
ANNUAL
REPORT
2019
KLIMA2050

Vega Scene. Photo Åse Holte

Content

ORGANIZATION

Photo: Skanska

A successful mid-way evaluation

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:

An exciting meeting and inspiring evaluation report

Tuesday 2 April 2019 was an exciting day for the Centre. The mid-way evaluation team met with the Board Chair, the Centre management team, partner representatives, postdoctoral and PhD Candidates, and representatives of SINTEF, the host. The Centre management team had completed a thorough self-assessment, and all partners had made their own evaluations of the Centre's innovation achievement, its strengths and weaknesses, and lessons learned. The management team had also provided the evaluators with a complete list of deliverables and publications.

Innovation achievement

The evaluation team found that the website and Annual Reports were excellent in themselves. However, during the meeting it became clear to the evaluators that the full magnitude of the work carried out by, and achievements of, the Centre was significantly greater than that reported and demonstrated in external media. The evaluators thus

Photo: Erik Burås / Studio B13

encouraged us to improve our profiling of the totality of our research and innovation achievement. This can be accomplished by better dissemination in the public domain and international academic arenas, and by future research projects with new and existing partners.

Long-term investment in knowledge building

Assessments of the Centre by user partners demonstrated that the majority of these partners appreciate the research aspects of the Centre, highlighting its long-term investment in knowledge building. The Centre's private sector user partners include companies that have either restructured themselves or have invested heavily in research as a consequence of opportunities offered by their collaboration with the Centre.

Internationalisation

The evaluation team stated that the research profile of the Centre has attained a high level internationally, and that some aspects can be described as excellent. It also emphasised that the Centre's research partners had succeeded in obtaining funding for five international spin-off projects. The level and quality of international activity is declared to be satisfactory, but there is scope for expansion, which could be important for the sustainability of the Centre, especially after termination of the SFI funding period.

Education and researcher training

The Centre's approach to researcher training of its PhD Candidates is cited as an example of good practice. However, there is scope for improvement in terms of collaboration between PhD Candidates and user partners, and in reaping the mutual benefits that such collaboration creates. The Centre has successfully involved more than 70 M.Sc. students in its research activities, which have proved to be very popular among the students themselves.

Closing recommendations

In terms of the most recent period of Centre activity, the evaluation team has

"The Centre leadership is excellent and the Centre is conducting internationally competitive research in response to user needs and has unique opportunities to be world leading by improving the scientific collaboration across research in the work packages".

The overall assessment from the Research Council of Norway evaluators

recommended that the Centre boost its multidisciplinary research approach across the work packages, and raise its ambitions with regard to both research and innovation. We were encouraged to have identified a range of means of maintaining the Centre's activities aimed both at promoting end-user innovation as well as involvement in the global academic community in the long term.

We are grateful for the advice provided by the mid-way evaluation team, which has enabled us to prepare for our improvement work. We are confident that the report demonstrates that we are progressing.

Grethe Bergly, Multiconsult
Chair of the board

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.

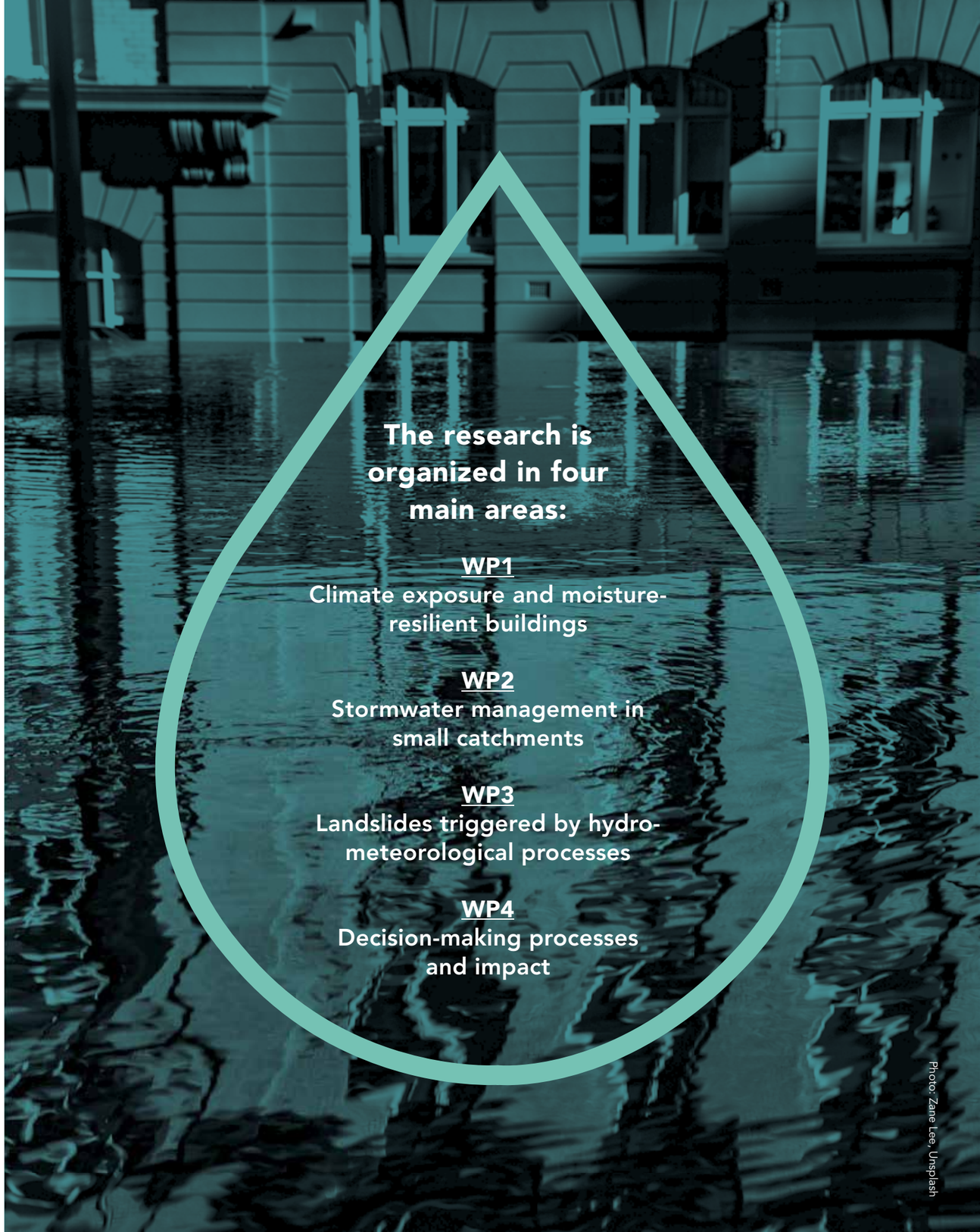


Photo: Zane Lee, Unsplash

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 2019: *Finans Norge, Isola AS, Multiconsult AS, Mestergruppen Arkitekter AS, 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 municiplity 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

SKANSKA
MESTERGRUPPEN ARKITEKTER
Multiconsult
Finans Norge
SKJÆVELAND GRUPPEN
NORGESHUS
Leca
isola
powel

Public sector

Statens vegvesen
NVE Noregs vassdrags- og energidirektorat
AVINOR
Jernbane-direktoratet
STATSBYGG
TRONDHEIM KOMMUNE

Research & education

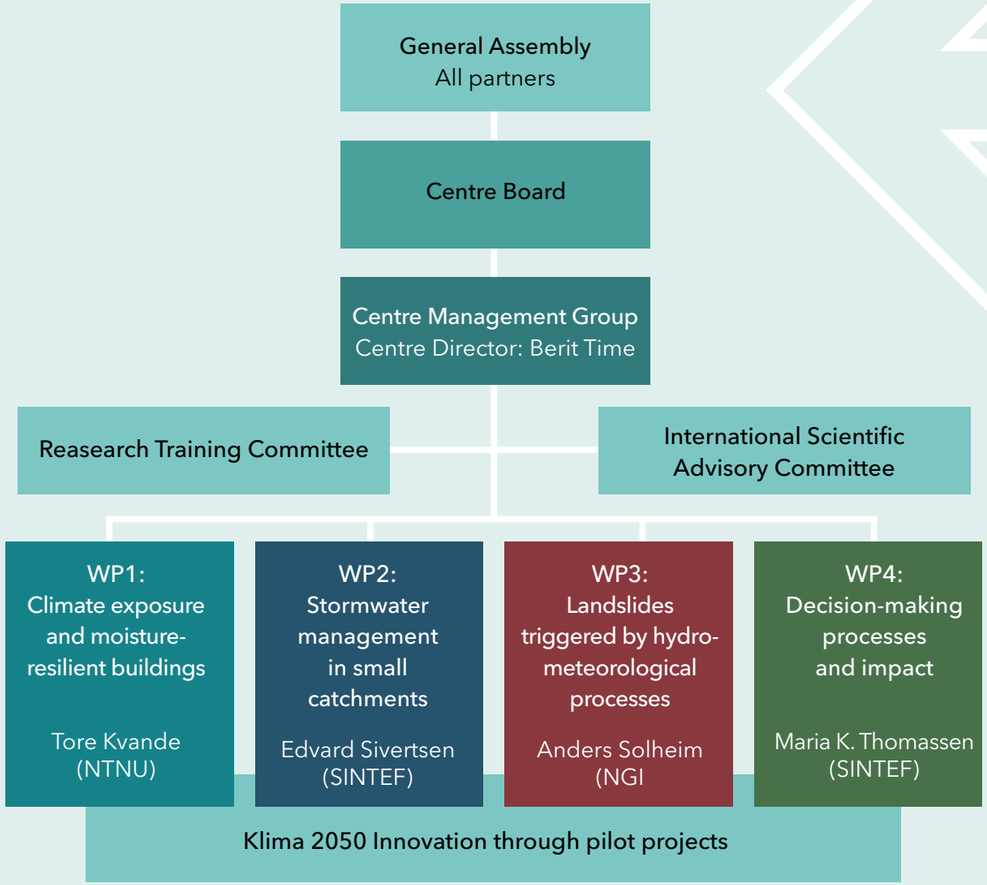
SINTEF
BI
NTNU
Meteorologisk institutt
NGI

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 SINTEF (WP2)*
Anders Solheim *senior geologist at NGI (WP3)*
Åshild L. Hauge, *senior research scientist SINTEF (WP4) until June*
Maria K. Thomassen, *research manager SINTEF (WP4) from July*
Lena Bygballe, *associate professor at BI Norwegian Business School (WP4)*
Jorunn Auth, *administrative coordinator at SINTEF (adm)*

Centre Board
Grethe Bergly, *Multiconsult (Chairwoman)*
Christoffer Serck-Hanssen, *Jernbanedirektoratet*
Anders Fylling, *Statsbygg*
Einar Aassved Hansen, *Trondheim kommune*
Rune Egeland, *Skjæveland Gruppen*
Rune Stene *(until October)*, Kristin Holte *(from November) Skanska Norge*
Lars Andresen, *NGI*
Carl Thodesen, *(until July)*, Vikas Takur *(from August)*, *NTNU*
Hanne Rønneberg, *SINTEF*
Svein Erik Moen, *The Research Council of Norway (observer)*

Chairman of General Assembly: Jørgen Young, *Isola*



sfi Centre for Research-based Innovation
The Research Council of Norway

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* (2017).

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 aiming for all PhD candidates interact with user partners and stay at least one week at one of the partners location.

In the 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.

This year the PhDs met with four international invited experts within the fields of the Centre to a *First international seminar and publication preparation* in Trondheim, Norway, which took place November 26-27th. We were pleased that all invited guests immediately confirmed the invitation and contributed to two thought-provoking days in Trondheim.

"The SFI status attracts international networks and institutions and the results must be embedded also in international activities in order to benefit from other knowledge outside the consortium. This is also a benefit for our partners from private and public sector."

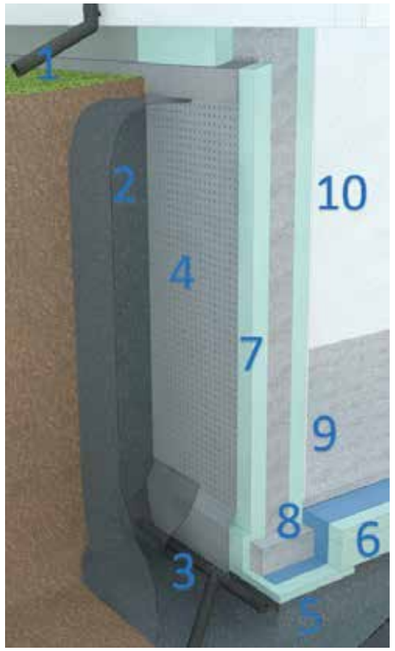
Hanne Rønneberg, Board member, SINTEF

INTERNATIONAL COLLABORATION

Photo: Forum Wood Building Baltic, TalTech

Moisture control strategies for habitable basements in cold climates

Basements are utilised as dwellings in many cold-climate countries. This raises major issues in terms of moisture safety design. Greater volumes of stormwater and increased annual temperatures and precipitation due to climate change are expected to increase the risk of moisture-related damage in basements. We have, together with international experts, examined the primary moisture control strategies for habitable basements in western cold-climate countries. Using Norwegian design guides as a baseline, we have identified ten key challenges and compared them with recommendations produced in four other cold-climate countries. The results show that these recommendations differ from the Norwegian design guides in a number of key aspects. The main differences relate to the exterior damp proofing of walls, the use and location of dimpled membranes and vapour barriers, and the use of permeable thermal insulation. Comparison shows that other countries place varying emphasis on the “Norwegian ten” key challenges, so that although the recommendations display many similarities, the relative weight given to some factors distinguishes the moisture control strategies adopted by the five countries.



Ten key challenges related to habitable basements as discussed by Asphaug, Kvande, Time, Peuhkuric, Kalamees, Johanssone, Berardi and Lohne (2020): Moisture control strategies of habitable basements in cold climates. *Building and Environment*, Vol 169 106572

Klima 2050 researchers win Emerald Literati Award

SINTEF's Cecilie Flyen seen here receiving the award when Ian Schroeder of the Emerald Group visited Oslo in October 2019

The article "Municipal collaborative planning boosting climate resilience in the built environment"* was awarded the Emerald Literi Award for the Outstanding Paper of 2019. The study identifies the drivers behind increased efforts among Norwegian municipalities during the past decade to achieve better climate-adaptive planning and building practice by incorporating climate-adaptive changes in legal planning and building frameworks into municipal practices and policy instruments. Risk mitigation and climate resilience continue to receive inadequate focus in many Norwegian municipalities. A gap exists between political and administrative levels in terms of communicating needs and expectations linked to the implementation of adaptive measures. Moreover, organisations responsible for building process demand policy instruments that support climate change adaptation. Extreme weather events appear to be the major driver behind the incorporation of climate change factors into municipal policy instruments. Networks are also important arenas for boosting learning in the field of climate change adaptation.

*Flyen, C., Hauge, Å. L., Almås, A. J., & Godbolt, Å. L. (2018). Municipal collaborative planning boosting climate resilience in the built environment. *International Journal of Disaster Resilience in the Built Environment,* 9(1), 58-69.

International expert involvement in the LaRiMiT web tool

Photo: Odd Arne Jensen, NVE

The web tool "Landslide Risk Mitigation Tool" (LaRiMiT, www.larimit.com) is designed to assist decision-makers in the selection of appropriate landslide mitigation measures, and can be specifically tailored to local needs. LaRiMiT was officially released in autumn 2018 and will be continuously updated throughout the lifetime of the Klima 2050 Centre. During autumn 2019, a process was initiated to invite international landslide experts to assign scores to the various mitigation measures (parameters) described and included in the tool. Currently, these evaluations are based on only limited input from a small number of experts. Improvement of the value and reliability of the data requires a greater number of expert evaluations. The involvement of Norwegian and international experts is being conducted via a straightforward and fast-response questionnaire that has been sent to more than 100 scientists. The responses have been compiled, interpreted, and subsequently implemented in the web tool. We believe that this will greatly increase the value of the tool and offer even greater benefits to decision-makers at all levels.

Photo: Tone Muthanna

Tone Muthanna
NTNU

Travelogue from INSA

From August 2018 to July 2019, Tone Muthanna at NTNU spent a year at INSA (*Institut national des sciences appliquèes*) in Lyon, France, as a visiting professor affiliated to the DEEP research group. The group carries out interdisciplinary research into water and environmental engineering, and waste management. The group maintains a very high academic level and is headed by Prof. Jean-Luc Bertrand-Krajewski, with whom the Klima 2050 Centre has developed an extensive collaboration ever since Vincent Pons started his Ph.D. work at the Centre in 2019. At INSA, Muthanna worked on setting up an experimental study looking into the modelling of green roofs. Lyon is situated on the banks of the Rhône, close to the French Alps. Runoff detention and water storage below the substrate during dry periods constitute key design criteria for green roofs. Educationally, it was an inspirational year, with many great experiences and memories to take home to Trondheim. Lyon is a fantastic city offering lots of pleasant green infrastructure and blue-green stormwater solutions.

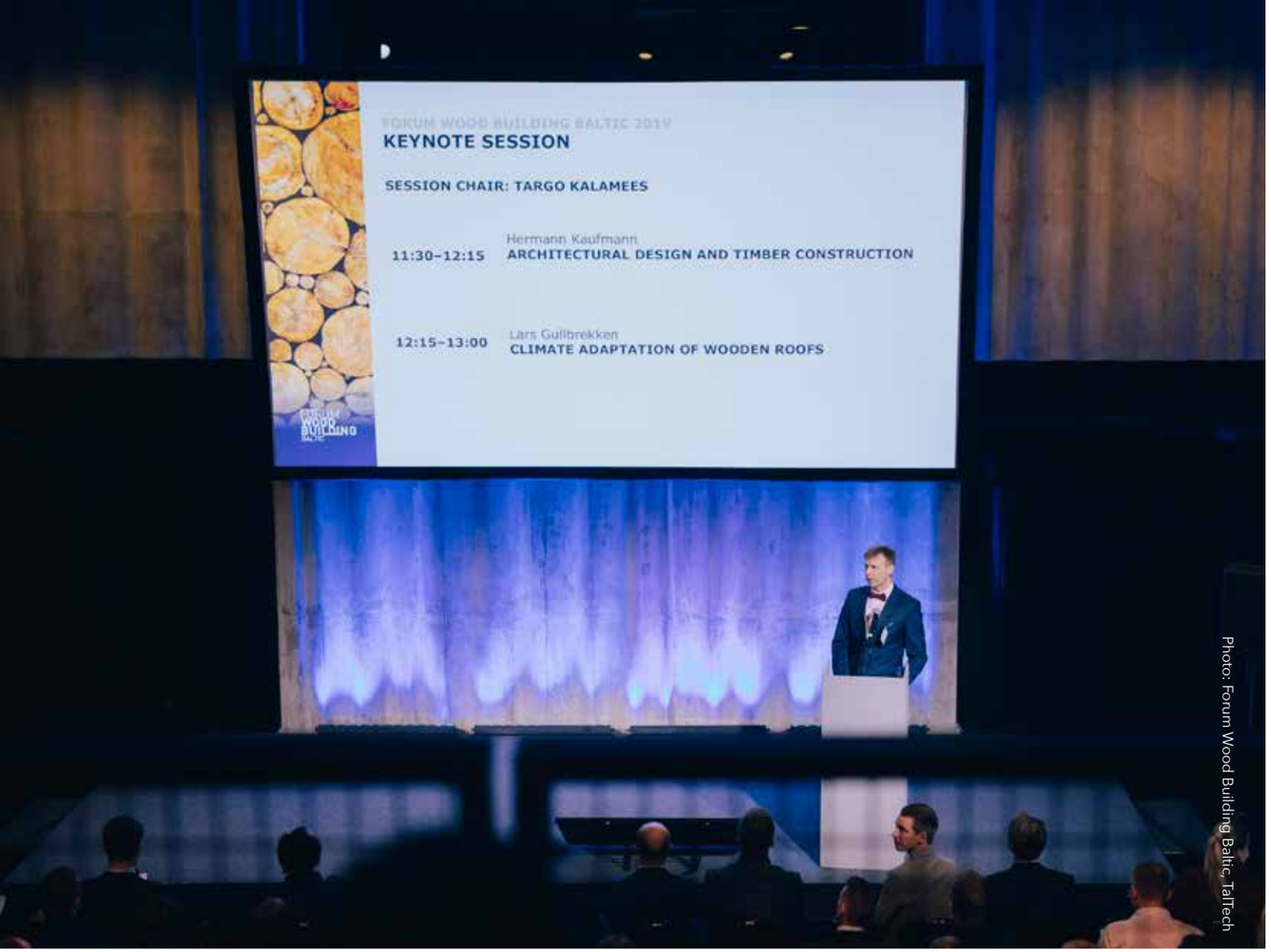


Photo: Forum Wood Building Baltic, TalTech

Forum Wood Building Baltic

Wooden building elements from the Baltic countries are imported to Norway, and are widely used by the building industry. Senior Researcher Lars Gullbrekken was invited as a key note speaker at Forum Wood Building Baltic which was held in Tallinn in Estonia 27 February - 1 March gathering more than 300 participants from all over the world. The topic of the lecture was *Climate adaptation of wooden roofs.*

Photoes: Forum Wood Building Baltic, TalTech

2

INNOVATIONS

Photo: Unsplash

Climate change adaptation network takes the lead

The organisation “Network Climate Adaptation Trøndelag” was established in 2017 and is unique because it has succeeded in involving all of the county’s municipalities in its work to address climate change adaptation. This is of key importance, not least for the smaller municipalities with little resources.

“Network Climate Adaptation Trøndelag” was launched by the County Governor of Trøndelag, Trøndelag County and Trondheim Municipality, and is incorporated as a pilot project within the Klima 2050 Centre.

“The network is innovative because it adopts an entirely new approach to working with multidisciplinary topics. Public administration is beset by many silo processes, but this project enables us to collaborate on climate change adaptation issues at national, regional and municipal levels”, says Ellen-Birgitte Strømø, who coordinates climate change adaption work at Trondheim municipality and is a member of the network’s management team.

She believes that this approach to organisation is not only essential when addressing an all-encompassing issue such as climate change, but also inspiring and fun.

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Ellen Birgitte Strømø
Trondheim Municipality

Meeting the municipalities in their communities

Strømø gives many lectures on climate change adaptation and meets many people who are very interested in how the network works. She points out that Klima 2050 has published reports that recommend how to succeed in establishing networks based on the Trøndelag model.

– *What would you to highlight as particularly important when launching regional networks?*

"It's incredibly important to get a local authority representative on the management team because the national and regional systems doesn't always know where the problems lie. It's also important to visit the municipalities and meet local communities", says Strømø.

Regional seminars on sea level rise

Strømø briefly summarises the network's achievements to date. Firstly, it visited all the municipalities in Trøndelag county in groups of between three and six in order to gain an impression of their knowledge requirements and the way they were approaching the issue. Moreover, all the municipalities organised workshops on topics such as vulnerability mapping and how to address climate change adaptation in-house.

"The coastal municipalities were interested in knowing more about sea level rise and storm surge, and we arranged regional seminars on this topic", says Strømø. "This was an eye-opener for many. Holiday cabins along the seashore may look like a great idea, but will be a waste of time if sea level rise is not included in the planning phase", she says.

In the periods between workshops and seminars, the municipalities are given what Strømø calls "homework". In autumn 2019, they were tasked with creating risk and vulnerability assessments. This will be followed up in 2020 with action plans and strategies.

Reducing societal risk

– *How does the climate change network help reduce societal risk?*

"Local authorities will plan accordingly when they receive knowledge about adaptation", says Strømø. "This applies to residential, leisure area and infrastructure planning. Knowledge enables them to take steps to reduce potential damage to existing infrastructure and avoid painting themselves into corners", she says.

Strømø adds that because local authorities can be held liable for damages, it is important that they understand their roles and responsibilities in relation to climate change adaptation. They require knowledge and tools to better equip themselves to assess vulnerability and implement risk mitigation measures.

"It's incredibly important to get a local authority representative in the management team because the national and regional systems doesn't always know where the problems lie. It's also important to visit the municipalities and meet local communities."

Ellen-Birgitte Strømø, Trondheim Municipality

New tool for documentation of nature-based solutions

Nature-based solutions, such as rain gardens and green roofs, are becoming more and more popular for stormwater management. A report published by the Klima 2050 Centre describes a new tool that makes planning, documentation and maintenance easier.

Climate change is leading to higher rainfall and more frequent extreme rainfall events, exerting particular pressures on urban infrastructure. One of the answers to this problem is to use nature-based solutions (NBS), such as rain gardens, green roofs and permeable covers.

SINTEF researcher Gema Raspati points out that one of our current challenges is that the profusion of NBS suppliers employ different terminologies to explain how their solutions work.

“Our overall goal is to establish a common framework with a fixed structure and fixed concepts that everyone can recognise. This will facilitate the flow of information between the supplier and the user and reduce the risk of misuse”, says Raspati.

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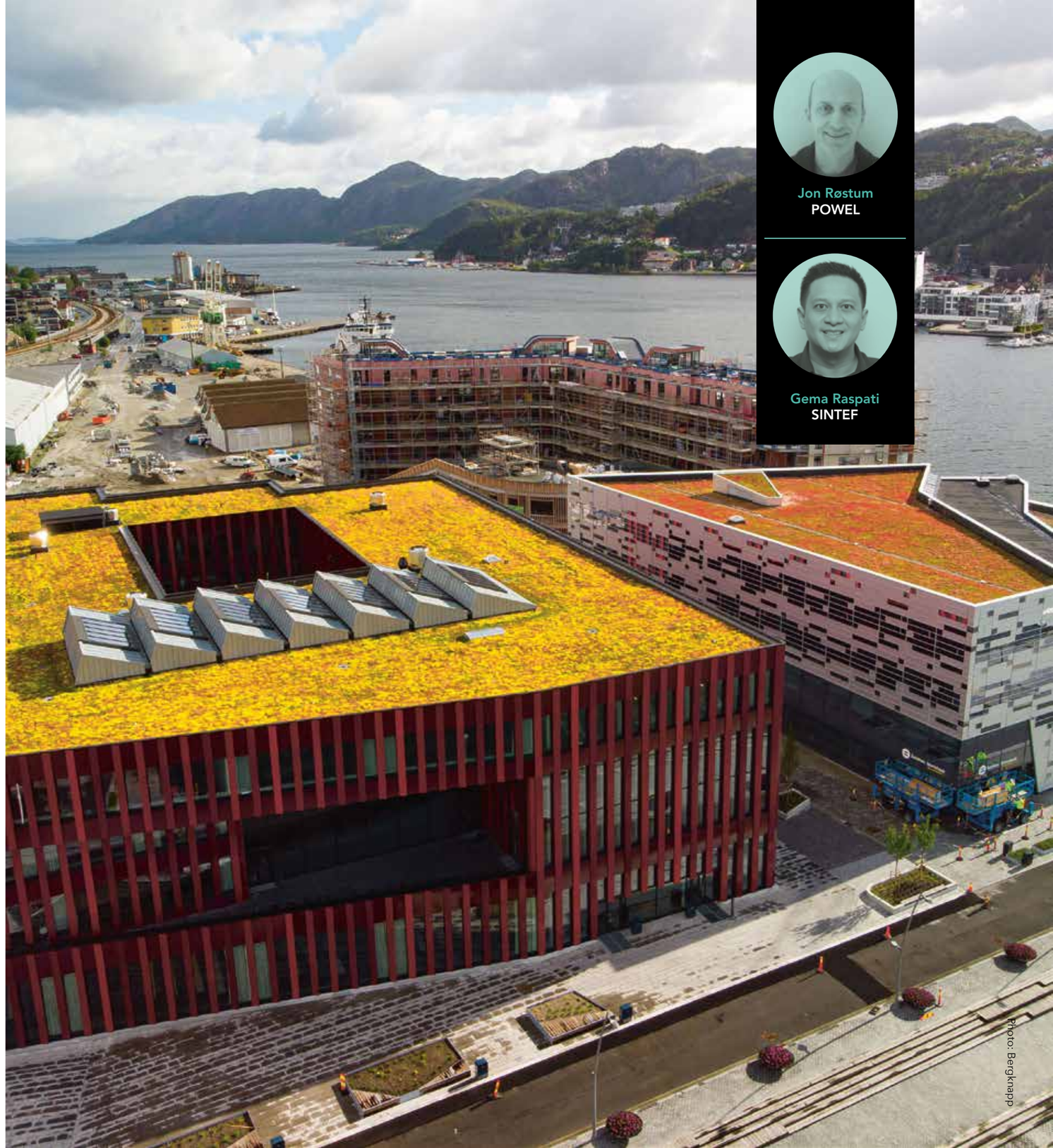

Jon Røstum
POWEL

Gema Raspati
SINTEF

Photo: Bergknapp

ANNUAL REPORT 2019

From suppliers to builders

The report 'Documentation tool of nature-based solutions – a guideline' describes a user-targeted NBS documentation tool with instructions for use.

The tool functions as a data structure that enables the user to keep track of essential and useful information about nature-based solutions. Everyone from suppliers to builders will now be able to collect information on the documentation, operation and maintenance of NBS.

For instance, NBS buyers or owners can use it as a checklist of requirements during planning, operation and maintenance, while the public authorities will be able to use it to assess the effects of NBS implementation.

"The tool will provide structured answers to many problems, such as why keeping drains open is an important part of green roof maintenance", says Raspati.

The importance of documentation

Photo: Vega Scene, ÅseHolle

Chief Strategist Jon Røstum at the software company Powel, which supplies IT systems in the fields of water supply and sewerage infrastructure, cannot emphasize enough the importance of documentation for nature-based solutions.

"Because of the relatively recent emergence of nature-based solutions, the lack of documentation has yet to be experienced as a problem", he says. "However, it is incredibly important to have documentation and registration systems in place before extensive planning and construction work is implemented", says Røstum.

Clients installing and hoping to enjoy a variety of rain gardens and blue-green roofs during the coming 20 to 30 years need to know how to operate and maintain their systems in accordance with suppliers' recommendations. They also need to have precise design and construction drawings, not least for resale purposes. All this information can easily be stored and updated within the data structure.

Important for local authorities

Powel has already developed systems for use by local authorities, enabling them to document the function and maintenance requirements of their water and sewerage systems.

"There is currently a need to develop similar systems for nature-based solutions whose function is to absorb and retain water, and we plan to develop a solution based on the structure described in the report' says Røstum.

Photo: Informasjonshuset AS ved Inger Anita Mørkesdal

Geir Vatne
Bane NOR

Christoffer Serck-Hanssen
The Railway Directorate

Photo: Istock

Protecting railways with a new landslide warning system

The current Norwegian landslide early warning system is regionally-focused and cannot detect local landslide risk. A pilot study being conducted in Bodø and Eidsvoll is testing an entirely new and cost-effective warning system for local landslides.

In Norway, rainfall is 20 percent greater than it was a century ago and climate change research is predicting that the future will be even wetter. Consequently, the danger of landslides is on the increase.

The Norwegian state rail infrastructure company Bane NOR is responsible for maintaining more than 4,000 kilometres of track across the country, and the protection of its assets is becoming a challenging and expensive job.

Need for a local early warning system

“We have to try to keep up and respond to climate change, but protecting infrastructure against landslides can be expensive, and is not always possible”, says Geir Vatne at Bane NOR.

So Bane NOR is looking for new approaches. In collaboration with the Norwegian Railway Directorate, it is project owner of the Klima 2050 pilot “Railway Corridors

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“We live in an age where uncertainty and risk linked to climate change is increasing at the same rate as society’s demands for safety and reliability. So we’re looking for new solutions.”

Christoffer Serck-Hanssen, the Railway Directorate

- Landslide monitoring and surface water management”, which is an instrumentation-based project designed to test landslide warning systems and the collapse of railway fillings.

Vatne explains: “The system is based on sensors, deployed at particularly exposed locations, which monitor key parameters known to influence landslide development, such as pore water pressure and precipitation. Together with topographical and ground condition data, our goal is to develop a warning system that triggers an alarm when critical values are exceeded and the risk of a landslide is greater than is acceptable for a train to pass.

Testing in Bodø and Eidsvoll

The problem with current warning systems, such as *varsom.no*, is that they tell us nothing about landslide risk linked to individual slopes or fillings. The pilot provides a major innovation opportunity for linking general meteorological, topographical, hydrological and geological data with local measurements, and this is the key aim of the project.

The pilot is being conducted at two locations – at Bodø station in Nordland, and along the inter-city stretch between Venjar and Eidsvoll in Akershus. At Bodø, sensors to monitor pore pressure and soil moisture, as well as temperature and precipitation gauges, will be placed along a slope that has been subject to several minor landslides in the past.

“A physical, sensor-based, warning system could provide a better assessment of actual landslide risk in this critical area”, says Vatne.

ANNUAL REPORT 2019

Photo: NGI

The Railway Directorate – looking for new solutions

Christoffer Serck-Hanssen, who holds a senior position at the Railway Directorate, believes that projects such as these have an important role to play in reducing societal risk resulting from climate change.

“We live in an age where uncertainty and risk linked to climate change is increasing at the same rate as society’s demands for safety and reliability. So we’re looking for new solutions”, he says.

Traditional methods of protecting infrastructure are very expensive. Serck-Hanssen’s hope is that the pilot project will result in an early warning system that will enable more focused preventive measures and the optimal use of available resources.

ZEB Laboratory preparing for climate of the future

The new ZEB Laboratory in Trondheim is not just a zero-emission building. It offers innovative climate change adaptation solutions such as a “forgiving roof construction” and an interplay of blue-green roofing systems in which not a single drop of water is wasted.

The four-storey Zero Emission Building (ZEB) Laboratory, designed for the development, testing and demonstration of new and innovative zero-emissions materials and systems, is currently under construction.

The engineering consultancy Multiconsult has been responsible for the building physics and has worked extensively with moisture protection.

“Key to buildings such as the ZEB Laboratory is their potential to address moisture protection and climate change adaptation early in the construction phase,” says Rein Kristian Klich Raaholdt at

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Arkitekt: LINK Arkitektur

The ZEB Laboratory illustrating its BIPV and timber façade cladding.

Rein Kristian Klich Raaholdt
Multiconsult

Per Møller-Pedersen
Storm Aqua

Multiconsult. He commends the Klima 2050 Centre both for raising awareness and for its development of a moisture protection framework.

A forgiving construction

Raaholdt emphasises that the ZEB Laboratory is not only a zero-emissions building, but also boasts an innovative roof construction. Firstly, the sloped roof is covered with solar panels pitched at 30 degrees, which maximises its sunlight absorption potential. Very few tall buildings have pitched roofs, and it will be interesting to see how the roof performs. Secondly, a so-called smart vapour barrier has been installed to prevent condensation and enable the roof construction to dry.

'This provides us with what we call a more 'forgiving construction', reflecting the need for buildings that are both resilient to moisture and fitted with systems to eliminate it later", says Raaholdt.

Stormwater solutions in context

Raaholdt highlights the exterior blue-green system as the most innovative aspect of the project, and hands over to Per Møller-Pedersen, who is CEO at surface water consultants Storm Aqua, which is part of the Skjæveland Group. Storm Aqua has been responsible for proposing the stormwater management plan that addresses four surface elements: impermeable surfaces such as parking spaces and roads; rain gardens; permeable surfaces such as gravel, and green areas such as lawns and garden shrubs/bushes.
"The proposed plan is designed to link these elements together, enabling water runoff to be collected in one place – an underground Alma Smart Tank, developed by Storm Aqua. We want to approach stormwater management as an integrated system, and this in itself is an innovation", says Møller-Pedersen.

Potable water and 'utility water'

The water collected in the concrete Alma Smart Tank is what Møller-Pedersen calls utility water, which can be used for most purposes except drinking.

"Today, all the water we use in Norway has the properties of potable water. Climate change means that we will have to approach water supply in a different way. Water will become a precious resource", says Møller-Pedersen.

He is preoccupied with the idea that water in areas surrounding the ZEB Laboratory should not simply vanish into the ground, but that it could be used for watering plants and trees on dry summer days, or for cleaning.

Water is a precious resource

Viewed as a resource, water offers many exciting opportunities for innovation, and Møller-Pedersen, who is clearly passionate about integrated stormwater solutions, hopes that the project can stimulate innovation and lead in turn to other projects.

"It is quite possible that we will soon establish a scheme that incentivises builders to develop systems that collect water for re-use", he says.

"Today, all the water we use in Norway has the properties of potable water. Climate change means that we will have to approach water supply in a different way. Water will become a precious resource."

Per Møller-Pedersen, Storm Aqua

Thomas Skaugen
NVE

Photo: NVE

Important breakthrough for flood risk management

Flooding in small catchments is a growing concern, but very little hydrological data are available for most locations. However, a PhD Candidate based at the the Klima 2050 Centre has developed a method that makes it possible to forecast flooding in such catchments.

Floods resulting from heavy rainfall represent a major climate-related hazard and can cause significant damage. In small catchments, a lack of relevant data makes it difficult to plan road and rail infrastructure and to protect these assets from flooding. PhD Candidate Aynalem Tassachew Tsegaw, based at the Klima 2050 Centre, has been looking into this problem and has identified a new approach as part of further development of the DDD (Distance Distribution Dynamics) rainfall runoff model applied in small catchments.

Knut Alfredsen is a professor at NTNU and Tassachew Tsegaw's supervisor. "In Norway, the DDD model performs well in forecasting the flooding of large rivers such as *Gaula* and *Orkla*, but the model's one-day time frame is inadequate for small catchments, where floods can occur after only

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a few hours of extreme rainfall. This is why we have adapted it to calculate runoff on an hourly basis", he says.

The importance of fine-time resolution

The DDD model, developed by Thomas Skaugen at the Norwegian Water Resources and Energy Directorate (NVE), represented a breakthrough in 2014. It is based on information from digital maps, and was the first model developed in Norway to forecast flooding hazards and provide other kinds of hydrological information in low-data catchments.

'There are billions of catchments, but data are available for only a few thousand of them", says Skaugen. "We're very pleased that the Klima 2050 Centre has succeeded in introducing a fine-time resolution adaptation to the model, enabling us to detect rapid response in small catchments', he says.

Photo: NVE

Breakthrough for urban hydrology

The fine-time resolution option is important for urban hydrology.
'In the last two years, the NVE has been focusing more on urban hydrology, and our participation as a partner with the Klima 2050 Centre has been very beneficial for us", says Skaugen.

Tassachew Tsegaw's PhD Thesis is helping the NVE to develop a model with even finer (10-minute) resolution. This will be useful in predicting runoff from impermeable surfaces such as car parks in urban areas.

Forecasting flood peaks

Skaugen wants to highlight another important finding from the Ph.D. study. Tassachew Tsegaw has developed an approach that enables more accurate estimates of peak flooding. The new approach allows the model to take the ground's ability to absorb water into account.

'When the ground is wet its ability to absorb water is reduced. In response, runoff water forms a denser network of streams in which the water flows faster, and this in turn generates higher flood peaks.

Reducing risk to future infrastructure

Skaugen has identified a third interesting aspect of the modified model, which can now examine the nature of future floods, taking into account increases in precipitation and temperature predicted by various climate models for the period leading up to 2100.

'A great deal of infrastructure is adapted to current conditions. The hope is that the DDD model can be a key contributor in the future planning and operation of roads, railways and similar infrastructure as we face new conditions resulting from climate change", says Alfredsen.

Skaugen summarises what he thinks is the ultimate aim of the model – to be able to simulate hydrological processes and floods anywhere in Norway at any time resolution.

3

GLIMPSES FROM THE RESEARCH ACTIVITIES

Photo: Unsplash

Photo: Erin Lindsay

Landslide mapping in Jølster, Norway, using Sentinel-2 data

Landslide early warning systems rely on knowledge of past events to forecast the future. However, data from historic landslide events are often spatially biased in favour of sites such as transport routes, and contextual information may be inaccurate or incomplete. This problematizes the use of historic data for landslide forecasting. Multispectral satellite images from the Sentinel-2 mission were used to map landslides triggered by a summer rainstorm in Jølster, Norway, based on changes in the normalised difference vegetation index (NDVI) between pre- and post-event images. The events were characterised by type, area and estimated rainfall volumes. Mapped landslides were verified in the field. NDVI-based mapping increased the number of registered events from 14 to 99. Our study indicates that systematic mapping from Sentinel-2 images offers good potential to reduce biases in historic landslide data for events triggered by summer storms.

ZEB Laboratory – climate change adaption for a zero emission building (ZEB)

Measurement of moisture content in roof construction

The ZEB Laboratory is an experimental facility located on the NTNU Gløshaugen campus in Trondheim, and is a pilot project being conducted by the Klima 2050 Centre. The building comprises a four-storey, 2000 m², office space, which aims to achieve the stated ZEB-COM ambition over a lifetime of 60 years. The laboratory's contribution will be to accumulate knowledge related to zero-emissions buildings and to act as an arena for experimental investigations of user-building interaction. It will also function as a large-scale technology testing centre. We also aim to use the building to demonstrate climate change adaptation technologies, with a focus on building-related moisture proofing and innovative solutions for stormwater management. The ZEB Laboratory will demonstrate and document the building integration of solar cells (BIPV) in roofs and facades, and establish a research infrastructure for stormwater management. The project is already a great success due to its outstanding performance in the provision of student projects and in education.

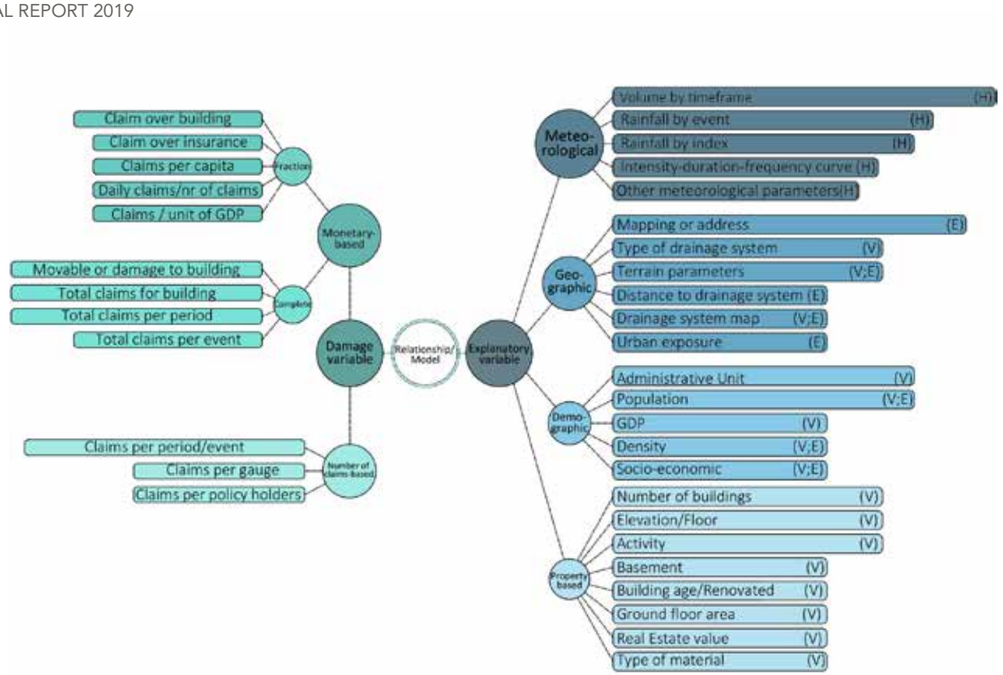
Improving cost–benefit analyses of climate change adaptation measures

Landslide mitigation measures used to protect a road. Even for this massive construction, there is a residual risk related to factors such as extreme, though very rare, landslide scenarios.

Cost-benefit analyses are key to priority assignment when selecting from among what are often costly risk mitigation measures related to climate change adaptation. Several tools are used for such analyses both in Norway (e.g. at the NVE and NPRA), and overseas. However, studies carried out at the Klima 2050 Centre have identified shortcomings in these tools. Mitigation measures such as landslide barriers cannot fully eliminate risk and thus always leave a residual risk. In general, residual risk is poorly communicated and seldom accounted for by the analytical tools. The Klima 2050 Centre is currently addressing the quantification of residual risk. It is essential that effective analytical tools account for the multiple aspects of climate change. This in turn demands a holistic view of the costs of climate change impacts on infrastructure and buildings in order to ensure that effective climate change adaptation measures can be seen as profitable.

The inclusion of climate change factors in cost calculations was the main topic of a Klima 2050 workshop arranged by the NPRA, BI and SINTEF. The workshop focused on assessing climate change adaptation measures using the NPRA tools EFFEKT (cost-benefit analysis) and MOTIV (maintenance costs).

Photo: NGI



Use of insurance data

Gradeci, K, Labonnote, N, Sivertsen, E & Time, B: The use of insurance data in the analysis of Surface Water Flood events – a systematic review, *Journal of Hydrology 2019*.

The Klima 2050 Centre has carried out a literature review into how insurance data are used to mitigate surface water flood events. In particular, the review has made an assessment of the variables used to describe, explain, and evaluate the extent of flood events. It is clear that the greatest benefit to be had from insurance damage data is when they are analysed in combination with meteorological, geographical and demographic data, as well as information about the buildings affected.

Based on this review, generic framework guidelines have been proposed for the use of flood damage-related insurance data. The guidelines provide detailed step-by-step instructions for data collection, data processing, parameter selection, modelling, model validation and the application of modelling results. Such models can be applied in risk assessment and decision-making processes.


Photo: NGI

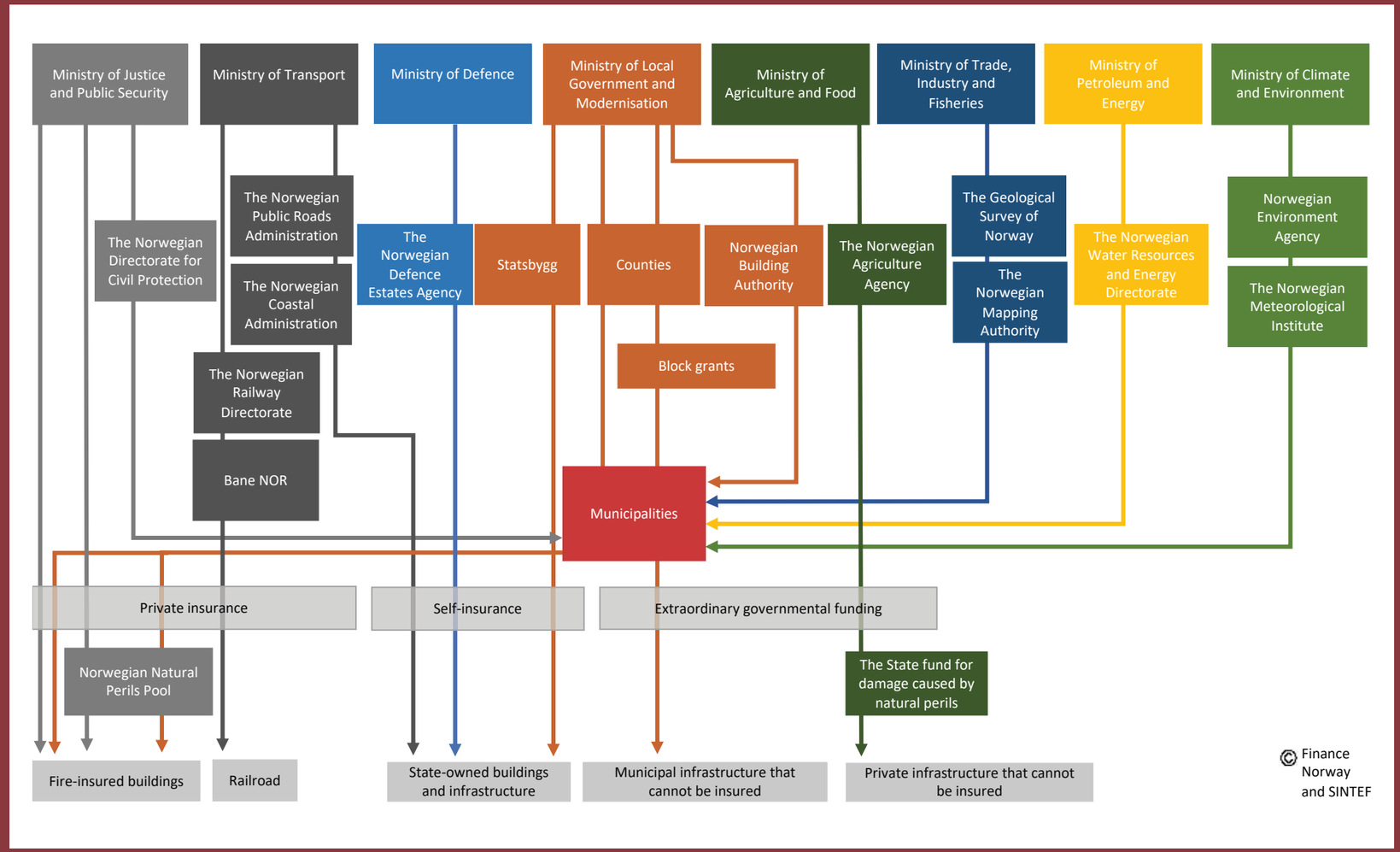
Using local data to improve landslide early warning systems

Many landslides in Norway are caused by mass failures induced by increases in pore water pressure. Inputs to current early warning systems comprise proxies of pore pressures interpolated onto a 1 km^2-cell grid system based on meteorological and hydrological data. Is it possible to improve this system by supplementing these inputs with local pore water pressure data? To answer this question, an assessment was carried out between 2013 and 2017 in the *Horvereidelva* river catchment, using both pore water pressure data and landslide observations.

The proposed technique consists of changing the warning level (from green to yellow, orange and red) depending on changes in pore pressure. Following application of this new technique, false alarms were almost halved (48% reduction). Moreover, two landslides that originally occurred during yellow alerts were shifted to higher levels (orange and red). These results indicate that the use of locally measured pore water pressure data in regional early warning systems has a potential to improve their performance.

Natural hazard compensation and insurance – a comparative study of schemes employed in different countries

This study maps official climate change adaptation responsibilities in Norway, Sweden, Finland, Germany, France and Canada. It focuses on natural hazard compensation and insurance schemes, and the degree to which these provide incentives for prevention rather than the restoration of buildings and infrastructure after an accident has occurred. Scheme design varies between the countries, both in terms of the factors covered and the causes of damage for which compensation is awarded. Some insurance schemes are private, while others are semi-voluntary or based on private-public cooperation. Current structures provide only limited incentives for prevention because the schemes typically only cover recovery costs to original standard. The inclusion of building codes and guidelines in insurance contracts may increase levels of adaptation, but do not as yet appear to offer adequate incentive. The major incentives continue to reside in past accidents and legal recourse.



The pilot project Ovase.no will develop Ovase.no into a national focus point for stormwater knowledge, in the form of a web-based information portal for stormwater

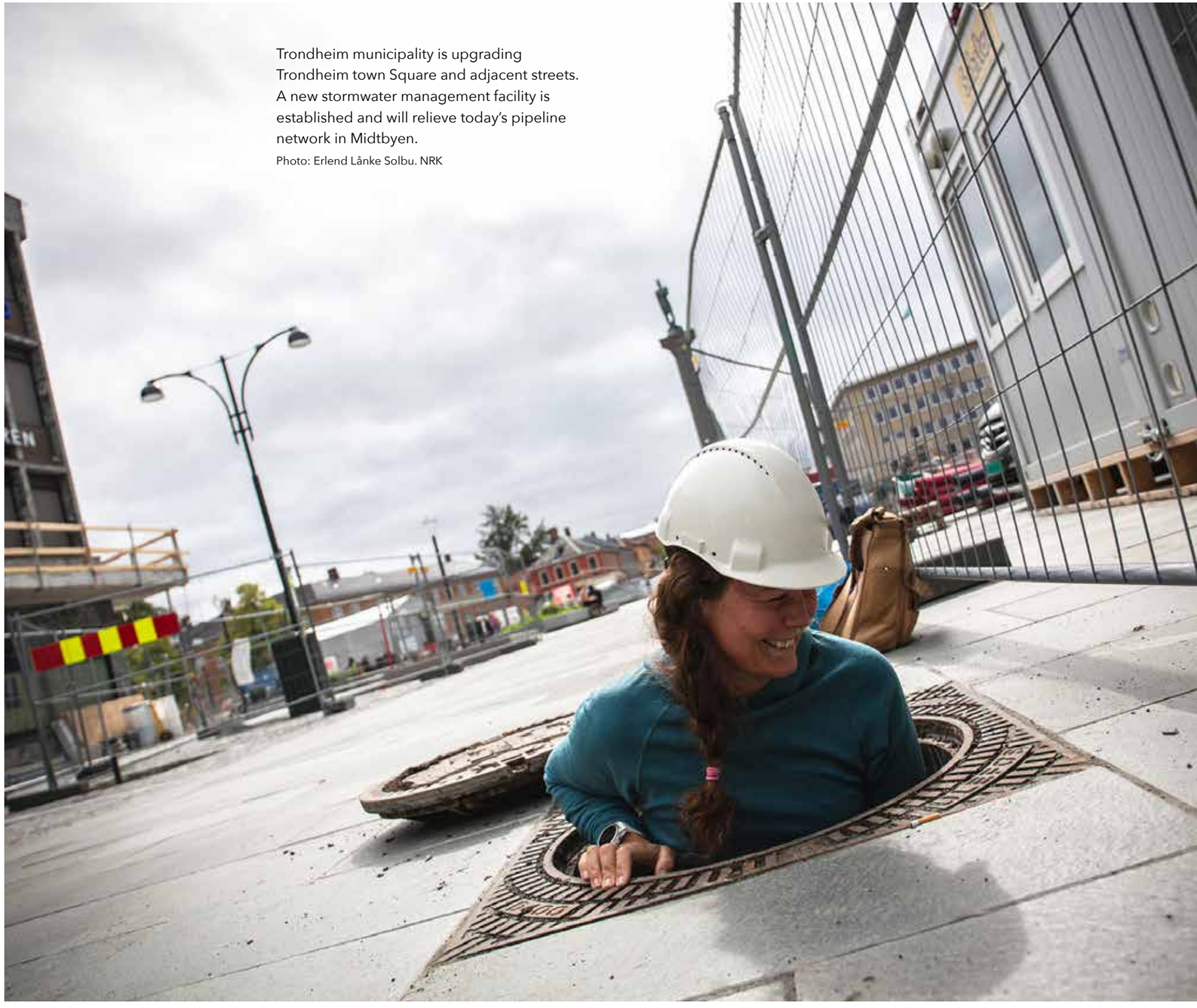
User evaluation of climate service websites

This study, conducted at the Klima 2050 Centre, evaluates the development and use of two websites designed to facilitate decision-making processes related to climate change adaptation. The websites address stormwater (Ovase, www.ovase.no) and landslide risk (LaRiMiT, www.larimit.com), respectively. Both services have to incorporate user needs during development in order to ensure appropriate implementation and use. Too great a focus on technology, content and user group mapping can be expensive and time-consuming. Moreover, since the processes and networks surrounding website development are key to attitudinal change and learning, it is beneficial to promote communication using such means as user surveys, testing, networks and learning arenas, as well as information and experience sharing among user consortia and/or networks of researchers and public and private sector organisations. Public sector organisations are key users of climate service websites, and better coordination between such organisations and website designers will contribute to improved development, implementation and use.

Infiltration and detention of stormwater beneath Trondheim town square

Trondheim municipality has upgraded the city's town square and adjacent street network. At the same time, a new stormwater management facility has been installed to relieve the city centre's existing pipeline network. The new facility consists of an infiltration system and detention magazine and is designed so that the magazine is only used when the infiltration system reaches maximum capacity. Researchers at the Klima 2050 Centre will analyse and verify the functionality of this combined system. In order to monitor system efficiency over time, the facility is equipped with multiple sensors with remote access to logging data.

ANNUAL REPORT 2019



Trondheim municipality is upgrading Trondheim town Square and adjacent streets. A new stormwater management facility is established and will relieve today's pipeline network in Midtbyen.

Photo: Erlend Lånke Solbu. NRK

Photo: Skjæveland Gruppen

On the site of Multiblokk (Skjæveland Gruppen) south of Sandnes, the Norwegian Public Roads Administration has a pilot project to document the treatment efficiency, operation and maintenance of an implemented solution for treatment of stormwater from the new bridge and a connecting road.

Treatment of road water runoff

In October, the Klima 2050 Centre arranged a thematic meeting attended by invited guests from the Norwegian Environment Agency and NIVA to discuss stormwater and road water runoff treatment requirements in a Norwegian context. Norwegian environmental legislation prohibits pollution, unless a dispensation is granted by the relevant County Governor. Dispensation applications are assessed on a case-by-case basis, taking into consideration the water quality of the receiving watercourse, user interests and the availability of cost-effective measures across pollution sources. The approach to, and timing of, the treatment of road water runoff is regulated by the N200 Guideline, which takes into account annual average daily traffic (AADT) and the vulnerability of the receiving watercourse. The guideline sets out clear targets for the removal of suspended solids during the first treatment step, but is less specific in terms of exempted removal efficiencies for other constituents, and the second treatment step. Researchers at the Klima 2050 Centre are planning to look into this issue as part of the Fv505 pilot project.

KEY FIGURES

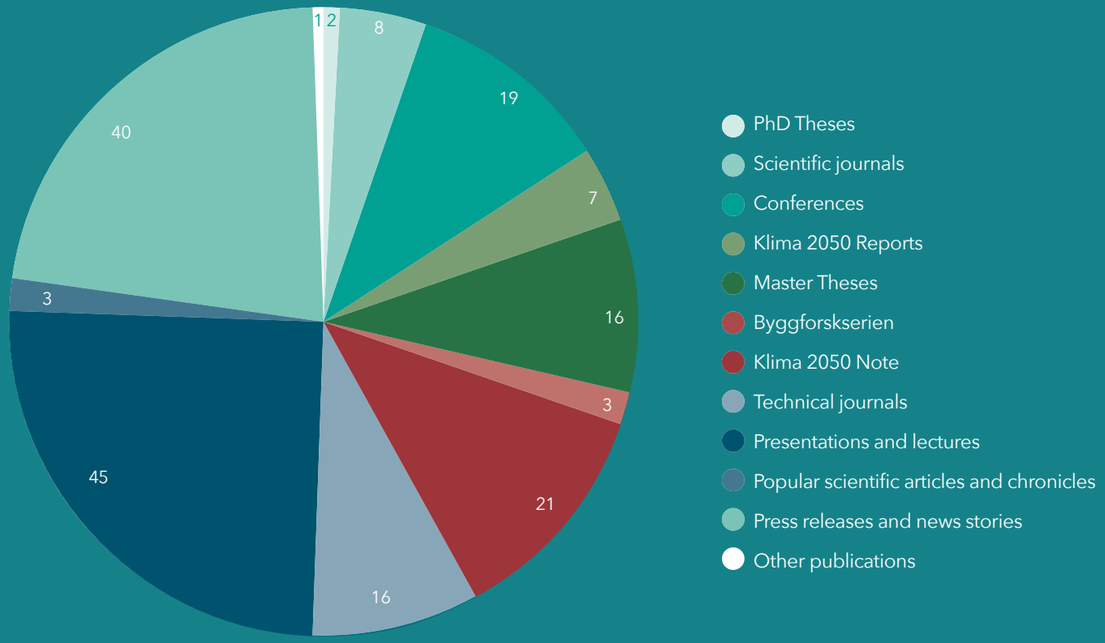
Events throughout the year have shown the relevance of Klima 2030, and the general interest from media has been high

Photo: NVE

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 2019 shows following distribution of publications.

All publications are listed on **www.klima2050.no**



Publications

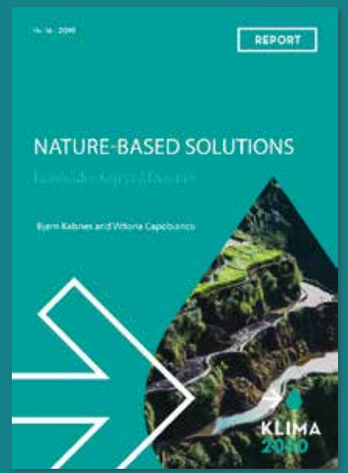
Some examples of publications in 2019

Byggforskserien

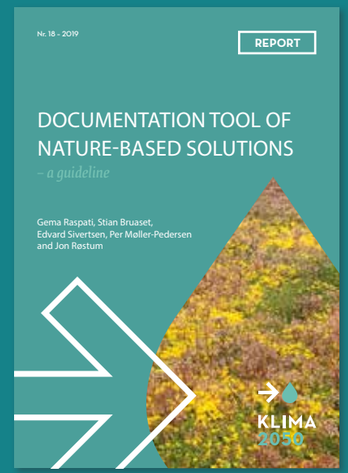
Technical journal

Scientific journal

Technical journal



Klima 2050 Report



Klima 2050 Report

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.

• ***Blågrønt tak på R5 Regjeringskvartalet,*** Statsbygg, Oslo, 26. april

• ***Overvannshåndtering – status***, Klima 2050 HUB, Trondheim, 8. mai

• ***Risikovurdering som verktøy for klimatilpasning***, NGI, Oslo, 7. juni

• ***Rammeverk for klimatilpassa bygning***, Klima 2050 HUB, Trondheim, 19. juni

• ***Seminar om naturskadeordninger i Norge***, DSB, Tønsberg, 29. august

• ***Klima 2050 Pilot Project Tour Trondheim***, Trondheim, 2. oktober

• ***Water treatment requirements for stormwater and road run-off***, Klima 2050 HUB, 22. oktober

ANNUAL REPORT 2019

Snapshots from Thematic Meetings and partner interactions

Recruitment

Klima 2050's PhD candidates financed by the Centre in 2019:

Aynalem Tasachew, NTNU - awarded PhD 22. November
Silje Asphaug, NTNU
Erlend Andenæs, NTNU
Erin Lindsay, NTNU
Petter Fornes, NTNU
Vladimir Hamouz, NTNU
Bridget O'Brien Thodesen, NTNU
Hervé Vicari, NTNU
Lars Gullbrekken, NTNU – awarded PhD (2018)

Associated PhD candidates in 2019:

Birgitte Gisvold Johannessen, NTNU/Trondheim kommune – awarded PhD 7. May
Manuel Franco Torres, NTNU/Multiconsult
Kaj Pettersson, Chalmers University of Technology
Atle Engebø, NTNU

Post.docs 2019:

Anne Kokkonen, BI
Vittoria Capobiano, NGI
Jardar Lohne, NTNU

72 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!

ANNUAL REPORT 2019

Photo: Skanska

Annual account 2019

FUNDING

The Research Council	12 800
SINTEF (host institution)	2 413
Research partners	2 798
Private partners	9 078
Public partners	5 206
Sum	**32 295**

COSTS

SINTEF (host institution)	10 858
Research partners	13 699
Private partners	7 548
Public partners	190
Sum	**32 295**

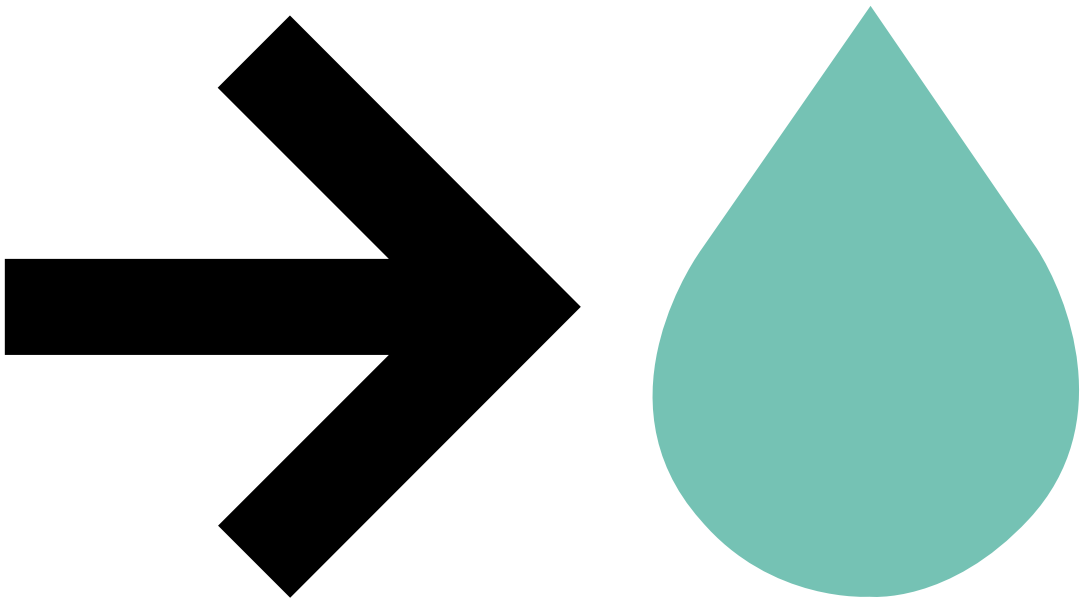
All figures in 1000 NOK

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

Vega Scene. Photo Åse Holte

For more information about Klima 2050 go to our webpage:

www.klima2050.no



Klima 2050 Report no 20

Annual Report 2019

Berit Time (editor)

Keywords: Klimatilpasning, bygninger, overvann, skred, beslutningsprosesser

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