

# ANNUAL REPORT 2018

sfi



KLIMA  
2050

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**ORGANIZATION**



## Innovations for reduced societal risk towards 2050

The Research Centre Klima 2050's ambitious goal is to reduce the societal risk associated with climate change due to an increased rainfall load in the built environment. The ambition requires solutions on several levels:

### **The regulations**

– The Norwegian legal system, including the building regulations, is function-based and thus takes the climate-adaptation of the built environment into account. The legal system is however vague about how climate change should be taken into account. Revisions and greater clarity are required. Klima 2050 is therefore developing a framework for the climate adaptation of buildings. This will aid designers when responding to the climate challenges pointed to by the building regulations. In this report the Norwegian Building Authority responds to what they believe will be important when adopting such a framework (see page 44).

### **Municipal plans and building processes**

– Solutions also lie in clearly defined measures for climate adaptation in municipal plans and building processes. Municipalities are important actors and initiators. Trondheim municipality is a partner and a driving force in the efforts to raise awareness of and in finding good solutions for climate adaptation in planning and building processes. In order to bring in players with the right climate adaptation expertise in the projects, Klima 2050 has prepared guidelines for procurement (see page 36).

**Robust technology**

– Society needs more robust technical solutions, both hardware solutions (e.g. building technology), and software solutions (e.g. computer programs). Early warning is an example of an important evolving technology, that must be made more “accurate” and relevant. Klima 2050 is contributing knowledge leading to innovations in both building technology and software development. Two examples of such solutions are discussed on page 28 and 41.

**Nature-based solutions**

– There is a need to take future solutions back to nature. Newer solutions for handling stormwater are largely based on open and nature-based principles. Nature-based solutions are also important in landslide protection. In addition to being risk-reducing measures, these types of solutions can help to create better physical environments, with areas for leisure and biodiversity. Klima 2050 is researching the effects of various delaying solutions in large-scale set-ups through pilot projects, such as Høvringen in Trondheim and FV 505 in Sandnes, see page 33.

**Incentives and business models**

– The solutions are also found in better incentives for climate adaptation and new business models for the market. The rewards for doing preventive climate adaptation are currently small, this will change towards 2050. Klima 2050’s research can trigger changes in organizations and during decision-making processes. Idar Kreutzer, CEO of Finance Norway, explains how the insurance sector is developing on page 24.

The SFI scheme aims to strengthen innovation and develop expertise at a high international scientific level. The relevance of the expertise is ensured through close partner collaboration.

Grethe Bergly  
*Klima 2050 Chair*  
*Multiconsult*

” The Centre’s  
consortium  
plays a key role  
in promoting  
opportunities for  
innovation among  
partners ”

Grethe Bergly, Klima 2050 Chair,  
Multiconsult.

# Vision and main goal

## Vision

The Centre for Research-based Innovation Klima 2050 shall be synonymous with excellence within risk reduction through climate adaptation of buildings and infrastructure exposed to enhanced precipitation and flood water. Klima 2050 shall be an effective instrument for the development and implementation of adaptive innovations for the Centre partners and society.

## Main Goal

Klima 2050 will reduce the societal risks associated with climate changes and enhanced precipitation and flood water exposure within the built environment. Emphasis will be placed on development of moisture-resilient buildings, stormwater management, blue-green solutions, measures for prevention of water-triggered landslides, socio-economic incentives and decision-making processes. Both extreme weather and gradual changes in the climate will be addressed.

The Centre will be recognised for its research training within the field of climate adaptation of the built environment. Through education of graduate students, training of highly qualified research personnel through PhDs and training of professionals in the sector, the Centre will stimulate new solutions and further research and development in the building, construction and transportation (BCT) sector long after the term of the Centre's existence.

The research is organized in four main areas:

### WP1

Climate exposure and moisture-resilient buildings

### WP2

Stormwater management in small catchments

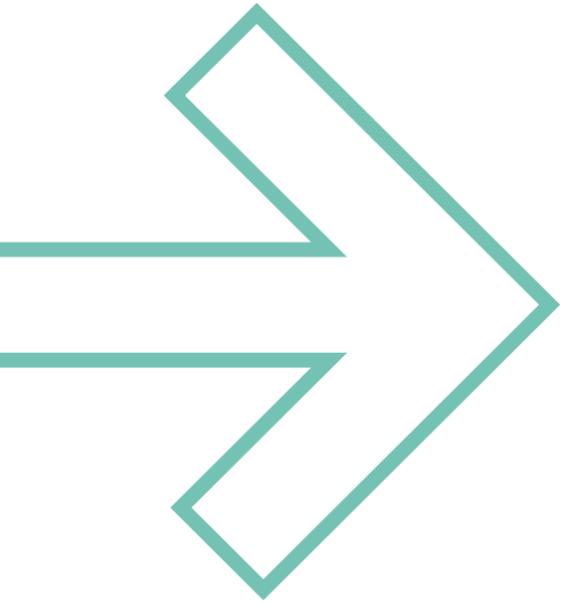
### WP3

Landslides triggered by hydro-meteorological processes

### WP4

Decision-making processes and impact

# The partners / consortium



The user partners represent important parts of Norwegian building industry; consultants, entrepreneurs, property developers, producers of construction materials and authorities. The value chain within Klima 2050's fields of research is complete. Private partners in the consortium in 2018: Finans Norge, Isola AS, Multiconsult AS, Mesterhus/Unikus, Norgeshus AS, Powel, Leca Norge AS, Skanska Norway and Skjæveland Gruppen. Public partners: Avinor AS, Jernbanedirektoratet, NVE (the Norwegian Water Resources and Energy Directorate), Statens vegvesen, Statsbygg, and the municipality Trondheim kommune.

The host institution for SFI Klima 2050 is SINTEF, and the Centre is directed in cooperation with NTNU. BI Norwegian Business School, Norwegian Geotechnical Institute (NGI) and Norwegian Meteorological Institute (MET Norway) are research partners.

## Private sector



## Public sector



## Research & education



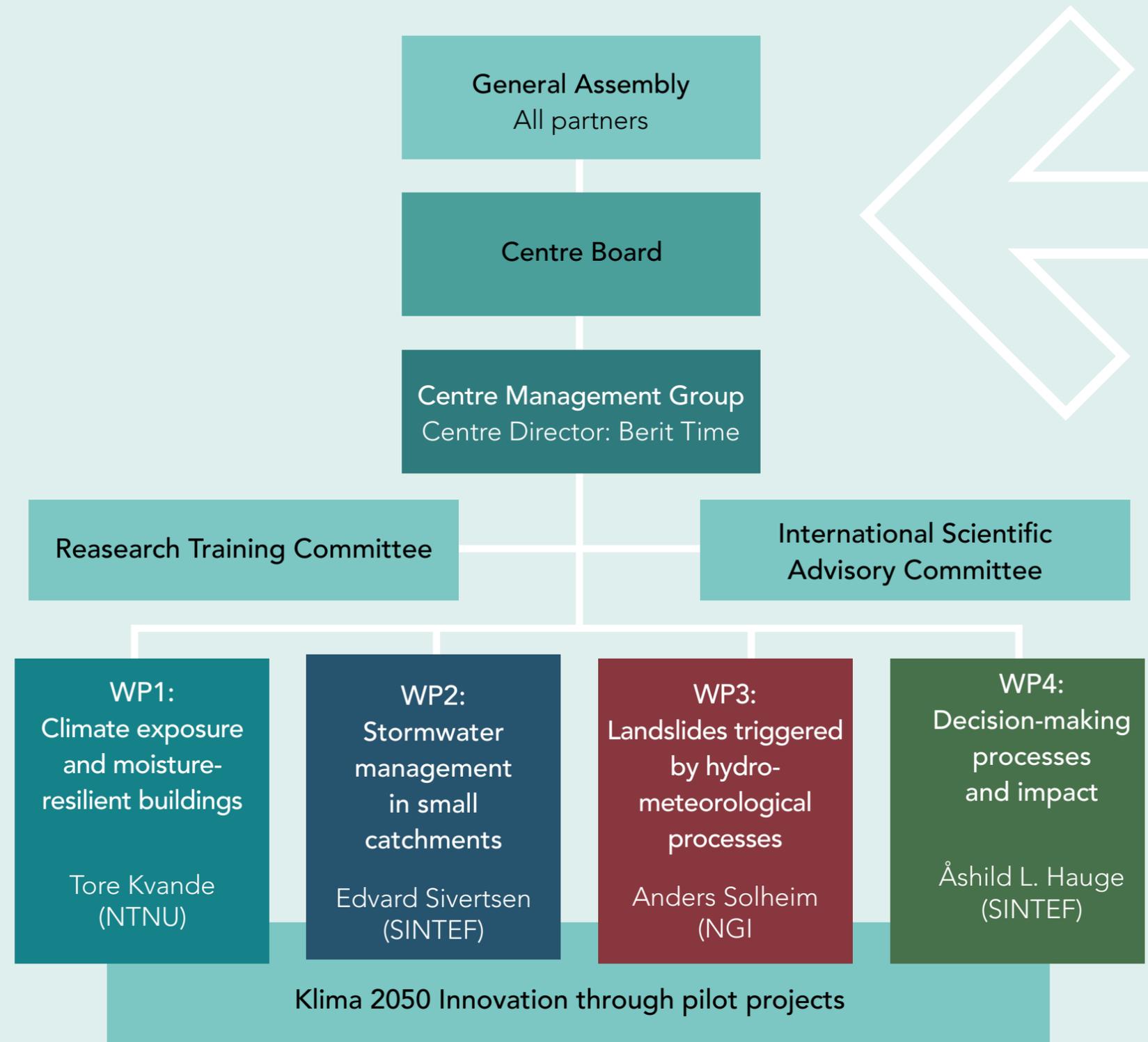
# The organization

## Centre Management Group

Berit Time, *chief scientist at SINTEF, Centre Director*  
 Tore Kvande, *professor at NTNU, Principal Investigator (WP1)*  
 Edvard Sivertsen, *senior research scientist at SINTEF (WP2)*  
 José Cepeda, *senior advisor at NGI (WP3) until July*  
 Bjørn Kalsnes, *senior engineer at NGI (WP3) until July*  
 Anders Solheim, *senior geologist at NGI (WP3) from August*  
 Åshild L. Hauge, *senior research scientist at SINTEF (WP4)*  
 Lena Bygballe, *associate professor at BI Norwegian Business School (WP4)*  
 Linn Frost, *administrative coordinator at SINTEF (adm) until July*  
 Jorunn Auth, *administrative coordinator at SINTEF (adm) from August*

## Centre Board

Grethe Bergly, *Multiconsult (Chair)*  
 Christoffer Serck-Hanssen, *Jernbanedirektoratet*  
 Rune Stenbro, *Statsbygg*  
 Einar Aassved Hansen, *Trondheim kommune*  
 Rune Egeland, *Skjæveland Gruppen*  
 Rune Stene, *Skanska Norge*  
 Anders Solheim (until July)/Lars Andresen (from August), *NGI*  
 Carl Thodesen, *NTNU*  
 Hanne Rønneberg, *SINTEF (Deputy Chair)*  
 Svein Erik Moen, *The Research Council of Norway (observer)*  
 Chairman of General Assembly: Jørgen Young, *Isola*



# Researcher training

Klima 2050s overall aim is to reduce societal risk, something which can only be done through joint work and inter- and transdisciplinary interest and focus from the Centre researchers. The researcher training initiative emphasis this aspect as outlined in Klima 2050 Note 23 Researcher Training.

The activity concerning researcher training focus publication activity, Ph.D.-gatherings, and partner support for the Ph.D.'s by use of writing lab's.

The Centre is targeting:

- 15 Ph.D.-candidates educated during the life-span of the Centre
- 15 M.Sc. students involved in the Centre yearly
- 15 scientific journal publications and 30 other peer reviewed publications each year.

In the biannual PhD-gatherings emphasis has been laid on sociability and common challenges. Research ethics has been a core subject in all gatherings. Equally, responsibilities from the student side to the overall project has been a continuous effort to transmit. Social bonding has been actively sought in order to create synergy effects between the different research initiatives.

The PhD-gatherings in 2018 took place in Røros in January and in Åre in November.

”

”The International Scientific Advisory Committee deeply acknowledges the researcher training initiatives, which has led to an impressive increase in the scientific publishing last year.”

Dr. Thomas Glade,  
Professor at University of Vienna, Austria



## Master thesis for Klima 2050



**Tore Hoven**  
Study program  
manager NTNU

The ambition was 50 students to write their master thesis in connection with Klima 2050 during the Centre's eight-year period. However, the goal has already been reached today.

– A win-win situation for both the students and Klima 2050, says Tore Hoven, study program manager at the NTNU program for Civil and Environmental Engineering, referring to the fact that so many postgraduate students want to write a master thesis within Klima 2050.

– The students get a great possibility to work on highly relevant issues and real research projects, while Klima 2050 gets relevant research of use for the Centre. They put a lot of work into it, continues Hoven.

### Climate and particularly stormwater management very relevant

Hoven says that 90% of the students get offered a job even before they finish their studies. A thesis on climate has a high relevance in the job market today. This applies particularly to the many who choose to write about stormwater management, a topic that has become very popular among the master students.

– We have just hired someone who will work to ensure that postgraduate theses become more innovative. The experience they gain from developing innovative solutions in Klima 2050 is fully in line with our commitment, says Hoven.

### Awarded master students:

**2016**

**Mareike Anika Becker**

awarded Næringslivsringens award for best master thesis in building and environmental technology.



**2017**

**Fredrik Slapø**

awarded Næringslivsringens award for best master thesis in building and environmental technology.



**2018**

**Thea Ingeborg Skrede**

awarded the RIF award (Consulting Engineers' Association) for this year's best master thesis.



Master thesis reward to Thea Ingeborg Skrede, NTNU

## The applicability of urban streets as floodways

Urban streets as floodways will require additional hydraulic performance and safety criteria. In her master thesis Thea identified and evaluated such criteria, and a method for evaluation of urban streets applicability as floodways is proposed. The method can be used to evaluate the applicability of multifunctional streets used as urban floodways and can be adapted by municipalities as a decision support tool for stormwater management.



Photo: Christen Reastad

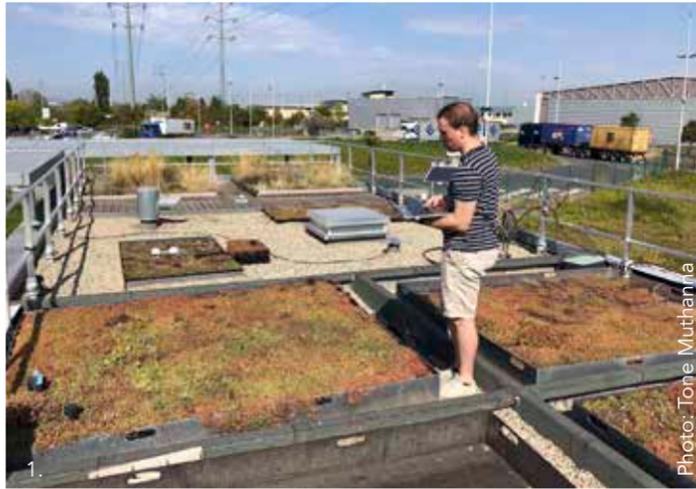


Photo: Tone Muthanna



Photo: Inger Anita Merkesdal



1. The DEEP Laboratory at INSA, Lyon
2. Collaborators towards Insu Resiliemce
3. Dennis Kliewer working on Alma Regnbed
4. The International Scientific Advisory Committée visiting Høvringen



## International collaborators

The SFI status attracts international networks and institutions and the results are embedded in international activities.

InsuResilience is a global partnership for climate and disaster risk finance and insurance solutions, launched at the 2017 UN Climate Conference. The Klima 2050 report on attitudes for sharing of insurance loss data gives new insight in models for private-public cooperation for climate adaptation. The report is presented on InsuResilience web page.

One of the tools of Skjæveland Gruppen, Alma Regnbed, has been selected by the EU program BRIGAD as one of six innovations to receive funding and expertise support for further development. Two master students in Klima 2050 work on issues related to the innovation in their projects, one of them an exchange student from Münster University of Applied Sciences.

The recently awarded Horizon 2020 project SAFEWAY, with Klima 2050 partners, leads to significantly improved resilience of transport infrastructures, developing a holistic toolset with transversal application to anticipate and mitigate the effects extreme events at all modes of disaster cycle.

Tone Muthanna, one of the Centre key researchers is spending 12 months at the DEEP Laboratory at INSA (Institute National des Sciences Appliquees) in Lyon. The collaborative focus is on green roof research and modelling of such systems. In return the Centre will host an internship student, Vincent Pons, working with data from Høvringen in 2019.

European Water Platform (WssTP) contributes to the development and implementation of key policy on the water sector in the EU. Mehdi Ahmadi, SINTEF, was recently assigned as the Green Infrastructure Working group leader.

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INNOVATIONS

# The insurance companies will share their loss data

Insurance payouts due to stormwater have doubled from 2008 to 2016. Now, insurance companies will share their loss data with the municipalities to facilitate their work with climate adaptation.

Research on climate change indicates that extreme rainfall will be the most serious nature-based challenge for the built environment in Norway in the future. Stormwater damage proves to be the most expensive factor, more so than floods and other natural disasters. Data from Finance Norway shows a drastic increase in stormwater damage: From 18,000 damages in 2008 to 26,000 in 2016.

– Unlike the impression you get from the media, problems with stormwater in densely populated areas is a far greater problem than flooding. In order to implement the right prevention measures, there is much to be gained from

Stormwater damages has increased from 18 000 in 2008 to **26 000** in 2016.



Idar Kreutzer  
CEO of Finance  
Norway



Photo: Shutterstock

getting a clear picture of the risk, says Idar Kreutzer, CEO of Finance Norway.

## **Everyone gains from sharing data**

Insurance companies are the ones that hold the most complete data today. Research has shown that loss data on address level from insurance companies are useful to the local municipalities.

– We know that by combining our microdata on loss with community planning, we obtain better foundations, both to prevent and to plan so that robust

communities are created. The fact that the municipalities now can use the data is for the benefit of most people, for the insurance companies, and for society on the whole, maintains Kreutzer.

### Creating a new database

The challenge of accurately knowing what to do remains: What does it take for insurance companies to be willing to share loss data – with whom, on what level, and in what ways?

Klima 2050 has collaborated with Finance Norway on a research project to unearth these attitudes. The recent report *“Attitudes in Norwegian insurance companies towards sharing loss data”* was based on a qualitative interview study among leaders in the largest companies. It demonstrated a strong willingness to share providing the privacy of the customers is protected. Those who are interviewed prefer that sharing of the data should be a requirement.

Practically, the question remains of how the data be collected without undermining the competition in the market and violating the right to privacy. Together with Finance Norway, The Norwegian Directorate for Civil Protection (DSB) is working on creating a knowledge base with data on natural hazards and other climate-related damages. The intention lying behind this work is that the municipalities can facilitate well-informed decisions on what areas to prioritise in implementing prevention measures.

– DSB and Finance Norway are now working together to find a solution. The loss data must be reported to the knowledge base where the information cannot be traced back to the insurance company.

### The project is gaining international recognition

Kreutzer says the project is pioneering and it is gaining international interest from both the World Bank, OECD, UN and the EU. He believes the value of implementing prevention measures must be highlighted.

– Philosophically said; We as a society spend a lot of money on repairing, whether it is in health or in damaged buildings. But we spend little in preven-

tion measures. The return the bank can give a couple of percent, The Government Pension Fund Global three to five percent, but by investing in climate adaptation, the return can be between 500 and 700 percent, says the CEO of Finance Norway.

According to the UN and the World Bank, \$ 1 in invested prevention can mean \$ 5 to \$ 7 saved in damage costs.



# New tool shows best location for blue-green infrastructure

The amount of rain is increasing, and in urban areas the big question is what to do with all the water? A new GIS-based tool indicates where blue-green infrastructure, such as rain gardens, is best located.

Today, it rains 20 percent more in Norway than it did 100 years ago, and according to climate research, extreme precipitation will be a great challenge in the years ahead. One way to reduce and delay the runoff is to use blue-green infrastructure, such as rain gardens, green swales and permeable pavements. These solutions are also called Sustainable Urban Drainage Systems (SUDS).

Klima 2050 together with the Drenssten project have developed a tool based on GIS (Geographical Information System) that indicates the best location for blue-green infrastructure. The NTNU Gløshaugen Campus, where NTNU is to be co-located, is used as a case study.

## **Good understanding of the flow paths**

– The tool gives a good understanding of where the water is and where it runs, available area and altitude differences in the terrain. With all this acknowledged we can find the best location for the blue-green infrastructure, says senior researcher in SINTEF, Edvard Sivertsen. He leads Klima 2050's work on stormwater management.

The GIS data for Norway are of good quality, they provide an overview of



**Edvard Sivertsen**  
Senior research  
scientist, SINTEF



**Jonas Vevatne**  
Senior engineer,  
Statsbygg

where buildings and roads are located, and altitude differences in the terrain. When the data is analysed with the new tool, as it is done with Gløshaugen, one can detect the flood paths and where the water accumulates. Sivertsen shows how the flood paths are marked in red on the map.

### Measuring the infiltration capacity in the soil

– GIS is a desktop tool, and cannot say anything about the actual local infiltration capacity which depends on the qualities of the soil, clarifies Sivertsen.

Therefore, the second part of the tool consists of taking measurements that show how fast the soil absorbs the water, in the areas that GIS in part one identified as most promising. In collaboration with associate professor Tone Muthanna at NTNU and her students, 20 areas in Gløshaugen have been measured.

### Must be applied at an early stage

The tool should be utilised early in the project. Then roads, buildings, car parks etc. can be located where they do not interfere with the water's natural paths or destroy the sites suitable for blue-green infrastructure.

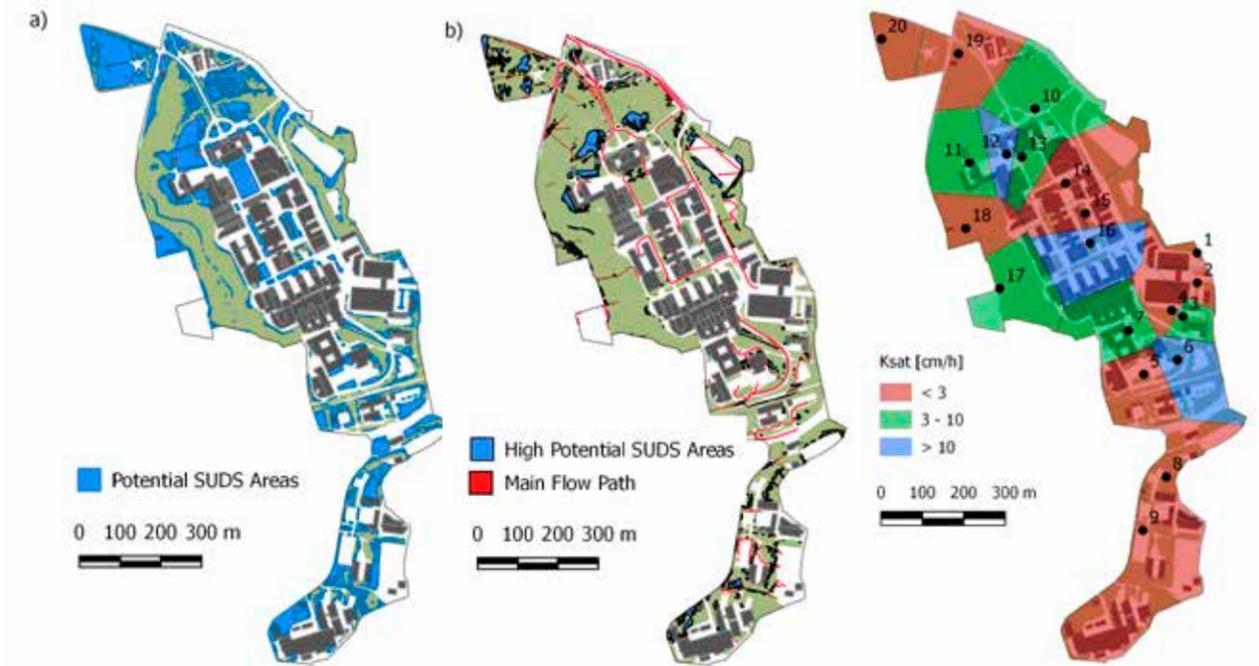
Statsbygg, which is a partner in Klima 2050 and will lead the work on the co-location of NTNU at Gløshaugen, agrees.

– The tool is very useful. Not the least at NTNU Campus at Gløshaugen where 92,000 square meters of new buildings will be constructed, and 45,000 square meters will be upgraded, on a limited area. As the tool is applied at an early stage, we know where the water paths are and where to locate the blue-green infrastructure at an early stage, says Jonas Vevatne, senior engineer in Statsbygg.

### Prevents problem with stormwater

He believes it is important to remember that densification, which is highlighted as a good environmental measure, also comes at a cost. It leads to more dense surfaces and more stormwater that needs to be handled.

– It is important that this type of analysis is done early in the project in parallel with the zoning and planning. Unfortunately, this does not happen automatically in real life. But for a construction company, it is beneficial to take these considerations to prevent problems with stormwater later, says Vevatne.



**In the last 7 years, precipitation has been the cause of 5 extreme weather forecasts.**



**Lene Sørli Heier**  
Chief engineer,  
Norwegian Public  
Roads Administration



Foto: Iija Hendel

## New method for treating stormwater runoff

More frequent and heavy rain increases the problem of contaminated stormwater that flows from roads and into streams and the ground. Klima 2050 is now testing a new method for treating stormwater runoff.

It rains 20 percent more in Norway today compared with 100 years ago, and during heavy rainfalls the ground loses the capacity to absorb the water. Stormwater runoff from roads and car parks contains a cocktail of various environmental pollutants deriving from brake pads, exhaust and so on', leading to the pollution of nearby streams and groundwater.

A pilot project in Klima 2050 will test a new method for treating stormwater runoff from the county road 505 Skjæveland – Foss-Eikeland in Sandnes.

– This summer, stricter demands were made to reduce emissions of pollutants in the treatment of stormwater. The Norwegian Public Roads Administration needs to look for new opportunities and is very interested in the development of new solutions, says Lene Sørli Heier, chief engineer in the Norwegian Public Roads Administration.

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### Traditional stormwater management faces ethical dilemma

The Norwegian Public Roads Administration owns the pilot project, and the Skjæveland Group is also a part of the project. Both are partners in Klima 2050.

Sørli Heier sees it as an advantage to get more of the treatment of the stormwater runoff below the ground in a closed system, which also requires less space. The traditional method of handling the stormwater runoff is to build open ponds along heavily trafficked roads, but this method has its challenges.

– Different animals, such as frogs and newts, are attracted to these treatment ponds that look like lakes. It is an ethical dilemma. According to most surveys we do, it seems that the animals are doing well. But for example, in the ponds situated by heavily trafficked roads, increased DNA damage has been observed in the fish that is living in the pond compared with fish from a nearby river with no stormwater runoff.

### Examines the treatment effect from three different pipes

The new method to be tested consists of three large pipes placed below ground. These are designed in different ways and placed lateral to each other, enabling parallel testing and comparison.

The objective of the pilot project is to document the treatment efficiency, operation and maintenance of the pipe solutions for treatment of stormwater from the new bridge and the connecting road south on the FV 505, as well as facilitate further development of the treatment solutions.

### Long time testing in the environment is an advantage

The experience from the project may form the basis for new guidelines for the design, operation and maintenance of the new type of solutions.

– It is very beneficial that it is tested on a large scale, not just in a lab. Now it will be exciting to see how this works and monitor the performance of the instalments through the tests starting in 2019, says Sørli Heier.

” The new method to be tested consists of three large pipes placed below ground. These are designed in different ways and placed lateral to each other, enabling parallel testing and comparison.”

Lene Sørli Heier, Norwegian Public Roads Administration

# How to plan and build a climate-adapted building

What is important to consider when building a climate-adapted building? Klima 2050 has, in cooperation with the municipality of Trondheim, prepared a checklist of 21 points describing how to proceed in the different construction stages - from the concept to the completion.

Klæbu and Trondheim municipality (merging in 2020) wanted that the new health and welfare centre in Klæbu should become a climate-adapted building, but did not quite know how to proceed. They contacted Klima 2050 and decided that together they should develop a tool to ensure that climate adaptation was taken into consideration throughout the whole construction process.

– In the planning and preparation of the pre-project before construction bidding we had a great focus on looking through possible solutions for a cli-

mate-adapted construction project. It has been an exciting and enlightening collaborative project, says Anne Grete Valstad, the municipality's project manager for the construction of new Klæbu Health and Welfare Center.

## **Concise and clear checklist**

At the end of 2018, Klima 2050 published a report («*Klimatilpasset bygning. Anvisning for anskaffelse i plan- og byggeprosessen*») which presents the tool:



Anne Grete Valstad  
Project manager,  
Trondheim kommune



Illustration: PKA arkitekter



A checklist consisting of 21 points with an overview of what to be aware of in the different stages of building a climate-adapted building. A climate-adapted building is planned, designed and built to withstand various types of external climate impact - from precipitation to snow load, wind, solar radiation, temperature and flood water - throughout its intended lifetime.

– We discussed the fact that it had to be concise and clear, so it became easy to use, says Valstad.

### **The courtyard handles the water**

Thoughtful choices must be made throughout the construction stage for a construction project to be climate-adapted. The checklist is divided into different phases: It starts with the planning phase, and goes through the idea and sketch phase, pre-project, detail design and finally the operation and maintenance stage.

For the new health and welfare centre in Klæbu, they have concentrated particularly on the stormwater management. They have chosen to build the construction around a courtyard where rain gardens will reduce the amount of stormwater that overloads the waste water network.



“ I recommend other municipalities to use the checklist.”

Anne Grete Valstad, Trondheim kommune

### **Must be a living document**

Valstad believes the checklist will be very useful in future construction projects. Her experience is that although there exist quite a lot of guiding material and other similar information, it is not easy to get an overview.

Therefore, she values the fact that the checklist refers to where to find more information and which guiding material can be used in each part of the building process.

– I recommend other municipalities to use the checklist. It is a good and useful tool when it comes to incorporating climate adaptation measures into construction projects, says Valstad.



**Jørgen Young**  
Business and Product  
Development  
Manager, Isola



**Snorre Bjørkum**  
Technical manager,  
Norgeshus



Lower building height and material usage, robust moisture protection, efficient building process and additionally financial gain; Snorre Bjørkum, technical manager at Norgeshus, sees many advantages with smart vapour barriers.

## Finding the Gore-Tex jacket for flat wooden roofs

NTNU and SINTEF, in cooperation with Isola, have conducted extensive calculations and laboratory tests on compact unventilated wooden roofs. This is a structure that have traditionally not been recommended because of problems with moisture though they are interesting because they are more economical to build.

The laboratory tests, on the other hand, have shown that the structure can function well if a so-called smart vapour barrier is used. Klima 2050 is now testing the mechanism in a pilot project in a residential building with a flat compact, unventilated wooden roof at Sveabakken in Malvik municipality, in collaboration with Norgeshus and Isola.

### **Smart because it reduces moisture**

Three out of four building damages are due to moisture, and the problem with leaking vapour barrier may be one of the causes.

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A vapour barrier is a plastic membrane that is placed in all exterior structures in the wall and in the roof to prevent air leaks and to stop moisture transfer. The function of a vapour barrier is primarily to prevent the house against moisture, fungus and rot. What is then the advantage of the so-called “smart vapour barrier”? Jørgen Young, who leads business and product development in Isola, which is the distributor of the product in Norway, compares it with a Gore-Tex jacket.

– A Gore-Tex jacket breathes and releases heat from the body while protecting the body from rain. The smart vapour barrier works a bit in the same way and is called “smart” because it can control the moisture in the construction since the membrane is flexible. If there is high moisture in the construction, it tends to open up, while closing when the humidity is low, says Young.



### **Norgeshus: Easier to build**

Snorre Bjørkum, Technical Manager at Norgeshus, is particularly concerned that the smart vapour barrier ensures good moisture protection between the wall and the roof. This has been an unresolved issue with traditional compact roofs on flat houses. This also reduces the height of the building because there is no need for ventilation in the support structure. And also, compact unventilated wooden roofs with smart vapour barrier, are easier to build. He lists several other benefits:

– We can use traditional mineral wool or blow-in insulation, and there is no need to buy roof insulation from external suppliers. It is a particular advantage that the roofs can be produced in a production hall and assembled on the construction site, it makes it much more efficient and is also genius for avoiding moisture.

” With more wind and rain, we must build more robust”

Snorre Bjørkum, Norgeshus

### **A new product that can create a revolution**

The product was first introduced to the Norwegian market in 2014. But as it becomes more known, and the results from the pilot project can be presented, the demand and interest is expected to increase.

– This is very exciting and new for the construction industry, it can help both to increase the profit and the efficiency, says Young.

– With more wind and rain, we must build more robust. Now, when there is a way to do this that actually is more cost-effective, it feels very useful to participate in such a pilot project, concludes Bjørkum.

# A new framework makes it easier to build for the climate of the future

When building and maintaining it should last for several decades, but what does it mean that a building is climate resilient enough? Klima 2050 is working on a framework for climate adaptation of buildings that will clarify this.

Many struggles with how climate adaptation should be done in practice. The framework that Klima 2050 is developing is an answer to this. Previous research from Klima 2050 shows that there is a need for measures and solutions.

Firstly, the definition, what is a climate adapted building? It is a building that is planned, designed and executed to withstand various types of external climate impact - from precipitation, snow, wind, solar radiation, temperature and flood water - throughout its intended lifetime.

## **No legislation for climate adaptation**

Today's building regulations does not refer to climate adap-

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Christine  
Molland Karlsen  
Head of department,  
Norwegian Building  
Authority



tation as a separate standard, but references is made to requirements several places within the legislation.

The legislation is function-based, and by being so, it is implicit that the constructions must be climate-adapted. But it is up to each constructor to show that the building is resilient enough to withstand climate change. The challenge then becomes; what exactly is resilient enough?

Christine Molland Karlsen, head of department in the Norwegian Building Authority (DiBK) believes the framework will help to clarify this, and to increase the knowledge in the industry.

– The framework will make it easier to follow the building act and regulations because it shows how it can be done in specific terms. It is a good tool for the developers. It can provide a better basis for planning and design so one chooses robust solutions suitable for the future climate.

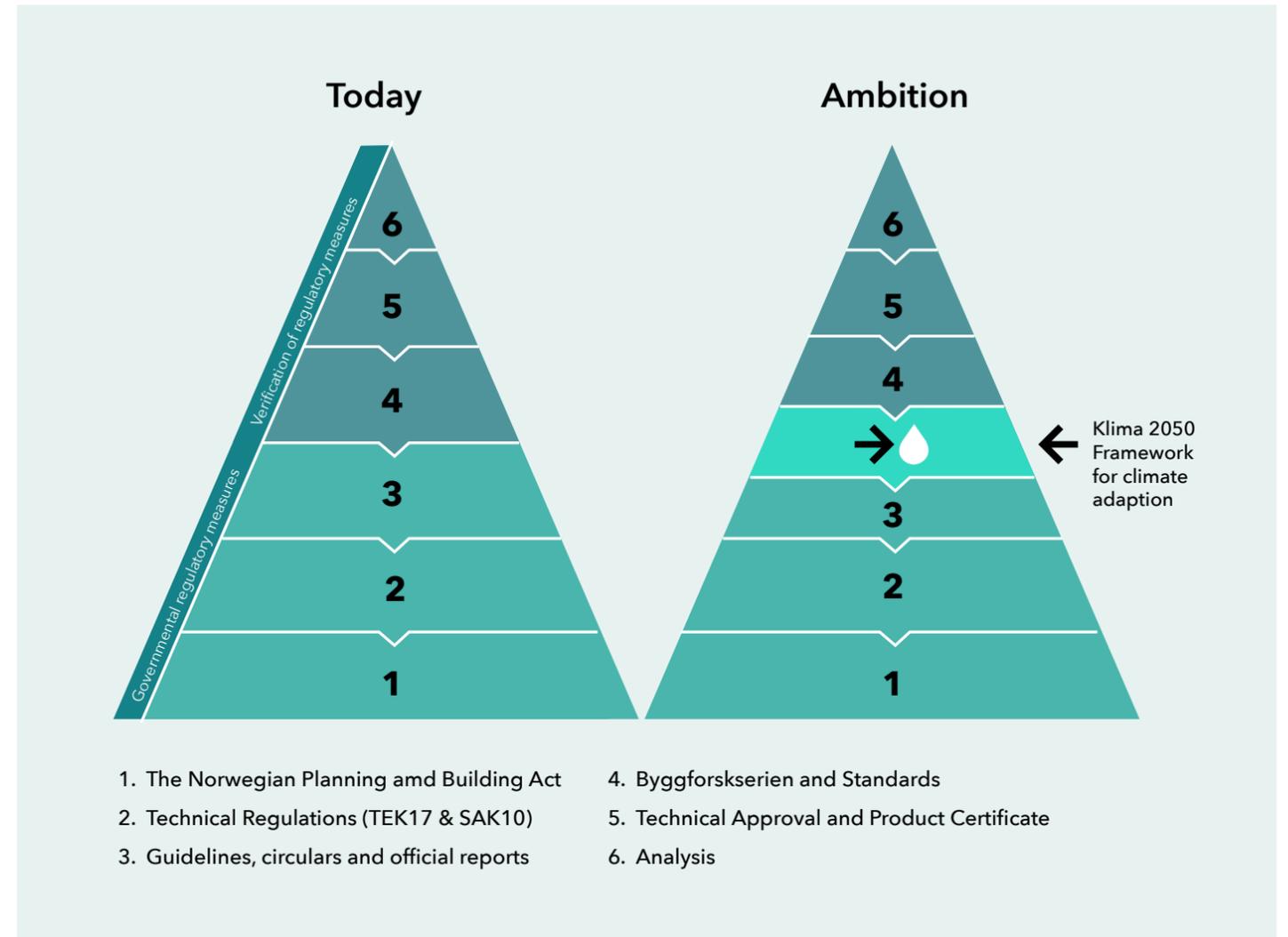
” The framework will make it easier to follow the building act and regulations because it shows how it can be done in specific terms. It is a good tool for the developers.”

Christine Molland Karlsen, Norwegian Building Authority

**Climate adaptation should be taken into consideration at an early stage**

The framework ensures that climate adaptation is taken into account during the planning stages of a new development, there are many opportunities at an early stage that will be closed later on. In addition, the framework will clarify what should be done when, during the different stages of a building process.

A critic to a lot of the guiding material, is that they are too general. The idea is that the framework should classify the information, the guiding material, the tools and the data that are already there, and indicate what is suitable to use in the different stages of the construction project.



**Must reach the target audience**

It is important to Molland Karlsen that the framework should be attractive and relevant so that it is used.

– Is this framework an answer to what the target group needs? It is important to have a good understanding of the needs of the users. Finally it is important that those who need to use it know about it, therefore it must be widely distributed.

The objective for Klima 2050 is that the framework will raise the standards of the entire industry and therefore contribute to reducing social risk associated with climate change. It will be finalised in 2019.

3

GLIMPSES FROM  
THE RESEARCH  
ACTIVITIES

## Extensive green roofs for reduction of stormwater runoff in cold and wet climates



PhD Candidate  
—  
Birgitte Gisvold  
Johannessen

**THE MAIN OBJECTIVE** of the work has been to study and quantify what role extensive green roofs can play as a part of stormwater management in cold and wet climates. The study is based on field observations (3-8 years of data) from several different configurations of extensive green roofs located in four Norwegian cities. The geographical spread enables an opportunity to study a variation of cold and wet climates with respect to temperatures, precipitation amounts and patterns.

**GREEN ROOFS WERE FOUND** to be efficient for small and medium precipitation events both with respect to reduction of stormwater volumes (retention), and for attenuation and delay of peak flows (detention). Green roofs can contribute in replicating predevelopment hydrology by promoting evapotranspiration and by prolonging the runoff times compared to a conventional roof. The performance shows large seasonal variations with best performance in the temperate season (May through October). Peak reduction and peak delay were found to decrease with increasing peak precipitation and increasing initial soil moisture, with limited efficiency for the highest intensity events. Retention performance was mainly found to be governed by the process of evapotranspiration, rather than the maximum water storage capacities. Rough estimates based on all observed configurations and locations in the temperate season were found to be approximately 45-55 mm retention per month and 5 mm retention per event. A green roof designed with a maximum water storage capacity of 10-15 mm was found to be sufficient for stormwater retention and detention performance in the studied climates, while 20-30 mm are recommended to promote plant welfare and reduce the risk of drought.

# Flood risk management in small catchments due climate and land use changes



PhD Candidate

Aynalem  
Tasachew

**FLOODS ARE ONE OF THE MAJOR** climate-related hazards and cause casualties and substantial damage on a global scale every year. Accurate and timely flood forecasting and design flood estimation for small catchments upstream of bridges and culverts are important to protect people and property. However, most of the small catchments are ungauged. The design flood, where the magnitude of the flood is associated with a return period, and hence a level of risk, is important in the planning, design and operation of hydraulic structures (e.g. bridges and culverts) and for protection.

**CURRENTLY THE MOST** used design flood estimation methods are based on stationarity assumption. However, there is a growing interest in continuous simulation method of flood estimation as an alternative to event-based and statistical frequency analysis methods. Climate and land use change could bring a change in the risk due to floods and stationarity assumption may be less valid when the flood potential at a location is changing along with the changing environment.

**THE PHD RESEARCH** work investigates and contributes an alternative method for design flood estimation for small (area < 50km<sup>2</sup>) ungauged rural catchments using continuous time rainfall-runoff modelling that could help in flood risk analysis and management. A more accurate design flood estimation method can be of use for the partners. The PhD work could be of use in revising the guidelines and policies related to flood risk management in small catchments in a changing environment.



Photo: Magne Kveseth, Aftenposten

## Risk assessment of blue-green and blue-grey roofs



PhD Candidate

Erlend  
Andenæs

**BLUE-GREEN ROOFS** are roofs wherein vegetation and water detaining substrates are used to store rainwater temporarily. The rainwater evaporates or drains away over time, drastically reducing the load on stormwater drains compared to a flat roof designed to drain water immediately. Blue-grey roofs are built for the same purpose, using a permeable pavement cover instead of vegetation, to allow foot traffic. Blue-green and blue-grey roofs have proven to be an effective measure for managing stormwater in urban areas. As stormwater fees are being implemented, with a greater focus on stormwater management, it is expected that blue-green and blue-grey roofs will become a more common element in buildings.

**HOWEVER, IN ORDER FOR LARGE-SCALE** implementation to be feasible, it is vitally important that the associated risks are understood. Blue-green and blue-grey roofs are usually built as compact roof constructions, which are known to pose challenges from a building technical perspective. In particular, roof membrane integrity and moisture management are essential for the roof to function throughout its lifetime. Additionally, the rainwater storage and drainage functions of the roof need to be maintained.

**THIS PHD PROJECT INVESTIGATES** the risks associated with blue-green and blue-grey roofs. This includes both negative risks associated with defects and their costs, as well as positive risks such as a higher building value and money saved on stormwater fees. A main goal is to develop a framework/methodology for risk assessment of roof-related issues for new builds and refurbishments.



Grandkvartalet i Larvik  
Illustration: Dark Arkitekter

# Towards an automated regional landslide mapping system using remote sensing images



PhD Candidate  
Erin Lindsay

**REGIONAL-SCALE LANDSLIDE** mapping is a crucial activity that contributes to estimate triggering thresholds to be used in early warning systems, emergency reliefs, hazard maps, and spatial planning. However, mapping hundreds or thousands of individual landslides is often a tedious and time-consuming preparatory step for those who require a quality landslide inventory in the other end. There is an increasing availability of free, relatively high-resolution satellite images, along with great developments in image classification techniques using statistical models and machine learning, and future prospects of drone-based land use monitoring.

**THE INNOVATION POTENTIAL** of the PhD for the partners lies in development of an accurate, user-friendly GIS-based tool for landslide mapping from remote sensing images. The tool may be based on a large global landslide database, which utilizes a machine-learning approach to image classification. This will supplement existing landslide identification efforts in Norway. It could also be used in other countries to develop a landslide catalogue, or early warning systems of their own, or to provide rapid landslide mapping following extreme triggering events, for the purposes of emergency response.



Rainfall-triggered landslides in Almåskroken, 13.08.2013  
Photo: Ole Jørgen Kjellmark taken from helicopter

## Innovative protection solutions for landslides

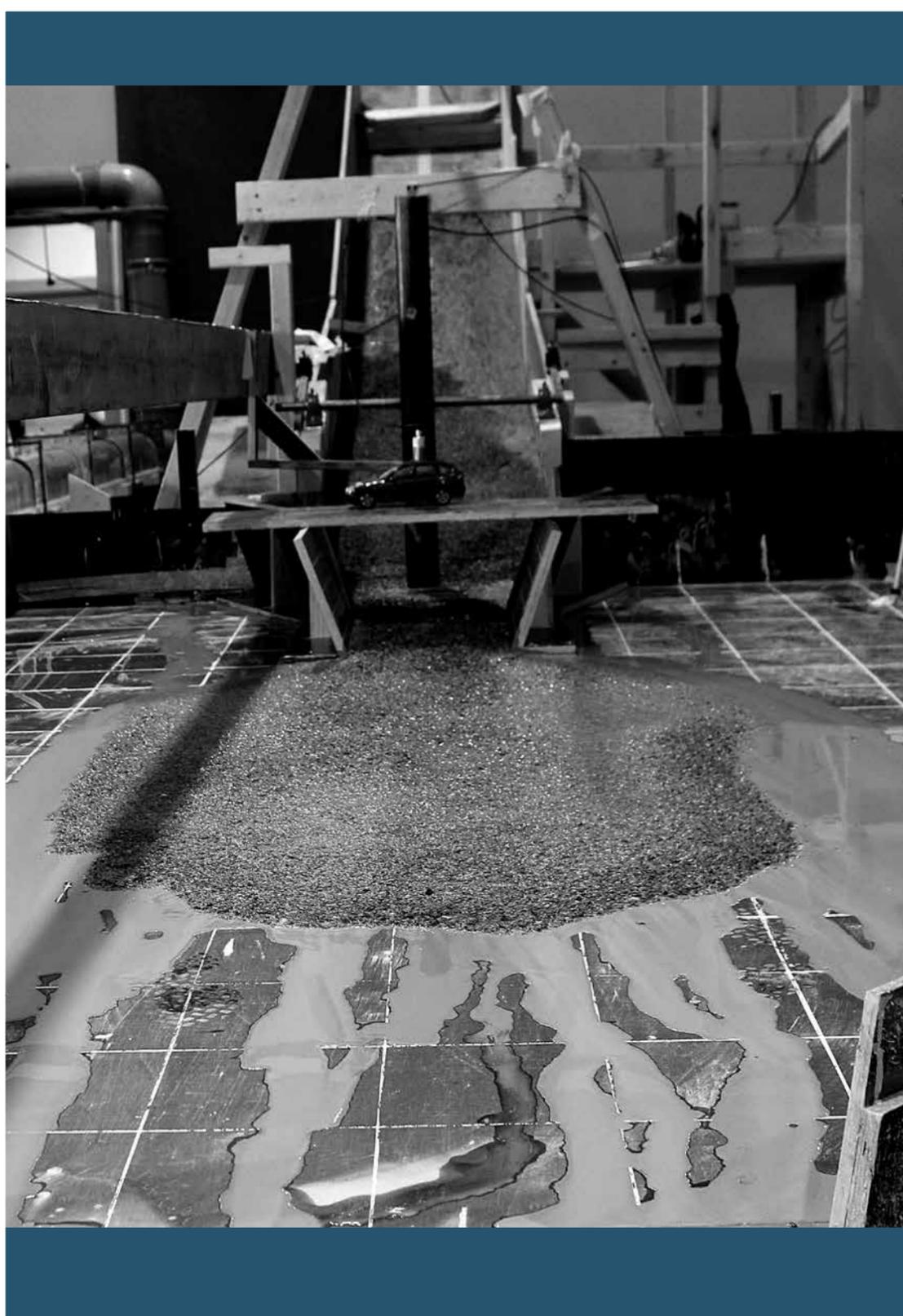


PhD Candidate  
Hervé Vicari

**IN A CHANGING CLIMATE**, infrastructure will be increasingly exposed to risk, and in particular, debris flows are a type of landslides involving the flow of sediment-water mixtures with a high destructive potential. Countermeasures need to be installed in order to reduce the risk. The aim of this PhD is to conceive and design innovative mitigation solutions to withstand extreme events.

**TO DEVELOP SOLUTIONS**, the dynamics of debris flows should be better understood. It is difficult to obtain useful field data, due to the randomness of the phenomenon and to the difficulty to place monitoring instruments. Physical modelling in laboratory scale is an alternative way to study debris flows. This also allows to check and control the boundary conditions and assess their influence. Furthermore, mitigation solutions, such as barriers and deflection structures can be placed to study their interaction with the flow and their effectiveness. Knowledge gained by performing small-scale experiments need to be applied at larger scales in the field to assess the scaling effects, which often introduce large uncertainties.

**INNOVATIVE COST-EFFECTIVE** protection solutions are of great importance for society and the outcome of the PhD-thesis can be useful for planners, designers and entrepreneurs. It can also be of use in revising guidelines and policies related to landslide risk management.



# Towards a new paradigm in urban water management



PhD Candidate

Manuel  
Franco-Torres

**THE URBAN WATER** managers' responsibilities have been clearly defined over the years: delivering enough and clean drinking water and conveyance of sewage and stormwater. That job was considered a purely hydraulic task and was conducted in a manner that was widely accepted. However, in recent decades, water authorities' tasks have been expanded. They must now have control over pollution, economics, risk, new technological developments, uncertain forecasts for climate change, an increasingly demanding legislative framework, secondary infrastructure functions, and, particularly, achieve cooperation among actors with confronted interests and worldviews. It is hard for today's managers to maneuver in such an environment of increasing complexity and they often choose to exclusively deal with the traditional needs and purely hydraulic solutions.

**RESEARCHERS HAVE SO FAR** proposed fragmented solutions to the increasing complexity and insecurity of water management. Manuel Franco Torres works in his PhD to concretize a new paradigm that gives a more comprehensive understanding of how the new reality of the urban water sector will be managed in the future. The work also includes an explanation of where the new paradigm comes from and what methods can be used to trigger the desired paradigm transition. This research is highly relevant for the partners of Klima 2050 as it provides insights on how new developments like climate change are used as an opportunity of positive change, enabling decision makers to create more resilient and livable cities.



Cheonggyecheon stream, Seoul.  
Photo: Francisco Anzola

## Landslides triggered by precipitation



PhD Candidate

Petter Fornes

**LANDSLIDES OF THE DEBRIS** flow type are a serious natural hazard. A debris flow is a mix of water and soil particles, forming a dense flow. This type of landslides is often triggered by extreme precipitation events, often in combination with snow melt and/or long wet periods.

**IN ENGINEERING PRACTICE**, the propagation of debris flows is usually simulated with depth-averaged models. However, for the design of measures resisting the forces from the flow, it can be necessary to use more advanced 3D numerical methods, simulating the impact forces in the flow better. The open-source Computational Fluid Dynamics (CFD) code REEF3D, used in this PhD project is a finite difference code, implemented on super-computers, which reduces the computational time.

**THE MAIN GOAL** of the PhD is to develop a numerical tool for improved design of mitigation measures. It involves implementing rheologies (physics) that describe the behavior of debris flows in a more realistic way than 'standard' run-out models. This will enable a more realistic estimate of run-out, as well as impact forces acting on an obstacle. The CFD code can be used to calibrate and back-calculate laboratory experiments, and to evaluate forces acting structures from debris flow impacts.

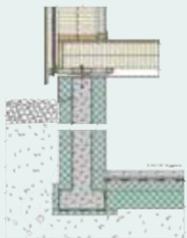
**IMPROVED AND MORE** efficient design of mitigation measures, which also may reduce cost, will be of use to public infrastructure owners, such as SVV, NVE and BaneNor, as well as to consultants designing the measures.

# Moisture performance of basement envelopes in cold climate



PhD Candidate

Silje Kathrin  
Asphaug



**IN EXTERIOR WALLS** and floors in basements and semi-basements (completely or partially below grade), moisture related damages are already a major challenge. Due to climate changes these challenges are likely to increase. In addition, the local municipalities are beginning to set restrictions to the handling of “stormwater run-off” in dense city areas to reduce the strain in local sewer systems. Water from roofs and down-pipes might then have to be handled by attenuation systems or infiltrated in to the ground/terrain adjacent to the building.

**BASIC PRINCIPLES**, solutions and recommendations for basement envelopes is given in SINTEF Building Research Design Guides (Byggeforskserien). However, lack of extensive research to substantiate the advices has led to disagreements among experts. Future climate challenges and need for more energy efficient solutions and environmentally friendly materials do underpin this uncertainty.

**THE PHD PROJECT** aims to provide an improved and thorough understanding of the moisture performance of basement envelopes for practical assessments, increased knowledge of the capability of modern simulation tools and better knowledge about important moisture related material properties. New knowledge, methods and tools can be used to substantiate and improve current recommendations and play an important role in future development of cost effective, energy efficient and moisture safe concepts for basement envelopes.



Foto: Silje Asphaug

## Blue-green solution in urban areas



PhD Candidate

Vladimír  
Hamouz

**STORMWATER MANAGEMENT** has experienced raised awareness due to an increased frequency of damaging rain-flood events across the world. The existing infrastructure is not typically fit to handle the combined effects of ever-increasing urbanization (including rapid increase of impervious surfaces) and climate change. Generally, rooftops remain unused, even though they cover a large part of the impervious surfaces. Rooftop retrofitting, using either vegetated (“blue-green”) or non-vegetated (“blue-grey”) solutions, has shown multiple benefits in terms of hydrology, biodiversity, and usage as living areas.

**THE ROOFTOP RETROFITTING** as a form offers a method to manage stormwater at the source while providing stormwater retention and runoff detention. Moreover, they contribute to the reduction of both sewer overflows and flood risks. The main drivers behind rooftop source control are detention and retention of runoff. Retention occurs through the combined process of evapotranspiration for vegetated solutions, and its annual runoff reduction has been extensively investigated. On the other hand, detention performance indicators are increasingly required by stormwater designers to alleviate urban flooding due to capacity exceedance in sewer systems.

**THIS PHD PROJECT AIMS** to find the blue-green/blue-grey configuration with optimal hydrological performance for stormwater retention and runoff detention. This includes investigation of stormwater modelling software which will in combination with observed data offer a tool to simulate expected hydrological performance under various current and future climate conditions. The main goal is to model the blue-green/blue-grey solutions in urban areas while finding the optimal location for their implementation.



# Climate implication and adaptation measures for buildings



PhD Candidate

Anna Eknes  
Stagrum

**NORWAY'S WEATHER** is extremely varied, the rugged topography being one of the main reasons for large local differences over short distances. The seasonal variations are also extreme. Scenarios for climate change indicate that Norway has to prepare for even more rain, more intense precipitation over parts of Norway, and an overall increase in temperatures over the next decades. Unfortunately, the building stock is particularly vulnerable even to the climate exposure of today. Hence, we are entering an era with a need for a much stronger focus on building physics, moisture-resilience and risk reduction measures related to potential moisture damage and increased occurrence of extreme weather.

**THE BUILDING STANDARDS** and design guidelines presuppose use of historic weather data, and may be an obstacle for efficient adaptation to a changing climate. It is an urgent need for increased knowledge about the climate influence on the building stock as well as for critical building components and materials.

**THE MAIN OBJECTIVE** of this PhD project is to analyse the potential consequences of climate change for Norwegian buildings. The result is needed in developing of effective geographical dependent adaptation measures, which is asked for by the Consortium partners, the Norsk klimaservicesenter and Byggforskserien.

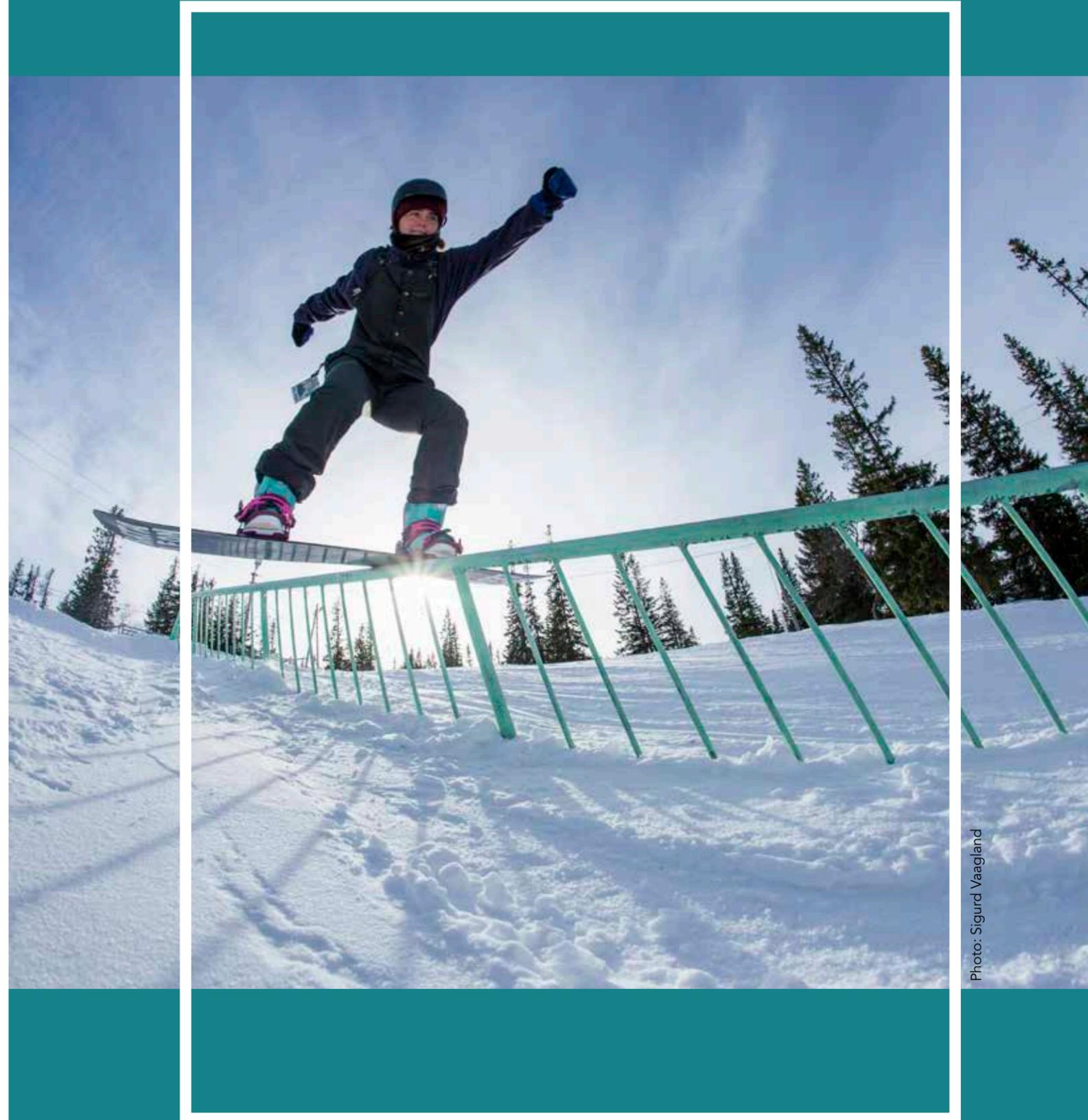


Photo: Sigurd Vaagland

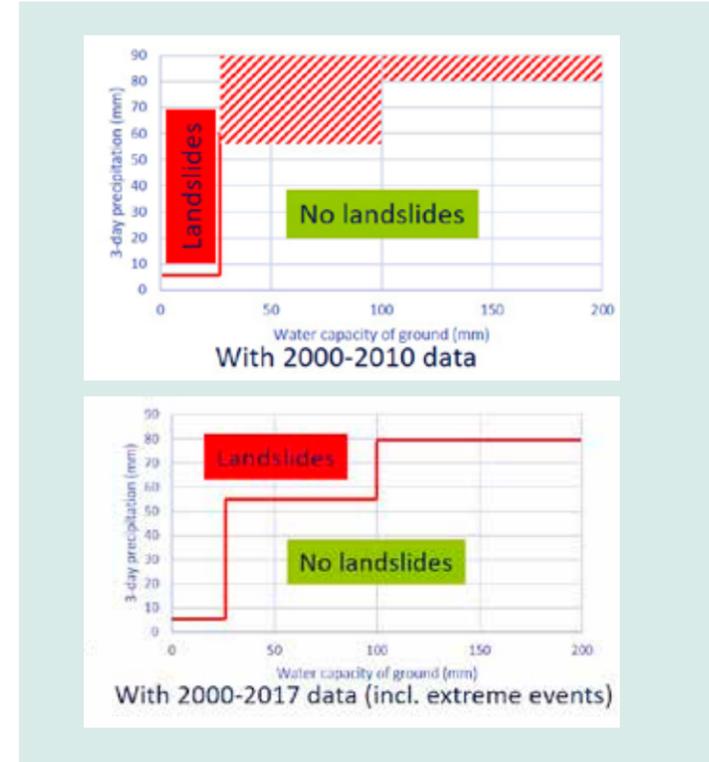


## Høvringen

The roofs of Høvringen was rebuilt in 2018 to explore new modified blue-grey and blue-green solutions, but before we did so, the roofs were subjected to heavy simulated precipitation. We have built a mobile equipment that can be mounted on the roof and simulate heavy rain.

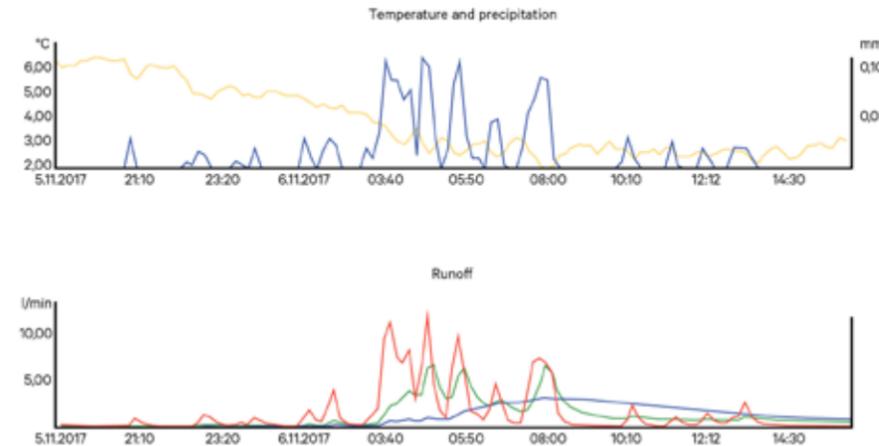
**20%**

Today it rains 20% more in Norway than 100 years ago.



## Treshold values

A study aimed at developing thresholds for early warning of debris flows on a local scale, investigated the effect of extreme events on estimated threshold values. Part of the study was based on data from Gudbrandsdalen, Norway, which experienced major events in the spring of 2011 and 2013. Estimated threshold for landslide initiation (red line), without (top) and with (bottom) these events included in the data. Reference: Falck, M., 2018: MSc. thesis, University of Oslo.



Precipitation events 06.11.2017 compared to runoff for the three test roofs at Høvringen; black roof (red line), green roof (green line) and blue-grey roof (blue line). Displacement of the runoff curves shows the ability of the structure to retain rainwater.

Illustration from: [www.klima2050.no/hovringen-data](http://www.klima2050.no/hovringen-data)

The annual mean temperature in Norway has increased with 1°C from 1900-2014

## UROP

The Centre has been active in the establishing of UROP (Undergraduate Research Opportunity Program) in civil and environmental engineering at NTNU. The purpose of UROP is to introduce students to research early and to stimulate the students to learn by themselves by practising. The involvement of students in UROP and as research assistants strengthen the Centres recruitment of excellent master students and employees after education.



Undergraduate student Hilde Norang (left), Jonas Røhne (back in the middle) and Heidi Storkås (right) measuring infiltration properties at NTNU Campus. The data is crucial input to a new GIS-tool for performance analyses of Sustainable Urban Drainage Systems, developed by i.a. Dennis Kliewer (back left) and Edvard Sivertsen (back right).

4

KEY FIGURES



# COMMUNICATION AND VISIBILITY

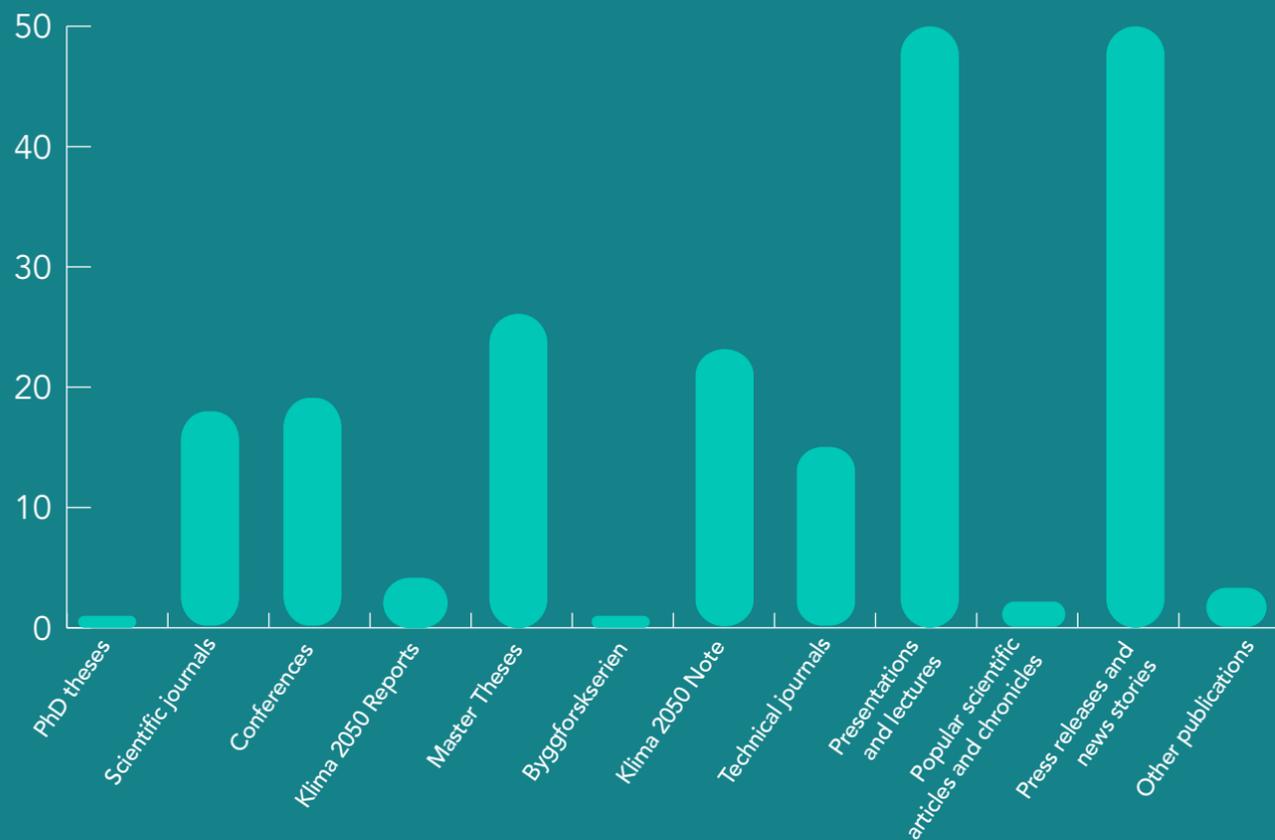
Events throughout the year have shown the relevance of Klima 2050, and the general interest from media has been high.



# Communication and visibility

The policy of the Centre is to publish at least one user-oriented/ public-oriented publication for each scientific publication focusing on the practical benefit of the scientific work. The counting by the end of 2018 shows following distribution of publications.

All publications are listed on [www.klima2050.no](http://www.klima2050.no)

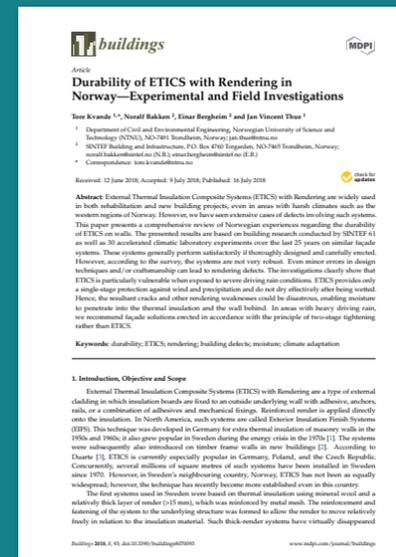


# Publications

Some examples from publications in 2018



Scientific journal



Scientific journal



Scientific journal



Technical journal



Klima 2050 Report



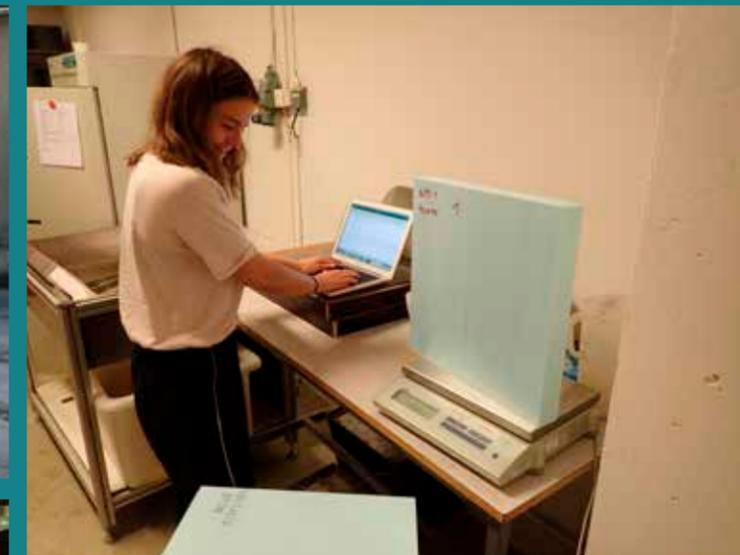
Technical journal

# Thematic meetings

- Gatherings organized including all or part of the consortium with the purpose of contributing to the dissemination of knowledge, experience exchange, research exchange and innovation.
- A meeting point for the partnership.

The gatherings, collecting between 15 and 50 people are important in view of knowledge exchange, the researchers receive direct input to the research work and areas of closer collaboration are pointed out.

- *Ombygging til blågrå og blågrønne tak*  
Klima 2050 HUB, Trondheim, 22. January
- *Uttesting av Ovase.no*, e-samling, 12. February
- *Decision support solutions for implementation and management of nature-based solutions (NBS) in urban environment*, Trondheim kommune, Thon Hotel Prinsen, Trondheim, 27. February
- *Private bedrifter og statlige organisasjoners samfunnsansvar for klimatilpasning*, Multiconsult, Oslo, 5. April
- *Ekstremnedbør*, Metrological Institute, Oslo, 20. September.
- *Beslutningsprosesser om overvann i urbane strøk*, BI, Oslo, 24. September
- *Innovative sikringstiltak mot vannutløste skred*, NGI, Oslo, 6. November
- *Stormwater modelling tools*, SINTEF/NTNU, Trondheim, 12. December



Snapshots from Thematic Meetings and partner interactions

# RECRUITMENT

## Klima 2050's PhD candidates financed by the Centre in 2018:

Lars Gullbrekken, NTNU – awarded PhD 3. May

Silje Asphaug, NTNU

Erlend Andenæs, NTNU

Erin Lindsay, NTNU

Petter Fornes, NTNU

Vladimir Hamouz, NTNU

Aynalem Tasachew, NTNU

Bridget O'Brien Thodesen, NTNU

Hervé Vicari, NTNU

Anna Eknes Stagrum, NTNU

## Associated PhD Candidates in 2018:

Manuel Franco Torres, NTNU/Multiconsult

Birgitte Gisvold Johannessen, NTNU/Trondheim kommune

Kaj Petterson, Chalmers University of Technology

Atle Engebø, NTNU

## Post.docs 2018:

Åshild Lappegard Hauge, SINTEF

Jardar Lohne, NTNU

Anne Kokkonen, BI

56 master students have completed their master thesis since the launch of the Center. Our goal was 50 thesis throughout the Centre period. We achieved the goal before half-time!



## Collaboration at Sveabakken

Ellinor Bratt Sletfjerdings (M.Sc Student),  
Inger Merete Birkeland (M.Sc Student) and  
Lars Gullbrekken (PhD, SINTEF)

# ANNUAL ACCOUNT

## 2018

### FUNDING

The Research Council	12 300
SINTEF (host institution)	579
Research partners	3 779
Private partners	10 985
Public partners	4 914

**Sum 32 557**

### COSTS

SINTEF (host institution)	8 108
Research partners	14 694
Private partners	9 485
Public partners	270

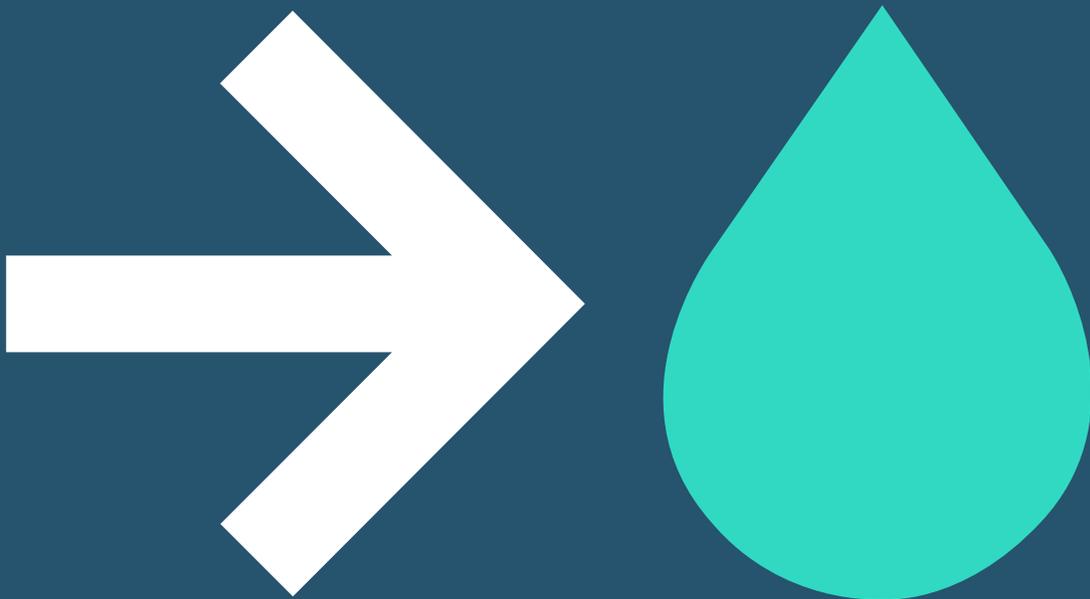
**Sum 32 557**

All figures in 1000 NOK



- **9 pilot projects running**
- **9 private enterprises**
- **6 public institutions**
- **5 research institutions**

For more information about Klima 2050  
go to our webpage:  
[www.klima2050.no](http://www.klima2050.no)



Klima 2050 Report no 14  
Annual Report 2018  
Berit Time (editor)  
Keywords: Klimatilpasning, bygninger, overvann,  
skred, beslutningsprosesser  
ISBN: 978-82-536-1612-4

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