stakeholders and NGOs in partnership with the Secretariat of the Pacific Regional Environmental Programme, the Secretariat of the Pacific Community and the International Federation of Red Cross and Red Crescent Societies through the FPPICS and FINPAC projects.
- Sudan and South Sudan 2012 to 2014 and 2016 to 2018: institutional capacity building to support the modernisation of the Sudan Meteorological Authority and the newly formed South Sudan Meteorological Service, especially in observation and aviation weather services delivery.
- Sri Lanka 2016 to 2018: Severe Storm Warning Service for Sri Lanka (SSWSS): developing a real time service system based on lightning location data and weather models, and its marketing and business model development for Sri Lanka. The service system provides warnings of approaching thunderstorms to various platforms (www, mobile apps) from zero to six hours and at best up to 10 days ahead.
- Macedonia 2015 to 2017: Further strengthening the capacities for effective implementation of the acquis in the field of air quality. Strengthening the capacity for the central environmental laboratory in Macedonia; strengthening the capacity for performing emission inventories and dispersion modelling; supporting the environmental policy and planning and implementation of Clean Air Action Plans; and strengthen the capacities for health impact assessment of air pollution to human health.
- Azerbaijan 2017 to 2019: Upgrading the national environmental monitoring system of Azerbaijan on the basis of EU practices, including a legislative and institutional framework, development of technical systems, capacity building and training, and real case tests of the practical implementation of the system.
- Nepal 2015 to 2018: Detailed design of the Department of Hydrology and Meteorology of Nepal, procurement and implementation support in order to enhance the capacity to mitigate climate-related hazards by improving the accuracy and timeliness of weather and flood forecasts and warnings.
- Kyrgyzstan 2014 to 2017: Improving the capacity of the Agency on hydrology and meteorology of Kyrgyzstan to deliver weather, climate, and environmental information and early warning services for the benefits of the Kyrgyz society.
- Tajikistan 2014 to 2017: Improving the capacity of the Agency on hydrology and meteorology of Tajikistan to deliver weather, climate, and environmental information and early warning services for the benefits of the Tajik society.
- Jamaica 2017: Improving Climate Data and Information Management: Providing advisory services for capacity building and finalising specifications of a weather radar.
- Bhutan 2017: Installing the FMI weather information system SmartMet to improve the real time weather forecasting capacity of the Department of Hydro-Meteorological Service of Bhutan.
- South East Europe: 2012 to 2014 and 2016 to 2017: Establishing a multi-hazard early warning advisory system through a joint USAID/OFDA and WMO capacity development project aimed at supporting weather and climate services.

- The Bahamas 2017 to 2018: Installing the FMI weather information system Smart-Met to improve the real time weather forecasting capacity of the Bahamas Meteorology Department in collaboration with Vaisala.
- Chile 2017: Designing a technological institution and environmental reference center for Chile in collaboration with the Finnish Environment Institute SYKE and the Technical Research Centre of Finland VTT.

In addition to the above-mentioned list of ongoing activities, the FMI is planning new capacity building projects in, for example, India, Nepal, Vietnam, Bhutan, Myanmar, and Kenya in the coming years; the projects will focus on institutional capacity building of the national meteorological and hydrological services, including observations, services, data management and strategic planning.

The Finnish Ministry for Foreign Affairs has supported higher education cooperation in developing countries for several years. It has funded two programmes that contribute to the Millennium Development Goals for reducing poverty and supporting sustainable development and that are in line with Finland's development policy guidelines. Since 2004, the Ministry for Foreign Affairs has funded the North-South-South (NSS) Higher Education Institution Network Programme, the purpose of which is to develop partnerships between HEIs in the North and South and enhance human capacity in all participating countries through interaction and mobility. The Higher Education Institutions Institutional Cooperation Instrument (HEI ICI) Programme, which contributes to capacity development by promoting administrative and educational development in developing countries, was launched in 2009.

A total of 15 applications were functional in 2010 to 2012. Projects have been implemented mainly in African countries, even though other projects were distributed across the world: Cambodia, Egypt, Indonesia, Kenya, Laos, Namibia, Nigeria, Mozambique, the Palestinian territories, the Republic of South Africa, Sudan, Tanzania, Uganda, Vietnam and Zambia. The projects represent different fields, such as agriculture, business studies and management sciences, education sciences and teacher training, social sciences, natural and medical sciences, and engineering, communication and ICT, as well as humanities. The majority of the projects have not only contributed to the development of curricula and degree programmes but have also improved teaching quality and pedagogical methods. Some projects have had an explicit objective of organisational development or of improving information systems.

In spring 2013, new projects were approved and a total of 23 projects received funding for the years 2013 to 2015. For instance, the following projects directly target climate change issues:

- Nepal, Ethiopia: Curricula Development for Efficient Lighting and Renewable Energy Technology – CELRE (Aalto University, EUR 0.3 million)
- Sudan: Landscape Planning and Management Training for the Environment in South Sudan – LAMPTESS (University of Helsinki, EUR 0.5 million)
- Laos, Cambodia, Myanmar: Sustainable Climate Change and Energy Education Development – SUCCEED (University of Turku, EUR 0.4 million)
- Mozambique: Higher education and capacity-development for sustainability (Aalto University, EUR 0.3 million).

In spring 2017, an additional 20 projects were approved for the years 2017 to 2020. Of these projects, the following directly target climate change issues:

- Tanzania, Mozambique, Ethiopia: Promoting Education and Research on Energy Efficient Lighting and Renewable Energy for Sustainable Development – EARLI (Aalto University, EUR 0.6 million)
- Kyrgyz Republic: Capacity Building in Fisheries and Aquaculture Education in the Kyrgyz Republic – FishEDU (University of Eastern Finland, EUR 0.5 million)
- Tanzania: Geospatial and ICT Capacities in Tanzanian Higher Education Institutions – Geo-ICT (University of Turku, EUR 0.7 million)
- Colombia, Peru: Native Crops for Sustainable and Innovative Food Futures in Peru and Colombia – HEI-ICI-PECOLO (University of Turku, EUR 0.6 million)
- Kenya: Building Higher Education and Research Capacity to Address the Physical Activity and Nutrition Transition in Kenya: The Kenya-Finland Education And Research Alliance – KENFIN-EDURA (University of Helsinki, EUR 0.5 million)
- Myanmar, Laos, Thailand: Partnership for Forestry Higher Education Cooperation in Mekong Region – PARFORM (University of Helsinki, EUR 0.6 million)
- Mozambique: Sustainable Management of Natural Resources in Mozambique – SuMaNatuRe (University of Jyväskylä, EUR 0.6 million)
- Kenya: Improving capacity, quality and access of Geoinformatics Teaching, Research and Daily Application in Taita Taveta County, Kenya – TAITAGIS (University of Helsinki, EUR 0.7 million)

The Academy of Finland and the Finnish Ministry for Foreign Affairs have annually funded problem-oriented and multidisciplinary development research projects. During 2013 to 2014, seven projects were funded from an additional targeted call to fund research projects investigating the impacts of climate change in developing countries. The two-year projects generated knowledge on climate change in developing countries, increased multidisciplinary knowledge and know-how, and promoted the establishment of multidisciplinary research environments in developing countries, as well as created new research-oriented networks between Finland and developing countries. A list of the funded projects:

- India: Black and brown carbon influence on climate and climate change in India – from local to regional scale (Finnish Meteorological Institute, EUR 0.3 million).
- Mozambique: Private agricultural investments and land use change impact on the adaptive capacity of local communities to climate change in Mozambique (consortium of University of Helsinki and Pellervo Economic Research Institute, EUR 0.2 million and EUR 0.2 million).
- Tanzania and Nepal: Towards Responsive Governance in Climate Change Adaptation and Mitigation? Comparative case study in Tanzania and Nepal (University of Eastern Finland, EUR 0.3 million).
- China and Nepal: Impact of climate change on water quality: a Himalayan case study (Lappeenranta University of Technology, EUR 0.2 million).
- China: Aquatic ecosystems in a changing climate – introducing a cost-effective tool to guide management options in poorly developed countries (University of Helsinki, EUR 0.2 million)
- Laos and Cambodia: Redefining energy and climate policies in least developed countries: Analysing institutions and initiatives in the Mekong region (RECLAIM) (University of Turku, EUR 0.4 million)
- Malawi and Zambia: Study on risk management of extreme weather related disasters and climate change adaptation in Malawi and Zambia (SAFE-MET) (Finnish Meteorological Institute, EUR 0.3 million)

The Natural Resources Institute Finland, Luke has been active in promoting the sustainable use of forest resources in developing countries. The activities have focused on resource assessment and the prediction of forest resources. Luke's activities include:

- Cambodia, Laos, Thailand, 2013 to 2015: Bamboo fuel chip production for renewable energy. Making technically and financially viable demand-driven business model for (bamboo) biomass fuel chip production in trans-boundary supply chains available for renewable energy applications, ready for up-scaling, and attractive to private sector investments.
- Kenya, 2013 to 2015: Improving the capacity in forest resources assessment in Kenya IC-FRA. Improving forest inventory methods to respond to the expanded information needs on forest and tree resources on different scales.
- Mongolia, 2013 to 2015: Strengthening Research Capacity for Sustainable Forest Management in Mongolia (StreFoMon). The project focuses on capacity building for sustainable forest management in Mongolia, based on silvicultural research.
- Mozambique, 2016 to 2018: FORECAS 2 Capacity building on novel approaches in sustainable management of forest and wood resources in Mozambique. Improving knowledge on the value chains of lesser-utilised wood species for small-sized business and industries increased, utilisation of the wood laboratory facilities, and information dissemination and promotion of national and regional networking of IIAM and UEM-FAEF.
- Myanmar, 2017 to 2020: Improving the Capacity of the Myanmar National Forest Inventory IC-MNF. This project aims to collect national level baseline information required for REDD+ and to institutionalise the Monitoring, Reporting and Verification (MRV) system.
- Tanzania, 2016 to 2018: INFORES Implementation support of results and data of first National Forest Resources Monitoring and Assessment (NAFORMA) at regional and local level in Tanzania. Strengthening the capacity of direct beneficiary organisations on NAFORMA maintenance and data dissemination, and improved capacity on multisource forest data processing and GIS. Improved capacity of forest inventory and management oriented research in SUA and TAFORI.
- Africa 2015 to 2019: Support programme for the Southern African Network for Biosciences (SANBio); BioFISA phase II. Extending the network activities and capacity building for sustainable network operations beyond 2016.

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Internet links

- Aalto University ice tank <http://icetank.aalto.fi/en/>
- Academy of Finland research programmes,
<http://www.aka.fi/en/research-and-science-policy/academy-programmes/>
- Academy of Finland strategic research programmes,
<http://www.aka.fi/en/strategic-research-funding/programmes/>
- ACTRIS - The European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gas. <http://www.actris.eu/>
- The Agricultural Model Intercomparison and Improvement Project (AgMIP):
<http://www.agmip.org>
- Algaline,
<http://www.jarviwiki.fi/wiki/Algaline?setlang=en>
- Arctic Centre at the University of Lapland,
<http://www.arcticcentre.org/EN>
- Arctic Monitoring and Assessment Programme (AMAP), <http://www.amap.no/>
- 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.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
- EUMETNET <http://eumetnet.eu/>
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<http://www.macsur.eu>
- FICCA research programme on climate change,
<http://www.aka.fi/en/research-and-science-policy/academy-programmes/completed-programmes/ficca/>
- Finnish Climate Change Panel, www.ilmastopaneeli.fi
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<http://www.syke.fi/en-US>
- Finnish Food Safety Authority Evira,
<https://www.evira.fi/en/>
- The Finnish Institute of International Affairs,
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http://www.tieteentiedotus.fi/files/Sciencebarometer_2016_web.pdf
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http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html

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>

ICOS Finland, <http://eng.icos-infrastructure.fi/>

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

National Institute for Health and Welfare (THL),
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<http://www.luke.fi>

Nordic Working Group for Global Climate Negotiations (NOAK),
<http://www.norden.org/en/nordic-council-of-ministers/council-of-ministers/nordic-council-of-ministers-for-the-environment-mr-m/institutes-co-operative-bodies-and-working-groups/working-groups/the-nordic-working-group-for-global-climate-negotiations-noak>

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

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>

Tekes (the Finnish Funding Agency for Innovation) programmes:
<https://www.tekes.fi/en/programmes-and-services/tekes-programmes/>

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>