Annual Report 2016

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Front page: Chemical lab, NILU. Photo: Ingunn Trones.
Page 2: Ove Hermansen, Ingjerd Sunde Krogseth and Finn Bjørklid.

MILJØMERKET 241 013 TRYKKSAK

Research, an important societal resource

We are flooded with information, and thus it is not easy to distinguish fact from opinion. For this reason, relevant high quality research is a vital tool for making the right social choices in a complex and rapidly changing world.

NILU's values are competence, integrity and community benefit. For almost 50 years, we have worked to make sure our society has access to the best possible knowledge base to make decisions, and one of the reasons why we attract excellent scientists is because what we are working on is important to society. In addition, it is often only a short leap from publishing in international journals to the research being used by authorities, thus actively helping to develop a sustainable society.

Research is an investment

Simultaneously, we know that environmental monitoring and research may seem costly, but this is a drop in the ocean when seen in relation to the cost of mitigation measures. A solid and sound knowledge base is the best investment one can make in advance of major decisions.

The long-term plan for research and higher education is currently revised. In view of the climate challenges we face, it is more important than ever to ensure that Norway, with its large land and sea areas, ensures that we have strong research groups able to develop the knowledge base on key societal challenges. Climate change challenges us to gather scientists across traditional disciplines – and thus, it is important to ensure that the individual disciplines maintain high quality so that they can provide valuable research contributions into these complex issues. We expect the six long-term priorities of the current plan to persist, and we will do our best to contribute to society as competently as possible.

Short leap from research to innovation

Social changes increase year by year. Thus, it is more important than ever to make the leap from research to socially beneficial innovations that can contribute to better quality of life, reduce the risk of health damage, and help restructure Norway from oil/gas to new knowledge-based industries.

NILU wishes to contribute with good solutions to environmental challenges, but also with creating new jobs – both at the institute and in our subsidiaries under Innovation nilu AS.

In this year's annual report you can read about current social challenges like climate and air pollution, the worldwide dangers of microplastics, and exciting news from our efforts in innovation.

Enjoy your reading!

Kari Nygaard
Managing Director

Foto: Ingunn Trones.

From monitoring stations to microsensors – air and health

New technology brings new opportunities. So why haven't we discarded those large monitoring stations and started using microsensors yet?

Christine F. Solbakken
Head of Communications

Along Norway's roads and streets stand two different types of air quality monitoring stations. The traffic oriented stations measure pollution from traffic, and thus stand close to the road. Urban background stations, on the other hand, must be able to capture total air pollution from various sources (traffic, heating, urban industries, natural sources, etc.), so they are found in parks or other open spaces.

Strict routines, high quality

Such monitoring stations house sensitive instruments that record very accurate data in near real-time. Thus, they are also expensive to install and operate.

– Currently, there is no alternative to these monitoring stations, says Kjersti Tørnkvist, Director of NILU's Department of Monitoring and Instrumentation Technology, and thus also strongly involved in the National Reference Laboratory for Air Quality. – We are required to monitor air quality as described in the European Air Quality Directive (2008/50/EC) and in the EU Commission Directive 2015/1480 and the Norwegian Pollution Control Act Chapter 7. Together this constitutes a very detailed regulatory framework for both what to measure, how, where and how often.

All European countries monitor air quality according to the same directives. This means they use the same reference methods and the same operating and calibration routines to ensure high quality data and low uncertainty. It also means that you can compare air quality data from cities across Europe – Tromsø with Berlin, Bergen with Barcelona.

Monitoring air quality to assess health risks

Tørnkvist is often asked why traffic oriented stations are placed next to roads, rather than in gardens or parks where people spend time outdoors.

– The location is related to what we call limit values for pollution, rules for how much pollution is allowed over a given period. These values are based on two things: what level of contamination we know can be hazardous to health, and how far away from the source of pollutants the monitoring stations are.

For instance, the limit value for NO_2 is max. 200 micrograms NO_2 per cubic meter of air ($\mu g/m^3$) per hour. It is allowed to exceed this limit value for 18 hours a year, but the nineteenth hour past 200 $\mu g/m^3$ breaks the law. That the permitted limit value is as high as 200 micrograms is because traffic orientated

Foto: Alle bilder, NILU.

About limit values

In Norwegian cities, NO_2 and coarse dust (PM_{10}) are the biggest air quality challenges, and we often talk about "limit values" for these substances. Limit values are rules for how much pollution is allowed over a given period.

For air pollutants, limit values are given for differing durations; 1 hour, 24 hours and annual. The limit values specify the level and period the concentration of a substance can be above a certain threshold, without breaking the limit value. The number of permitted exceedances varies from substance to substance.

The hourly limit value for NO_2 allows 18 hours a year with a value above 200 micrograms per cubic meter of air (µg/m^3). The daily concentration of PM_{10} allows 30 days a year with a value above 50 µg/m^3. Thus, the limit value is not violated until the nineteenth hour (NO_2) or the 31st day (PM_{10}) show too high levels during a year.

Scientists from NILU and the Technion Israel Institute of Technology evaluated 24 low cost AQMESH sensors (below) in 2015. These sensors were mounted on top of the traffic oriented monitoring station in Kirkeveien (above), so that the scientists could compare measurements from the AQMesh sensors to air quality measurements from the monitoring station at the same location.

stations are situated close to the source of pollution – that is, road traffic. Had the directive stated that the measurement stations were to be placed further away from the cars, the limit would have been lowered to make up for the increased distance.

– Health is the reason we monitor the air, says Tørnkvist. – The purpose is to provide authorities with real data about how the air quality actually is. This information is further used by scientists and managing authorities to develop measures that provide us with cleaner air and better health.

Limited micro-information

During recent years, microsensors have appeared on the market. Concerned citizens and other actors have begun purchasing these low cost air quality sensors to measure air quality where they live and work.

– We understand very well that people are engaged, says senior scientist Núria Castell from NILU's Department for Urban Environment and Industry, – and we appreciate that. At the same time, it is important to orient yourself in the market.

Castell has participated in several evaluations of various types of microsensors. She believes it is important that both private citizens and others are aware that these sensors are still in the development phase.

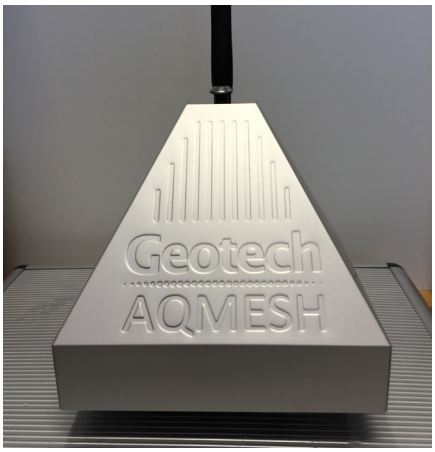
– Most microsensors for air quality monitoring available today are so unstable that we would not advise to use them in contexts that require high data quality and reliability, she explains.

– For instance health related or regulatory monitoring.

Engage yourself!

Currently, there are no EU directives, other regulations or independent quality assurance for microsensors, as for the stationary monitoring stations used in Norway today. Thus, it is difficult to be sure that data quality from microsensors is good enough. This must be taken into account when selecting surveillance solutions to help protect the health of citizens.

– It is necessary to establish a quality check framework for microsensors to be calibrated against reference stations, explains Castell. – Another challenge to be solved is how different weather conditions affect microsensors, for instance, when measurements are affected by changes in temperature and relative humidity. For now, data from microsensors must be quality assured by experts in order to be useful. We believe that the future of air quality measurement by microsensors is very promising, but for now we do not recommend using them as a basis for making health related decisions. Nevertheless, with proper calibration and quality control, some of the sensors on the market provide data



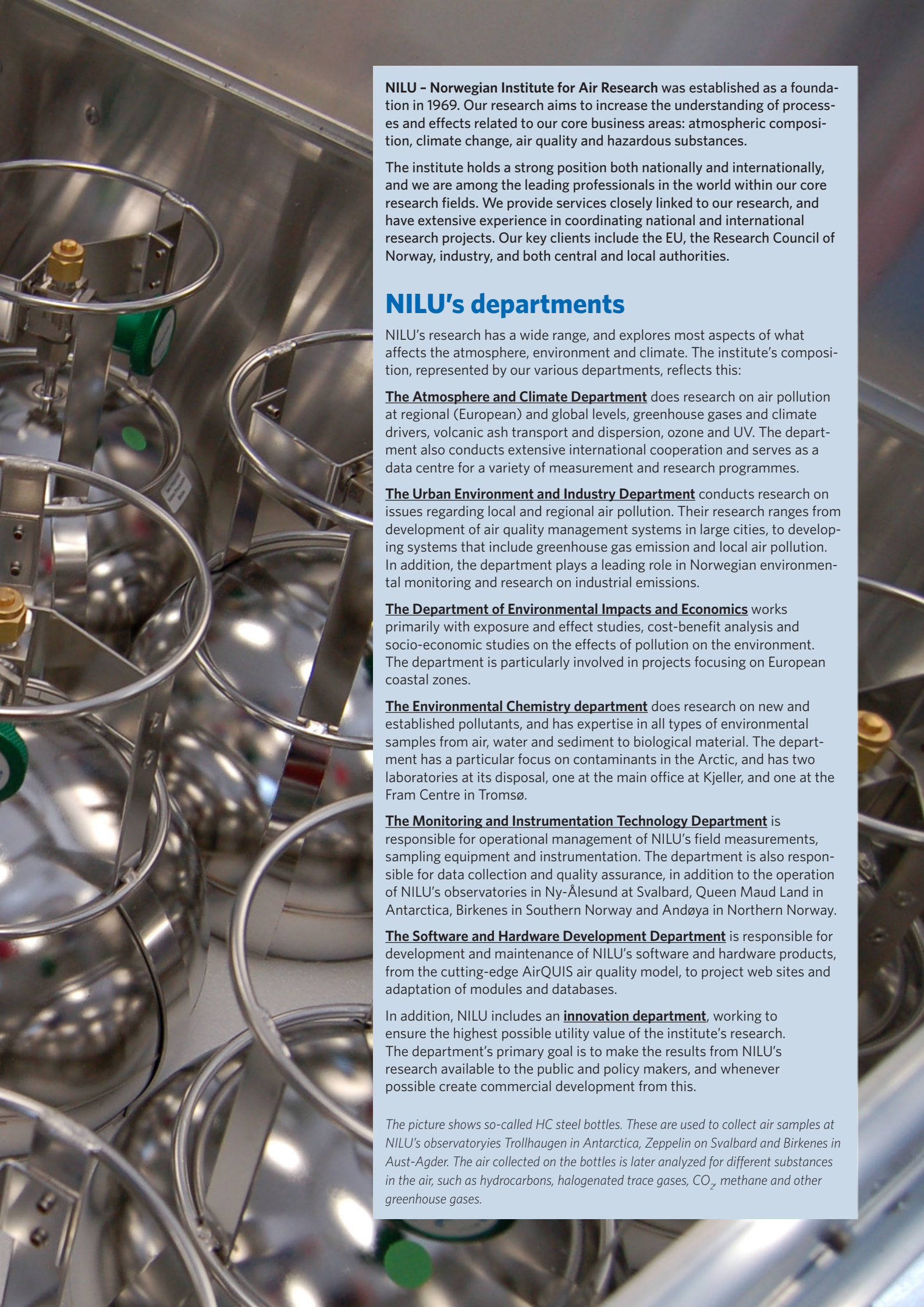
sufficiently reliable to determine whether the air quality is good, moderate or highly polluted. What this means is that that citizens can use these microsensors to get an overall opinion of the air quality where they live, she concludes.

Who places the monitoring stations?

When the owners of monitoring stations are to place new air quality monitoring stations, they are free to choose sites and monitoring methods, as long as they conform to the requirements laid out by EU Directive 2008/50/EC, Commission Directive 2015/1480 and Chapter 7 of the Norwegian Pollution Control Act with corresponding quality manuals. In practice, surveyors refer to the National Reference Laboratory for Air Quality (NRL) for guidance on the location of monitoring stations. The Norwegian Environmental Research Agency has appointed NILU – Norwegian Institute for Air Research as the Norwegian NRL.

Research for a clean atmosphere

Photo: NILU



NILU – Norwegian Institute for Air Research was established as a foundation in 1969. Our research aims to increase the understanding of processes and effects related to our core business areas: atmospheric composition, climate change, air quality and hazardous substances.

The institute holds a strong position both nationally and internationally, and we are among the leading professionals in the world within our core research fields. We provide services closely linked to our research, and have extensive experience in coordinating national and international research projects. Our key clients include the EU, the Research Council of Norway, industry, and both central and local authorities.

NILU's departments

NILU's research has a wide range, and explores most aspects of what affects the atmosphere, environment and climate. The institute's composition, represented by our various departments, reflects this:

The Atmosphere and Climate Department does research on air pollution at regional (European) and global levels, greenhouse gases and climate drivers, volcanic ash transport and dispersion, ozone and UV. The department also conducts extensive international cooperation and serves as a data centre for a variety of measurement and research programmes.

The Urban Environment and Industry Department conducts research on issues regarding local and regional air pollution. Their research ranges from development of air quality management systems in large cities, to developing systems that include greenhouse gas emission and local air pollution. In addition, the department plays a leading role in Norwegian environmental monitoring and research on industrial emissions.

The Department of Environmental Impacts and Economics works primarily with exposure and effect studies, cost-benefit analysis and socio-economic studies on the effects of pollution on the environment. The department is particularly involved in projects focusing on European coastal zones.

The Environmental Chemistry department does research on new and established pollutants, and has expertise in all types of environmental samples from air, water and sediment to biological material. The department has a particular focus on contaminants in the Arctic, and has two laboratories at its disposal, one at the main office at Kjeller, and one at the Fram Centre in Tromsø.

The Monitoring and Instrumentation Technology Department is responsible for operational management of NILU's field measurements, sampling equipment and instrumentation. The department is also responsible for data collection and quality assurance, in addition to the operation of NILU's observatories in Ny-Ålesund at Svalbard, Queen Maud Land in Antarctica, Birkenes in Southern Norway and Andøya in Northern Norway.

The Software and Hardware Development Department is responsible for development and maintenance of NILU's software and hardware products, from the cutting-edge AirQUIS air quality model, to project web sites and adaptation of modules and databases.

In addition, NILU includes an **innovation department**, working to ensure the highest possible utility value of the institute's research. The department's primary goal is to make the results from NILU's research available to the public and policy makers, and whenever possible create commercial development from this.

The picture shows so-called HC steel bottles. These are used to collect air samples at NILU's observatoryies Trollhaugen in Antarctica, Zeppelin on Svalbard and Birkenes in Aust-Agder. The air collected on the bottles is later analyzed for different substances in the air, such as hydrocarbons, halogenated trace gases, CO_2, methane and other greenhouse gases.

ACTRIS — a new infrastructure for

ACTRIS is an infrastructure enabling observation-based research to improve understanding of climate and air pollution. The main focus is aerosols, clouds and reactive gases in the atmosphere, and their physical, optical and chemical properties.

Christine F. Solbakken
Head of Communications

In 2016, ACTRIS (Aerosols, Clouds, and Trace gases Research Infrastructure) was selected for the European roadmap for research infrastructures.

– The fact that ACTRIS is now part of the ESFRI roadmap confirms that the infrastructure is considered an important tool for European research. Many European countries participate in the infrastructure, and our contribution to international cooperation is central for maintaining international leading research during the next decades, explains senior scientist Cathrine Lund Myhre from NILU's Department of Atmosphere and Climate.

Research that includes advanced analysis of high quality data provides the opportunity to study how the atmosphere changes as a result of man-made emissions. The results are used amongst others by the European Evaluation and Monitoring Program (EMEP) under the UN's Long Transport Convention, and by the Global Atmospheric Watch under World Meteorological Organization (WMO). The number of scientific articles using ACTRIS data is in the order of approx. 100 in scientific journals per year.

ACTRIS is important for future research...

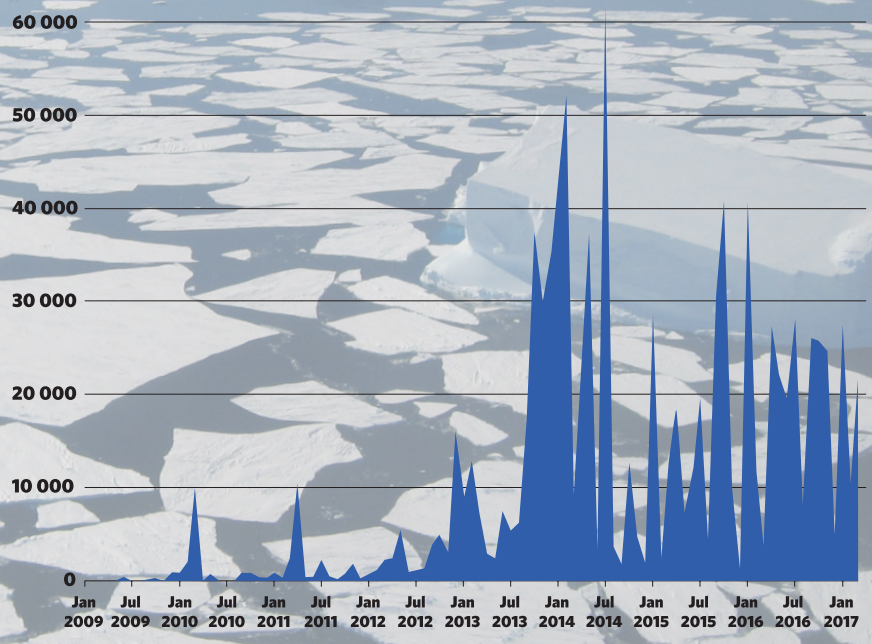
ACTRIS has gradually evolved over the last 10-15 years through a number of different EU projects. Right now, ACTRIS-2, an EU project under Horizon 2020 (http://www.actris.eu) is underway, and the ACTRIS Preparatory Phase (PPP) was recently launched. The purpose of ACTRIS PPP is to establish ACTRIS as a long-term operational research infrastructure for the next 20 years.

– This extended time span is important, continues Lund Myhre, – because comparable observations over time and in geographical distribution are crucial for improving our knowledge of different processes and long-term trends in the atmosphere. This knowledge plays a decisive role in how European countries will meet the societal and environmental challenges that will arise over the next few decades, such as air quality and climate change.

ACTRIS

- In 2016, ACTRIS (Aerosols, Clouds, and Trace gases Research Infrastructure) was made part of the European Strategic Forum for Research Infrastructure's (ESFRI) updated roadmap for research infrastructures in Europe.
- Many European countries have already expressed their political and financial support for ACTRIS, and 85 research-related organizations are committed to contributing resources to implement ACTRIS. With ESFRI status, ACTRIS will establish the necessary organizational framework to provide services for all kinds of users in the future.
- ACTRIS is expected to be fully operative early in the 2020s.

Distribution of users of data from EBAS, the data node for ACTRIS observatories: About 5500 different users from 80 countries since the summer of 2015



r atmospheric research

ACTRIS provides quality assured data and data products for the whole of Europe, with all key variables for particles, clouds and reactive gases in the atmosphere. All key optical and physical properties of particles are included, such as size distribution, scattering and absorption of particles, chemical composition with high time resolution, and distribution of particles in height using lidar measurements, as well as different cloud variables. In addition, reactive gases, including a wide range of light hydrocarbons and volatile organic compounds across Europe, are measured. The ACTRIS data form the basis for large and wide research in climate, air quality and weather forecast.

In addition to data access, ACTRIS also provides access to advanced laboratories and field observatories. Eventually, the ACTRIS research infrastructure will also provide access to atmospheric simulation chambers, which today is part of the EUROCHAMP infrastructure. This includes laboratories and chambers to study reaction rates for relevant processes that occur in the atmosphere.

...and for managing authorities in Norway and Europe

National and international authorities are key users of ACTRIS services today, and this will be strengthened in the future. ACTRIS will provide services necessary to ensure that national data for particle and reactive gases are harmonized at an international level, so that they can be used in regional and continental scale assessments of the atmosphere.

Such harmonization is necessary in order to assess the impact of environmental measures, develop more effective climate measures and to verify binding environmental agreements at national, European and international levels. Many instruments included in the Norwegian Environment Agency's program for national monitoring of greenhouse gases and particles are now quality assured through the EU project ACTRIS-2. A continuation of this is important in order to obtain good data also in the future

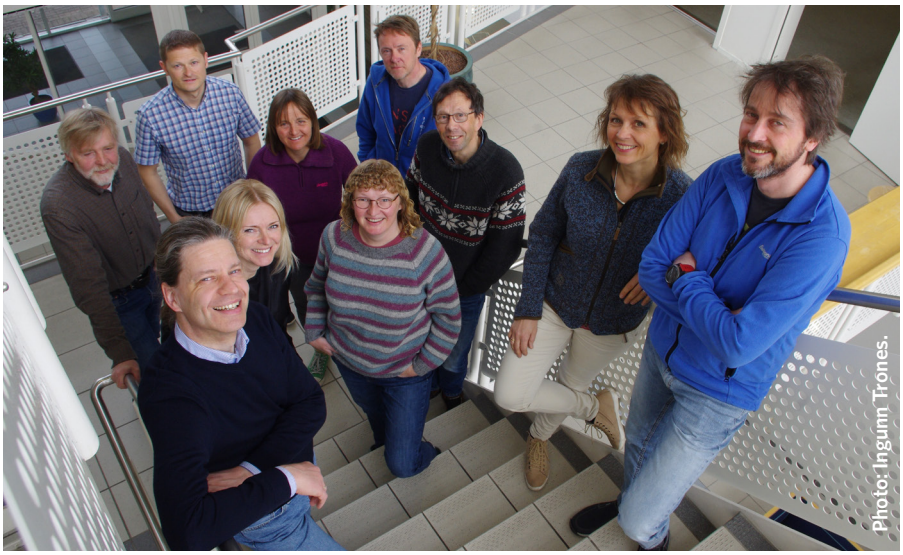


Photo: Ingunn Trones.

The access to and continuation of all research data and other services included in ACTRIS will be strengthened in the future. All countries contributing to this will have free access to all ACTRIS services.

NILU in ACTRIS

NILU contributes measurement data from the observatories in Svalbard (Zeppelin), Antarctica (Trollhaugen) and Aust-Agder (Birkenes). In addition, NILU manages the extensive data centre activity in ACTRIS, and coordinates all data flow and curation. All data are available through the ACTRIS data portal, http://actris.nilu.no.

Another part of NILU's role is being responsible for collecting, storing, accessing and documenting all ground-level observations. This is done in EBAS, http://ebas.nilu.no, which is topic data base for these measurements and datasets.

A large group at NILU (photo above) is involved in the data centre activity, and in a recent evaluation they received high praise for being able to harmonize heterogeneous data, making the products both useful and easily accessible.

– We work hard to facilitate both easy uploading and downloading of data in ACTRIS, says Cathrine Lund Myhre. – The data are very important for research groups all over the world, and a summary shows that since January 2015, ACTRIS users have downloaded more than 24,000 annual data sets of measurements. In 2016 alone, we had on average more than 1100 different visits to EBAS per month, and approximately 1050 sets of ACTRIS data were downloaded every month. Improving the infrastructure to meet the research communities' need for different data, formats and access is a continuous work we look forward to improving even more.

Hunting microplastics off the Svalbard coast

The fact that plastic waste pollutes the oceans is well known and has attracted a lot of media attention both in Norway and internationally. The visible plastic waste is what most people notice - but most of the plastic in the sea cannot be seen by the naked eye.

Christine F. Solbakken
Head of Communications

Plastic particles of 5 mm or less are called microplastics. Some of the microplastics in the ocean come from larger plastic objects and plastic waste that has been broken down by sun, sea and mechanical processes, but some also come from clothes.

Where is the plastic?

– Clothes made of synthetic textiles emit large quantities of microplastics when we wash them, says senior scientist Dorte Herzke of NILU's Environmental Chemistry department in Tromsø, – and these microscopic plastic fibres end up in the sea when the washing machine drains.

Once the microplastics have reached open waters, scientists find it again everywhere – in birds, in sediments and in the ocean as far north as Svalbard. It was at Svalbard that Herzke, together with Jan H. Sundet and Maria Jenssen from the Institute of Marine Research, conducted a study on microplastics in the seawater along the Svalbard coast.

The study received financial support from Svalbard's environmental protection fund in 2015 and 2016, with the main purpose to investigate whether there are differences in the amount of plastic particles in the Adventfjord water (where Longyearbyen is located) compared to the inhabited Isfjorden and uninhabited Breibogen.

– The reason we want to find out if there are microplastics in the ocean is because of the negative impact it may have on fish and other organisms that ingest it, explains Herzke. – The animals fill up their stomachs and intestines with plastic that gets stuck, but in addition we know that environmental pollutants can bind to the ingested microplastics. That way, toxic chemicals enter the food chain, but we still know too little about exactly what negative effects this may have.

Floating on the surface

The results from Herzke, Sundet and Jenssen's study shows that the level of both fibres and microplastic fragments was almost insignificant in all soil sediment samples, and in most of the samples from the shore. In the samples taken above the high water mark, however, significant deposits of microplastics, both fibres and fragments, were recorded. In the pilot study from 2015, the scientists found most of the microplastics and fibres in wastewater from the Longyearbyen water purification plant, which is not equipped to remove all of these particles.

– What we found corresponds to previous studies, which suggest that microplastics originating from drainage in Longyearbyen is essentially lighter than seawater. Thus, it floats near the sea surface, explains Herzke. – Over time, the plastic particles will sink down, due to chemical changes in the plastic and because organisms bind to them and make them heavier. But this process is slow, and in cold Arctic waters it is even slower.

Clean a beach!

The result of the survey is largely positive in the sense that scientists have not been able to detect more microplastics in the seawater in Adventfjorden and Kongsfjorden, where people live permanently, than in uninhabited Breibogen. However, Dorte Herzke emphasizes that a larger survey with several collected samples is needed to establish with certainty that there are no such differences.

She can also tell that they found most of the microplastics on the shore, above the high tide level. The reason for this is most likely that plastic waste is washed up by high waves and spring tide, or carried by the wind. When on the beach, the plastic is broken down into smaller particles, which precipitation then brings down into the sediments. From there it gradually washes out into the sea in the form of microplastics, and is thus exposed to the marine ecosystem.

– We hope this study can contribute to more knowledge about how plastic waste ends up as microplastics in the sea, concludes Herzke. – We also want to emphasize the importance of cleaning beaches, not only in Svalbard, but everywhere. Not only because it looks prettier, but to prevent more trash ending up as a microplastics.

Sediment samples from the seabed and shoreline were collected in jam jars and later analyzed.

Small, smart and safe: The rise of manufactured nanomaterials

We want small, smart and safe products, and nanotechnology can provide them. But are nanomaterials safe? Or could their peculiar nature have unintended effects on human health or the environment?

Sonja Grossberndt
Scientist

With a size of less than 100 nanometers (nm) in at least one dimension, nanomaterials are of interest to several industries. And as a consequence, there has been a rise of manufactured nanomaterials (MNMs) in a lot of processes and products.

In need of regulation

But are they safe? To answer this question, standardisation and validation of toxicity test methods and risk assessment tools are needed.

The EU FP7 project NANoREG, involving NILU's Health Effects Laboratory (HEL) as national coordinator for nanosafety as well as more than 70 other partners from all over Europe, addresses this issue.

– Regulation of MNMs is challenging, explains senior scientist Elise Rundén Pran from NILU HEL.

– Scientists working in the field need to provide information that satisfies the regulatory bodies. In NANoREG, we aimed at providing this information by developing a toolbox for risk assessment of MNMs. The project was finalised in early 2017, and all data produced within the project will become available through the project database.

Norwegian initiative

The Norwegian national initiative towards developing a suitable approach for regulatory testing of MNMs, NorNanoReg, is coordinated by NILU HEL with seven partner organisations, and financed by the Norwegian Research Council. NorNanoReg covers human toxicity testing, ecotoxicology, and physiochemical characterisation of MNMs. To narrow the knowledge gaps and improve communication between industry, science and regulatory bodies, a workshop was organised as part of NorNanoReg, where stakeholders within nanotechnology could meet and exchange knowledge about risks related to the use and production of MNMs.

– According to the paradigm of Paracelsus, the 'dose makes the poison,' says Rundén Pran.

– This paradigm is a bit twisted when it comes to nanomaterials, as physiochemical properties such as size, shape, charge and surface coating strongly influence their toxicity. This makes standardised toxicity testing and risk assessment a challenge.

Safe-by-design

NANoREG has shown the importance of performing physiochemical characterization as part of toxicity testing – but all the different features of every distinct nanomaterial makes it almost impossible to test all aspects of it. The challenge scientists are faced with, is developing a regulatory process that is robust enough to cope with the speed of innovation of new MNMs.

Thus, in the Horizon 2020 project NanoReg2, an attempt to improve efficiency is being developed, aiming at developing an innovative guidance document for industry and regulatory agencies for safe use of MNMs.

Safe-by-design has been identified as one fundamental pillar in this process, where toxicity testing is applied in parallel with nanotechnological development, not only at the end. This procedure should ensure a time- and cost effective way to produce safe MNMs that reduce the risk for human health and the environment.

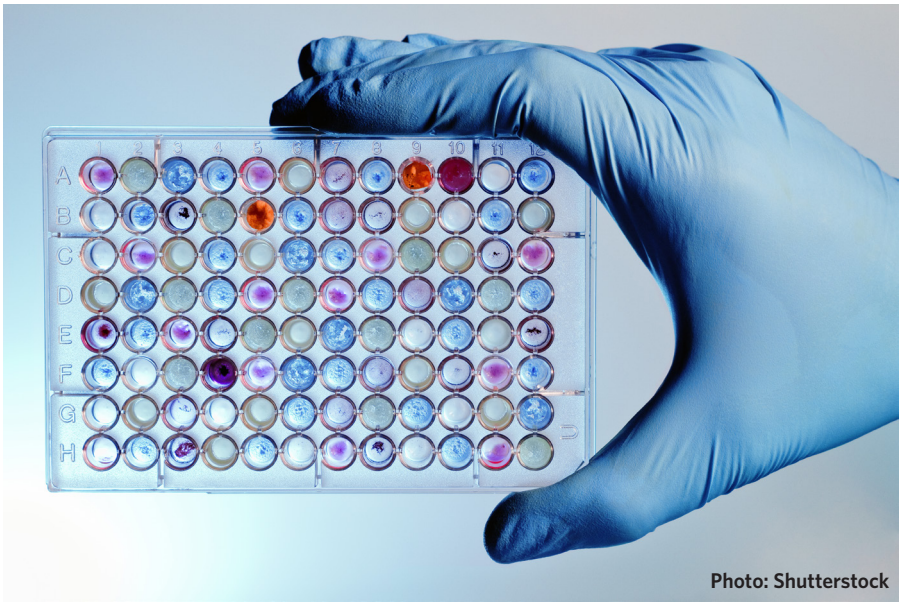


Photo: Shutterstock

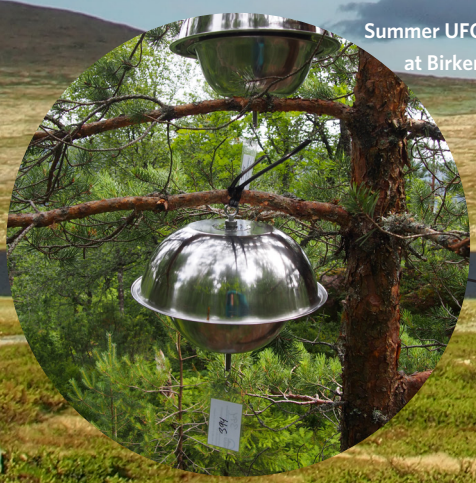
Searching for environmental contaminants using UFOs

In June and July 2016, PhD student Helene Lunder Halvorsen and scientist Ingjerd Sunde Krogseth from NILU criss-crossed Norway, from Hopseidet in the north to Birkenes in the south. Along the way, they deployed about 50 UFO-shaped passive air samplers for measuring old and new organic airborne contaminants. This was part of the Research Council's program Ecosystem Impact - Nature's Response to Changes in Climate and Environment (OKOSYSTEM). The scientists hope that the findings from the "UFO road trip" can help to develop more effective measures against environmental issues in the future.

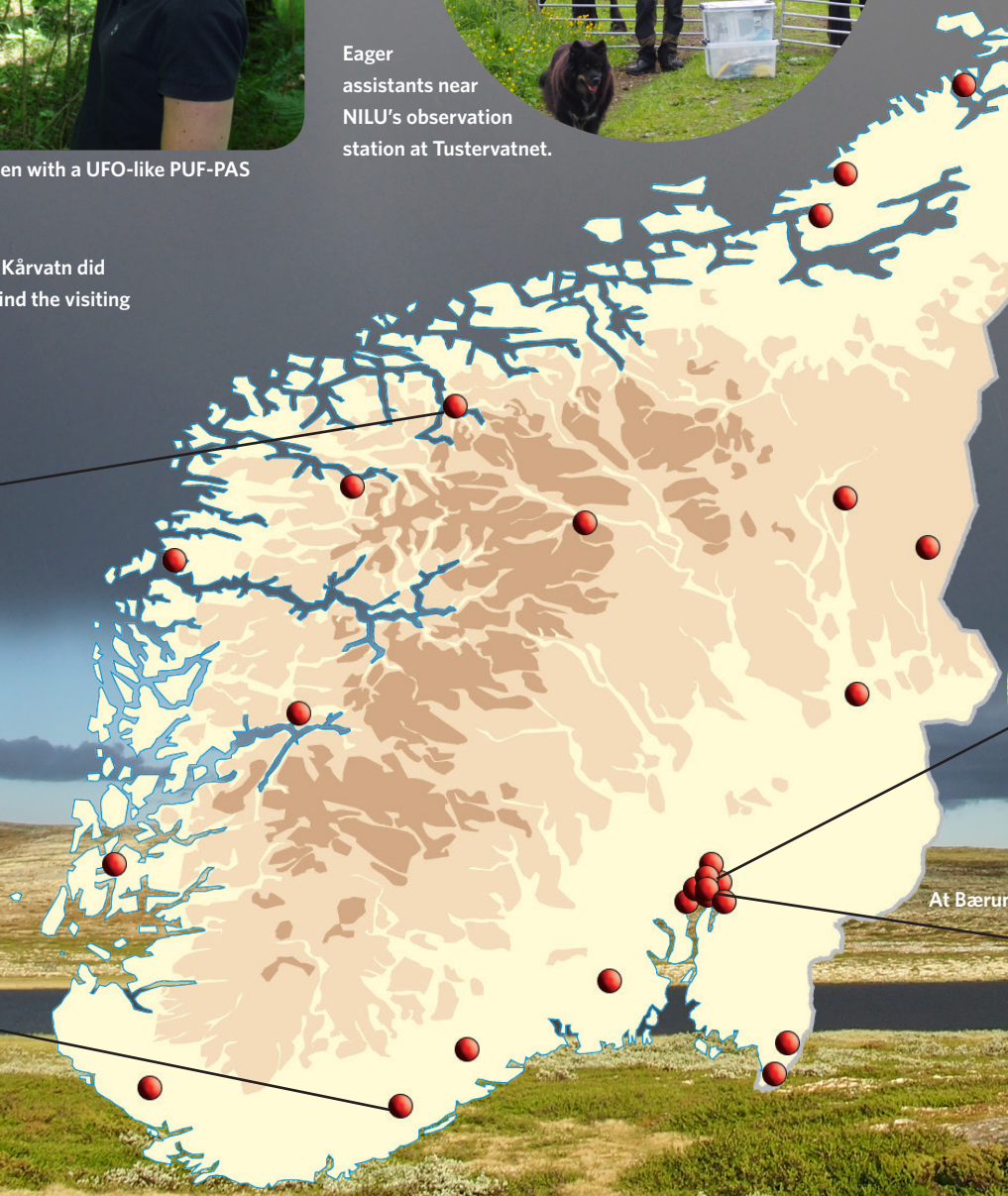
Ingjerd Sunde Krogseth and Helene Lunder Halvorsen with a UFO-like PUF-PAS passive air sampler.

Eager assistants near NILU's observation station at Tustervatnet.

The local lama at Kårvatn did not seem to mind the visiting scientists.



Summer UFOs at Birkenes.



At Bærur

To the left: Varanger peninsula, to the right: Neiden towards the Finnish border.

Junkerdal: Despite the rain and gnats, the scientists take soil samples at each location. Thus, they get the opportunity to analyse organic environmental contaminants from soil across the country.

Roadside scenery - Finnmark on its finest.

ms Verk.

The scientists putting together a UFO at Bærums Verk. The disc in the middle is the filter that captures various environmental contaminants from the air.

Foto: NILU

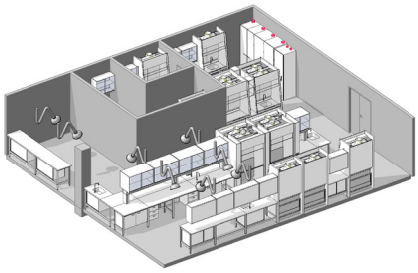
The road to Fram2

2016 has been an active and somewhat noisy year for NILU's employees in the Fram Centre. The reason can be found outside their office windows, where Fram2 is rising in all of its splendor.

Eldbjørg S. Heimstad
Research Director High North

The construction of the new Fram2 building for the Fram Centre in Tromsø started in spring 2016. In total, the new building is 9500 m^2 and will cost 500 million NOK. Since the start of construction, there have been many meetings and a lot of follow-up between NILU, the coordinator (Framsenteret AS), the builder Statsbygg, entrepreneurs and architects.

When Fram2 is completed in 2018, NILU's laboratory will consist of a clean room and lab facilities twice as large as what we have now. The new clean room will reduce the risk of contaminating environmental samples by preventing particulate matter and volatile organic gases from entering, emerging or remaining in the clean room. The lab will be especially suitable for new potentially environmental pollutants that are volatile and used in many consumer products, such as siloxanes, flame retardants and chlorinated paraffins. We will also be able to handle very vulnerable environmental samples from low-contaminated sites, such as ice cores, air and biological samples.



Above: 3D projection of the laboratory. Below: Floor plan of the Fram Centre, Fram1 to the left and the new Fram2 to the right, linked together by a glass mid-section. Drawings: HENT AS.

The NILU employees in Tromsø. Photo: Helge Markusson, Fram Centre.

Are PM sensors «accurate»?

On the portal *luftkvalitet.info*, you can access local air quality information from monitoring stations all over Norway. But how can we be sure that the data are reliable?

Ingunn Trones
Kommunikasjonsrådgiver

NILU is the National Reference Laboratory for Air Quality in Norway, and we asked its leader, Leif Marsteen, how they make sure that measurements are "correct."

Reference method

– In order for data to be reliable, the EU Air Quality Directive for local air quality requires that measurements be performed according to a reference method, says Marsteen.

– In simple terms, the method concerning particulate matter (PM) consists of air being sucked through a filter where dust is deposited. We weigh the filter in the laboratory before exposure, and to determine the amount of dust captured, we weigh it again afterwards.

– However, this method provides only one measurement per day, and the results are not available immediately. Nowadays, people expect measurement results to be available in real time on the Internet, so this is not an appropriate method to use, says Marsteen.

– The EU directive not only determines what method to use, but also that we inform the public. That is why we must have access to much more frequent measurements.

Pursuing the correct measurement data

In order to provide the public with updated information on air quality, the municipalities and road administrations now use automatic monitoring instruments that provide a new measurement every hour. But is this consistent with the reference method, and the air quality regulation and EU directives?

– The EU directive allows for the use of alternative monitoring methods as long as these instruments produce the same results as the reference method, says Marsteen. – We can prove this by letting the automatic monitoring instruments measure in parallel with the reference method.

In a project in 2015-2016, initiated by the Norwegian Environment Agency, Marsteen tested five different types of automatic PM sampling instruments commonly used at Norwegian monitoring stations. These types of instruments have not been tested against the reference method in Norway before, and the Norwegian Environment Agency wanted to know how the instruments performed under Norwegian conditions.

– Weather, wind and type of particulate matter affects the instruments' ability to measure PM. Thus, we tested the instruments during both summer and winter in two different places – by the traffic oriented station at the Hjortnes quay, and by the urban background station in the Sofienberg park, Marsteen explains.

– At the Hjortnes quay, we largely measured road dust coming from the nearby motorway, E18. There, we expected to find mainly PM_{10} particles with a diameter less than 10 micrometers. In the Sofienberg park we monitored the general urban pollution, and during winter season we expected to find a lot of finer particles from wood burning. These are particles with a diameter of less than 2.5 micrometers ($PM_{2,5}$).

They measured for a total of 24 weeks, six weeks in the summer and six weeks in the winter at each destination. Five different instrument types, usually two of each kind, were tested against four reference instruments, two of which measured PM_{10} and two $PM_{2.5}$.

– In addition to the reference instrument, we wanted to compare instruments of the same brand to detect any errors, explains Marsteen.

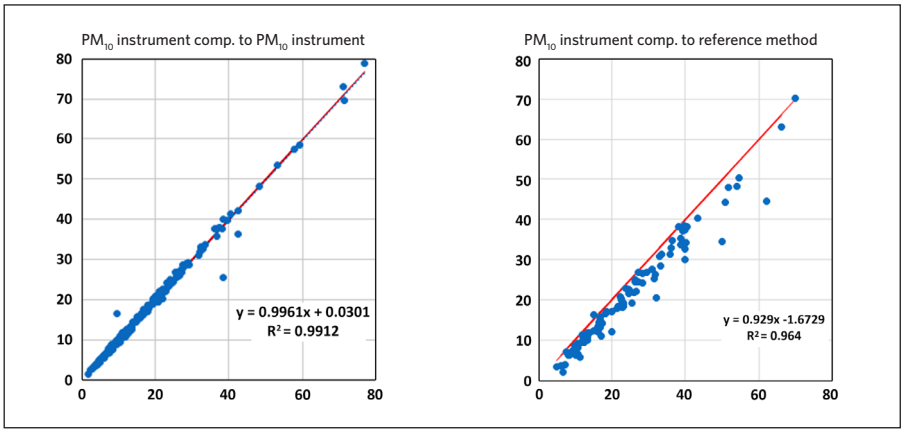
Test method

Since the reference method produces only one result per day while the automatic instruments provide values every hour, all measurements must be converted to 24 hrs mean values to be comparable.

Results from instruments of the same brand are plotted against each other in a dash chart to see how similar the measurements are, and then the results from each instrument are plotted against the results from the reference method. Each point in the chart represents a pair of measurements on a specific day. The unit on the axes is $\mu g/m^3$.

– If the instruments measure exactly the same, the points in such a chart will be on a straight line, says Marsteen. – But this is not always the case.

– The figure below to the left shows results from a comparison of two PM_{10} instruments of the same brand. As we can see, the measurements are almost alike, aside from 2-3 days. In the figure to the right, the results from a measuring instrument are plotted against the reference method. Here the points spread out. This means that the instrument measures slightly differently than the reference method. The points in the right chart are on a line that drops below perfect. This means that the instrument measures less than the reference method, in this case approx. 7% lower. Therefore, using this type of measuring instrument, results must always be multiplied by a correction factor of 1.07 to give the correct value.



Correction factors – the heart of the matter

– Finding the correction factor is the purpose of comparing the measuring instruments, says Marsteen. – When we know this factor for an instrument, we can correct the results so that they provide the right values both under Norwegian conditions and according to EU requirements.

Planning for better city air

With the new National Air Quality Planning Tool (NBV), environmental authorities and city planners get a web service that helps them plan better air quality in Norwegian cities and agglomerations.

Christine F. Solbakken
Head of Communications

The National Air Quality Planning Tool (NBV) was developed as a collaboration between NILU and MET, under the direction of the Norwegian Environment Agency in cooperation with the Norwegian Public Roads Administration, the Norwegian Institute of Public Health and the Norwegian Directorate of Health. Work began in 2014 on behalf of the Ministry of Climate and Environment, the Ministry of Transport and Communications and the Ministry of Health and Care Services. The first phase has now been completed.

– It has been a demanding, but also a very interesting task, says research director Leonor Tarrasón from the Department for Urban Environment and Industry at NILU. – The project participants have done a great job of incorporating model and emission data in compliance with international standards. We have managed to implement a comprehensive system for compiling air quality information – which is common for most of Norway and secures the comparability of the data across different cities, towns and agglomerations. We have also emphasized an educational design aimed to enable users to learn along the way, for example by using interactive maps and links to relevant explanations when variables are changed.

Scientific transparency and openness have been ruling principles, so the scientific basis underpinning NBV is well documented in reports available via the web-service. In addition, the data is freely available through two different web solutions and compiled using open source code.

The new web service is part of the development of a National Air Quality Planning Tool for local air quality and can be found at http://www.luftkvalitet-nbv.no.

Expert tool

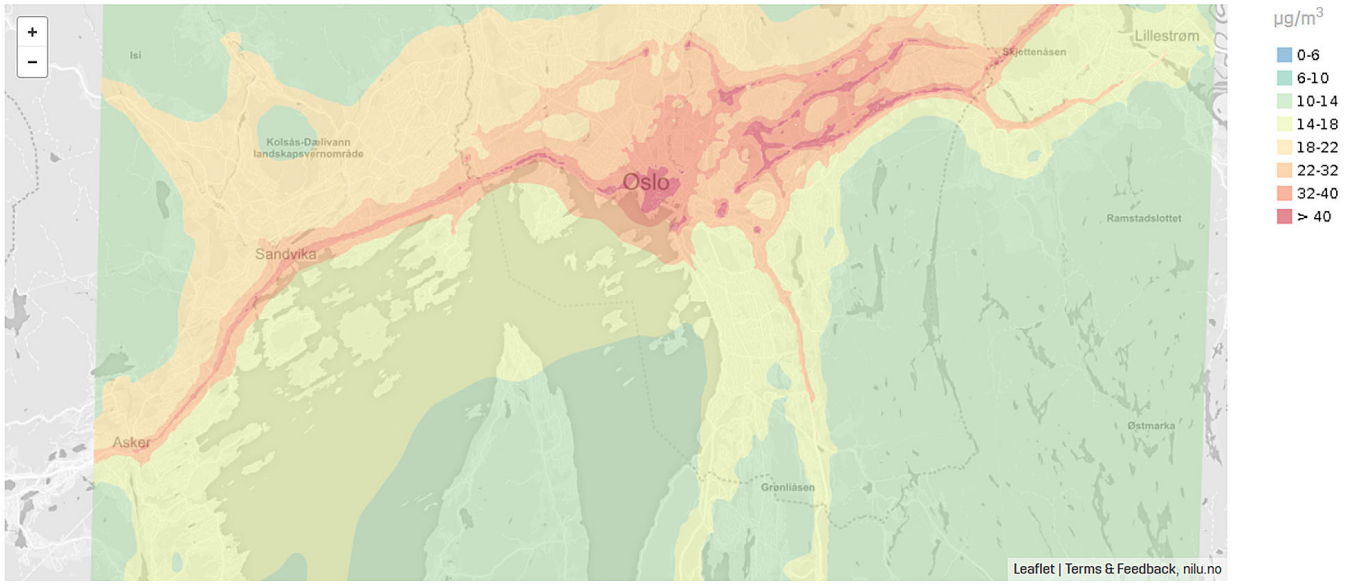
As of today, anyone can access the data and the maps in the NBV because the web-service is open to all. However, senior scientist Britt Ann K. Høiskar emphasizes that NBV is a dialogue tool that assumes existing knowledge and expertise from its users. Consequently, the main target group is air quality experts in administration and consulting companies.

– The air quality concentration levels and air zone maps are based on calculations made from a variety of different data for relevant indicators in 2015. They do not show the daily air quality situation or alerts for the next few days, as www.luftkvalitet.info does, so the tool is of limited value for the regular citizen looking for forecasts, says Høiskar.

Users get access to emission data, meteorological data and air quality concentration data for seven urban areas: Oslo, Trondheim, Bergen, Stavanger, Drammen, Grenland and Nedre Glomma (Fredrikstad and Sarpsborg). In addition, NBV comprises five other municipalities with towns and agglomerations, and can be supplemented with data from all of Norway using background maps gathered from www.luftkvalitet.info.

– The information in the maps for the urban and most populated areas are more detailed than those derived from agglom-

Annual mean concentration of NO_2 (µg/m^3)



This map shows the pollution situation in 2015 and indicates that Oslo has major problems with high concentrations of NO_2 measured as an average throughout the year. Dark red means concentrations above the limit values, i.e. the minimum requirement for acceptable air quality. Pink shows the areas where the NO_2 concentration is below the limit values but still high. Source: National Computing Tool (NBV) webpages.

Photo: Christine F. Solbakken.

erations, explains Leonor Tarrasón. – It's a natural priority, since the purpose of NBV is to plan better air quality where people live. Thus, we have focused on obtaining information about the areas with the highest population density.

Map solution and emission sources

The NBV website contains pollution maps displaying the levels of particulate matter (PM) and NO_2 in different areas within the seven cities. Particulate matter (PM_{10} and $PM_{2.5}$) and nitrogen dioxide (NO_2) are the main contributors to local air quality regulated in Norwegian cities.

The maps in the NBV website displays the air quality over longer periods (annual mean values) and also provides information in relation to daily and hourly values. On the maps, levels of air pollution are shown with a color scale. Dark red indicates where air is above the limit values, i.e. worse than the minimum requirement for acceptable air quality, while blue means that there is little air pollution.

What are limit values?

For air pollutants, limit values are specified for differing durations; 1 hour, 24 hours and annual. The limit values specify the concentration that a substance cannot exceed. If it does go above the level, then it is considered as an exceedance.

The number of permitted exceedances varies from substance to substance. The hourly limit value for NO_2 allows 18 hours a year with a value above 200 micrograms per cubic meter of air (µg/m^3). The daily concentration of PM_{10} allows 30 days a year with a value above 50 µg/m^3. Thus, the limit value is not violated until the nineteenth hour (NO_2) or the 31st day (PM_{10}) with too high levels during a year.

The website also contains maps that show sources of pollution in the various cities, such as traffic, ships, wood burning and industry. In addition, you can see how much each source contributes to local air pollution, and an indication of how many people are exposed to levels above the limit values in each city.

Uncertainty and variability

The data contains some uncertainties. This is partly because it is difficult to estimate the exact emissions that are important in order to correctly calculate air quality, partly because of the model's accuracy. It also contains some natural variability mostly in association with meteorological conditions.

– In order to get as solid knowledge as possible about the current emissions, cooperation with local authorities and other actors contributing to pollution is very important. We have established a good dialogue with the municipality, which gives us a better understanding of emissions in cities and urban areas in Norway, says Tarrasón. – Such an understanding is very important for the further development of the National Air Quality Planning Tool for local air quality. Currently, the NBV tool only contains data for 2015. Tarrasón emphasizes that meteorology varies greatly from year to year, and thus the air quality varies with it.

– Due to the current uncertainties on emission data and the natural meteorological year-to-year variability, the present results in NBV should be used as initial indications. For example, the number of exposed persons above the limit value should not be interpreted as an exact number, she concludes. – We expect this number to change from year to year. Therefore, it is important to keep working with NBV and updating the data every year.

As for the inherent uncertainties in air concentration data, cooperation with local authorities to improve emission data is essential. Also of great importance is the use of measurement data in combination with model data. These can contribute to future improvements to the results, so that the data becomes more robust in the years to come.

This is what you find in the National Air Quality Planning Tool

This web service provides access to three types of key data relevant for planning and controlling local air quality: meteorological data, emission data and air quality concentration data. The Norwegian Meteorological Institute has prepared and quality assured all meteorological data. NILU has done the same for emission and air quality concentration data.

The web pages of the National Air Quality Planning Tool contain the following products for Bergen, Drammen, Grenland, Nedre Glomma, Oslo, Stavanger and Trondheim:

- Pollution maps - geographic distribution of air pollution of NO_2, PM_{10} and $PM_{2.5}$ by 2015
- Air zone maps - geographic distribution of air pollution by 2015, based on regulation plans
- Population exposure - the number of people exposed to levels over the requirements stated in the Norwegian legislation for the year 2015
- Emission sources - contributions from relevant sources of emissions in 2015
- Source contribution - percentage contribution from relevant sources of air pollution concentrations levels in 2015
- Data download – all emission, meteorology and air concentration data is available for download as well as reports documenting the quality of the data

InnoSense – towards innovative microsensors

NILU has developed a prototype for an integrated microsensor platform that delivers air quality data of high quality.

Sonja Grossberndt
Scientist

As a result of a series of micro air quality sensor projects, NILU scientists discovered that off the shelf-sensors can achieve only limited results. While testing the sensors' precision and robustness, our scientists developed their own ideas on how to make these microsensors deliver good data – and thus be able to measure air quality reliably, where people actually are.

Exciting development

– In 2014, we understood that this was quite an exciting area for NILU and that we finally had the opportunity to develop a new technology area that might even result in a ground-breaking product, says Rune Åvar Ødegård, head of development at NILU's department of Software and Hardware Development (SHaDe).
– Based on our own experience from testing different microsensors currently available on the market, we developed plans to build our very own microsensor-based air quality sensor platform.

The proposal has been developed by NILU's previous director of innovation, John Ackerman III, and was funded through the Norwegian Research Council's FORNY program. This was the birth of InnoSense. With Kjeller Innovation as project lead and NILU's professional expertise, a microsensor platform has been developed that delivers air quality data of scientific quality. The sensor has been tested both in Oslo and Sarpsborg, both municipalities being partners in the InnoSense project. An additional project partner was Ericsson, contributing with commercial and business elements.

Future plans for commercialisation

– InnoSense has become a great success! The reason for this is the combination of Kjeller Innovation's extremely good management and NILU's solid experience and expertise within sensing technologies, electronic and software development, explains Pål Midtlien Danielsen. He is CEO of InnoSense AS, the next step of the InnoSense project. The development of the new technology shall continue in close cooperation with NILU.

– The aim now is to further develop our prototype so that the results can be commercialised, continues Danielsen. – InnoSense has applied for patent for our technology and we are working further on the development of a commercial product. In this context, the sensor platform will be tested over a longer period in Sarpsborg.

– We will continue testing the platform to see its applicability to smart city, explains Ødegård. –In the long run, our microsensor can be of interest to many clients, for example schools and kindergartens. This process will be exciting for everyone involved!


Foto: NILU

Hackathon – creative solutions

What can you get if you give a bunch of creative developers air quality data and task them with reducing the air pollution in Oslo?

The answer is "quite a lot", according to senior advisor The Nguyen Than!

The Nguyen Thanh
Senior Advisor

On request from the climate council in Oslo Municipality, NILU contributed open air quality data to the Smart Mobility Hackathon event in September 2016.

Oslo Municipality and StartupLab are behind this ICT-oriented event, where data providers, startup companies and data developers/students come together to solve a problem proposed by the organizer. This time the challenge was "Create innovative prototypes that will reduce air pollution (CO_2 and/or local pollution) from transport of people and goods in Oslo." The participants gathered together for two days to find partners, and to develop and present their solution. In addition to NILU, the Norwegian Meteorological Institute, Ruter, the Agency for Urban Environment and the State Road Administration contributed data and other background information.

In addition to providing data, NILU served as both mentor and jury member.

The first thing that struck me was all the expertise gathered in one place, as well as the great commitment among the participants. You get to access a network that is quite unique. Something magical happens when so many talented people get together, in an environment where no idea is too bad to be tested. I think success is definitely found in the combination of commitment, creativity and cooperation.

The Hackathon event was intense, and all the participants worked hard. When we finally reached evaluation, the jury emphasized how the ideas impacted on the environment, combined with market potential. The best idea this time belonged to the team behind «Urban-Mapping». Their solution focused on visualizing all available information in a simple, understandable and professional way via their own platform.

Do you have a problem, and need a creative solution in a hurry? Hackathon competitions are gold. The challenge is to define a relevant and interesting issue in order to attract relevant data providers and creative developers.

Foto: Nils Juell, Startuplab

Metals as harmful pollutants

Metals are among the most important pollutants emitted to the environment. On one side, they are critical resources for various uses and modern technologies. On the other side, many metals are toxic and have an adverse impact on the environment and human health.

Jozef M. Pacyna
Research Director

During the last few decades, society has dramatically altered the biogeochemical cycles of various chemicals. A steadily increasing human population requires larger amounts of energy, industrial goods and food. Thus, provision of these goods has generated increasing amounts of pollutants emitted to the atmosphere, as well as aquatic and terrestrial ecosystems.

Metals, environment and health

NILU has been involved in studying the emissions of trace metals and their impact on the environment and human health for the last 4 decades. From the beginning, the major emphasis was on preparation of a scientific justification for establishing a new UN Convention on reduction of emissions and exposure to mercury. The efforts resulted in the Minamata Conventions, signed in 2013. Knowledge about public health concerns associated with metals has been generated along the following questions:

- Has the biogeochemical cycle of a given metal been substantially altered by human activities, and on what scale?
- What are the critical pathways by which the most toxic species of a metal can reach the organ in man which is the most sensitive to its effect?, and
- What is the degree of public health concern associated with the metal?

Photo: NILU.

NILU scientists have contributed to the providing of answers to these questions. After being emitted to the atmosphere, metals can be transported with air masses and water currents at various distances before being deposited to the aquatic and terrestrial surfaces. Most of the metals are transported within the air masses on particles or with sediments in water.

Impact on climate change

Some metals, however, such as mercury and to some extent selenium, can be transported in their gaseous phase, resulting in long range transport within air masses and their perturbations of biogeochemical cycles on a continental scale, e.g. in large parts of the Northern Hemisphere. NILU studied the transport of metals to the Arctic and the impact of climate change on their biogeochemical cycling there in the EU project ArcRisk.

Climate change will affect metal pathways and levels in the Arctic and elsewhere. However, most results project only modest changes in levels within air, soil and water as a result of climate change. Understanding processes related to indirect effects, such as changes in

occurrence and distribution of species, carbon cycling, catchment hydrology, land use patterns and vegetation cover is limited, and associated with large uncertainties. The ArcRisk models contributed to explain these uncertainties.

Vital to new technologies

Recently, the main focus of research on metals at NILU has been on Rare Earth Elements (REE), also called emerging metals. These metals are essential for economic growth globally. However, many of these metals are difficult to extract in an economically viable and environmentally sound manner. This contradiction needs to be taken into account when the further use of these metals is considered in new technologies. In addition, the recycling of waste is a very important issue that must be addressed. The main objective of our study of REEs is to increase the understanding of environmental and human health implications of these metals, used in new industrial technology applications.

The "true value" of metals, including social and environmental costs and benefits, need to be taken into account when new metals are considered for application. Potential revenues from the entire value chain needs to be compared holistically with costs or benefits assessed according to a life-cycle perspective. To assist analysis, monetary valuation methods need to be employed.

NILU research on mercury provides an example of cost and benefit analysis performance. We have earlier compared the investment and operational costs to reduce mercury emissions from anthropogenic sources to damage cost that results from mercury pollution of the environment and subsequent human health impacts. Now, we are attempting to explore whether procedures from the mercury cost and benefit analysis could be modified and used to analyze other metals.

H																	He
Li 41	Be 63											B 41	C	N	O	F	Ne
Na	Mg 94											Al 44	Si	P	S	Cl	Ar
K	Ca	Sc 65	Ti 63	V 63	Cr 76	Mn 96	Fe 57	Co 54	Ni 62	Cu 70	Zn 38	Ga 38	Ge 44	As 38	Se 47	Br	Kr
Rb	Sr 78	Y 95	Zr 66	Nb 42	Mo 70	Tc	Ru 63	Rh 56	Pd 39	Ag 44	Cd 38	In 60	Sn 36	Sb 57	Te 38	I	Xe
Cs	Ba 63	*	Hf 38	Ta 41	W 53	Re 90	Os 38	Ir 69	Pt 66	Au 40	Hg 45	Tl 100	Pb 100	Bi 46	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fi	Mc	Lv	Ts	Og

* Lantanoider	La 75	Ce 60	Pr 41	Nd 41	Pm	Sm 38	Eu 100	Gd 53	Tb 63	Dy 100	Ho 63	Er 63	Tm 88	Yb 88	Lu 63
** Aktinoider	Ac	Th 35	Pa	U 63	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Degree of access

Excellent — Scarce

0 10 20 30 40 50 60 70 80 90 100

Global demand for high-tech products like modern electronics leads to further scarcity of already rare metals.

Read more

The results of NILU's studies on metals have been published in numerous scientific papers and recently summarized in two books: *Trace Metals and Infectious Diseases* by the MIT Press (edited by J.O. Nriagu and E.P. Skaar) and *Environmental Determinants of Human Health* by Springer Humana Press (edited by J.M. Pacyna and E.G. Pacyna).

Sofia Eirini Chatoutsidou

Sofia Eirini Chatoutsidou defended her PhD thesis at the Technical University of Crete on May 20, 2016. The title of the thesis was "Physical processes of indoor aerosols in modern microenvironments".

The thesis research was carried out at NILU's department of Atmosphere and Climate, and supported by the EU 7th framework programme HEXACOMM (Human Exposure to Aerosol Contaminants in Modern Microenvironments).

Air quality in the office

In her work, Chatoutsidou focused on indoor particles and their interactions, physical processes and reactions, which can alter their chemical composition, physical characteristics and concentration.

As people spend the majority of their time indoors, they are exposed to indoor contaminants. Indoor air quality, a term referring to air quality within buildings, involves the characterization of indoor sources, investigation of hazardous contaminants and their impact on ambient air. Indoor contaminants are also associated with adverse health effects, among them cardiovascular disease, asthma, nausea, cancer and more.

Outdoor vs indoor particle levels

Chatoutsidou focused on modern workplace environments in her study, performing measurement campaigns in offices at NILU, Kjeller, Norway, and in Chania, Greece. Indoor and outdoor particle (number and mass) concentrations were measured simultaneously in several offices equipped with a mechanical ventilation system, and the results showed that the outdoor environment plays an important role on indoor particle levels, especially in vacant offices. Both number and mass concentrations of indoor particles followed the profile of the outdoor particle concentration, indicating a significant infiltration of outdoor particles indoors.

At the same time, indoor sources associated with office equipment, such as printers, were identified as the main contributor of ultrafine particles indoors. Door configuration, internal layout and airflows played an important role on particle transport. However, the presence of people in the offices had significant impact on the coarse particles, as walking, moving objects, etc. caused resuspension.

In summary, the campaigns in Norway and Greece both demonstrated that indoor environmental conditions, in terms of particle concentration, are subject to both indoor and outdoor contributions, where primary emissions and particle dynamics determine the impact to the indoor environment.

Cristina de Brito Beirão Guerreiro

"Household combustion and agriculture are key emission sectors in future air quality management aiming at the reduction of negative health effects from exposure to PM, including BaP."

So states senior scientist Cristina de Brito Beirão Guerreiro in her doctoral dissertation "A novel combination of methods for air quality management support with focus on particulate matter."

Her doctorate was completed at the Technical University of Gdansk on September 21, 2016.

BaP and lung cancer

In the study, household combustion was identified as a major emission sector of primary PM and benzo(a)pyrene (BaP), and of increasing importance for PM and BaP concentrations in Europe.

Guerreiro's dissertation further estimated European population exposure to BaP and the related incidence in lung cancer, by combining measurements, dispersion modelling, and relevant auxiliary data. About 20% of the European population was exposed to BaP annual mean concentrations above the target value (1 $ng.m^{-3}$) in 2012, while only 12 % of the European population live in areas with concentrations under the estimated reference level for acceptable risk (0.12 $ng.m^{-3}$).

The Gothenburg Protocol not sufficient

Agriculture is the main emission sector of NH_3, an important PM precursor leading to the formation of secondary inorganic aerosols (SIA). SIA account for about one third of PM_{10} and half of $PM_{2.5}$ concentrations in regional background ambient air in Europe.

The model simulations in this study, combined with measurement data, show that the emission reductions agreed under the revised Gothenburg Protocol (GP) will not be sufficient to achieve compliance with PM standards in Europe in 2020; hence, additional European measures should be considered.

A further reduction of 30% of NH_3 agriculture emissions is achievable by the implementation of currently available mitigation measures. Such a reduction would lead to important reductions in $PM_{2.5}$ levels, reducing premature death due to air pollution in Europe.

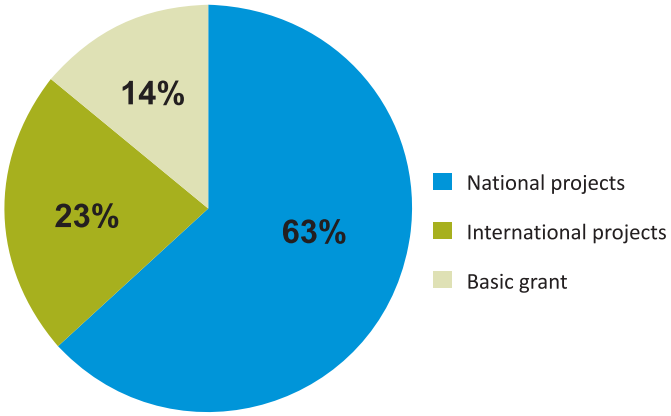
Key figures

Extract from the annual statement: All figures in MNOK

INCOME STATEMENT	2016	2015
Project revenue	158,0	158,9
Basic grant*	28,4	27,0
External expenses	16,3	11,0
STIM-EU	3,5	1,4
Other operating income	0,8	0,7
Operating revenue	**207,0**	**199,0**
Wages and social expenses	-138,1	-132,6
Direct project expenses	-27,8	-21,7
Other expenses	-35,9	-34,4
Operating profit	**5,3**	**10,3**
Net financial items	-1,0	9,8
Tax	-2,3	-6,5
Profit for the year	**2,0**	**13,6**

BALANCE SHEET	31.12.16	31.12.15
Fixed assets	100,0	98,9
Current assets	96,9	98,8
Total assets	**196,9**	**197,7**
Total equity	122,4	120,5
Long-term liabilities	0,0	14,5
Short-term liabilities	74,5	62,7
Total equity and liabilities	**196,9**	**197,7**

PROJECT PORTFOLIO – PERCENTAGE 2016



NUMBER OF MAN-YEARS	31.12.16	31.12.15
Total	163	160
– whereof research man-year	94	92
– whereof man-years of other personnel	69	68
Turnover per research man-year (MNOK)	**2 117**	**2 163**

NUMBER OF EMPLYEES	31.12.16	31.12.15
Total	176	175
– whereof women	92	87
– whereof men	84	88
Number of employees holding a doctorate	**68**	**67**

PROJECT PORTFOLIO - PERCENT	2016	2015
National projects	63%	63%
International projects	23%	23%
Basic grant	14%	14%
Total	**100%**	**100%**

NILU's PUBLICATIONS	2016	2015
Peer-review articles	130	147
Scientific reports	35	40
EMEP/CCC reports	4	5
Lectures	136	124
Posters	41	45
NILU scientists also contributed to the publication of:		
External reports	20	20
Chapters/articles in books/reports	33	25

Number and nationality of employees

2016: 176 employees of 20 different nationalities

2015: 175 employees of 22 different nationalities

**strategic institute initiatives included*

www.nilu.no

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