
Annual
report
2021
sfi
KLIMA2050

ANNUAL REPORT 2021

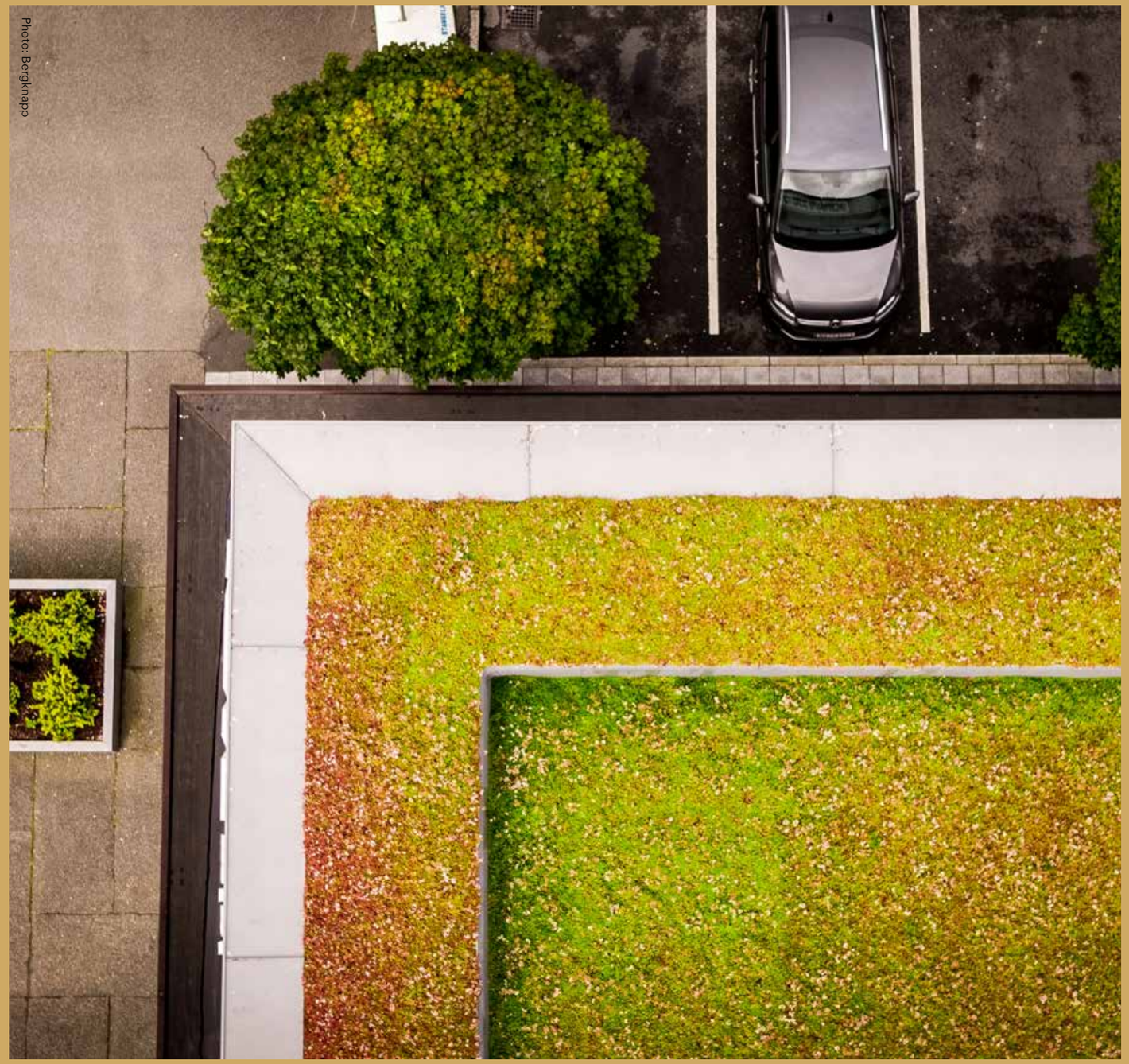

Photo: Bergknapp

Content

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Organization

Our social responsibility

During the summer of 2021 we were once again witness to dramatic climate-related events, this time linked to heavy rains and flooding in continental Europe. All this happened at about the same time as the IPCC published its 6th report, re-emphasising in the strongest possible terms the seriousness of the current situation.

The production of more knowledge about climate adaptation, as well as risk reduction strategies linked to climate change and increasing levels of precipitation in the built environment, is the social responsibility of the Klima 2050 Centre. As well as generating innovations and increased wealth creation for our partners, we all recognise that our work at the Klima 2050 Centre is part of a much bigger exercise in social responsibility.

Photo: Erik Burås/Fremtidens Byggenæring

The centre has previously made it clear how many Norwegian government ministries and public sector agencies have a role in the field of climate adaptation, but it is the local municipalities that have the primary responsibility for applying adaptation strategies in Norway. They have responsibility for holistic planning and risk management, as well as for community safety. The Norwegian Municipal Planning Act is key to all land management and building activities in Norway, and the municipalities have a duty to adapt their infrastructure to anticipated changes in climate, and to put measures in place to prevent damage and injury. Climate change thus puts ever-increasing pressure on the Norwegian municipalities.

Throughout 2021, the Klima 2050 Centre has contributed with research and innovations as part of our greater social responsibility. The building and construction sector is made up of more than 50,000 companies and employs 250,000 people, all of whom must contribute to the best of their ability towards reducing societal risk and adapting buildings and infrastructure to the threats posed by climate change. Much of our research is made available to the sector and those who work there.

In 2021, we have taken part in a number of projects and co-creational initiatives with players in the private and public sectors and other research centres, focusing on issues of interest also to many stakeholders outside the Centre's partnership group. We have developed guidelines that are of benefit to the municipalities and have participated in the work to revise BREEAM-NOR, which is the most frequently applied building certification system in

Norway. We link our research to other Norwegian initiatives and projects such as the Natural Hazards Forum, the Norwegian water sector organisation Norsk Vann, and SINTEF Building Research Design Guides. These are important fora for the dissemination of our research results. This year's Annual Report is full of stories highlighting the Centre's exercise of its social responsibility.

Grethe Bergly
Chair of the board

"Throughout 2021, the Klima 2050 Centre has contributed with research and innovations as part of our greater social responsibility."

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 2021:
Finans Norge, Isola AS, Multiconsult AS, Mesterhus, Norgeshus AS, 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
MESTERHUS
Multiconsult
Finans Norge
SKJÆVELAND GRUPPEN
NORGESHUS
Leca
isola

Public sector

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

Research & education

SINTEF
BI
NTNU
Meteorologisk institutt
NGI

The organization

Centre Management

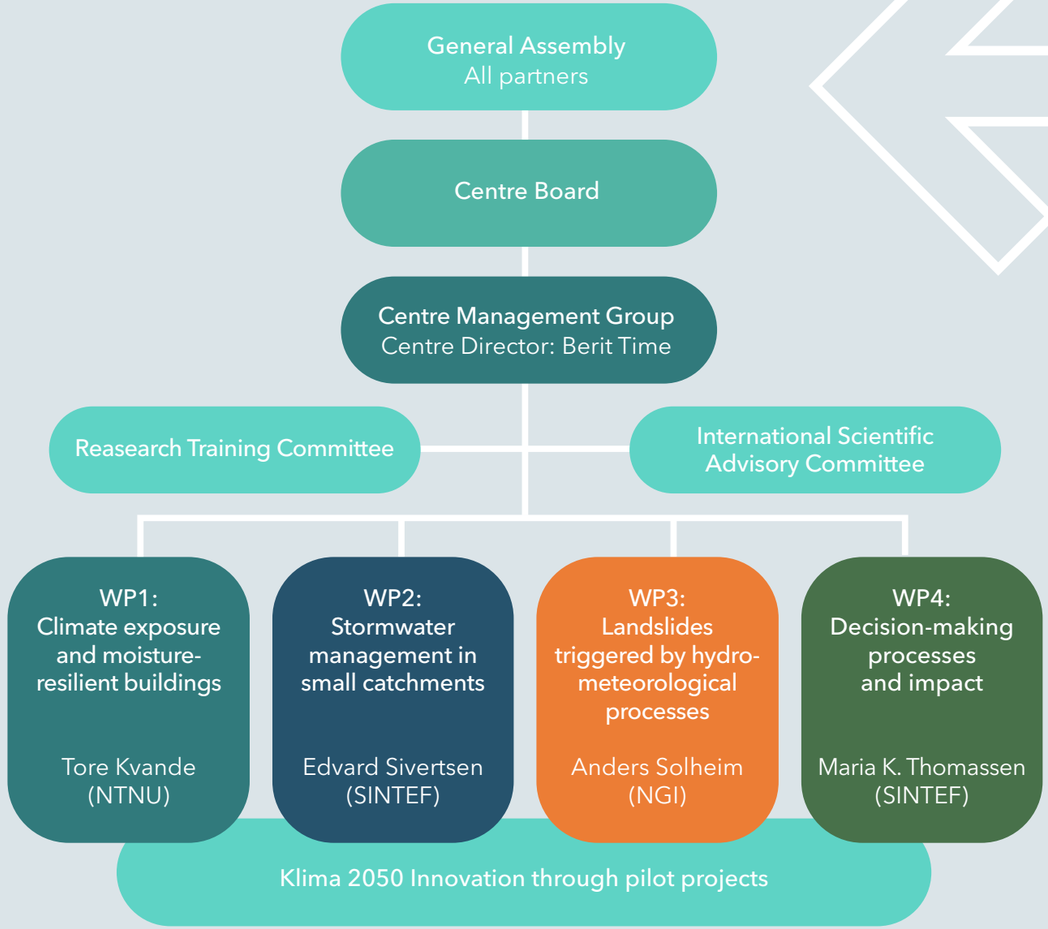
Berit Time, *chief scientist at SINTEF, Centre Director*
Tore Kvande, *professor at NTNU, Principal Investigator (WP1)*
Edvard Sivertsen, *senior research scientist SINTEF (WP2)*
Anders Solheim *senior geologist at NGI (WP3)*
Maria K. Thomassen, *research manager SINTEF (WP4) (until July 2021*)
/Katrin Knoth, *senior research scientist (from August 2021)*
Lena Bygballe, *associate professor at BI Norwegian Business School (WP4)*
Jorunn Auth, *administrative coordinator at SINTEF (adm)*

Centre Board

Grethe Bergly, *Multiconsult (Chair)*
Grethe Vikane, *Statens vegvesen*
Anders Fylling, *Statsbygg*
Einar Aassved Hansen, *Trondheim kommune*
Rune Egeland, *Skjæveland Gruppen*
Kristin Holte, *Skanska Norge*
Lars Andresen, *NGI (until August 2021)*/ **Dominik Lang,** *NGI (from September 2021)*
Vikas Thakur, *NTNU*
Hanne Rønneberg, *SINTEF*
Svein Erik Moen, *The Research Council of Norway (observer)*

Christoffer Serck-Hanssen, *Jernbanedirektoratet, 1. Deputy*
Dag Runar Båtvik, *Norgeshus, 2. Deputy*

Chair of General Assembly: Jørgen Young, *Isola*



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

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Social mission

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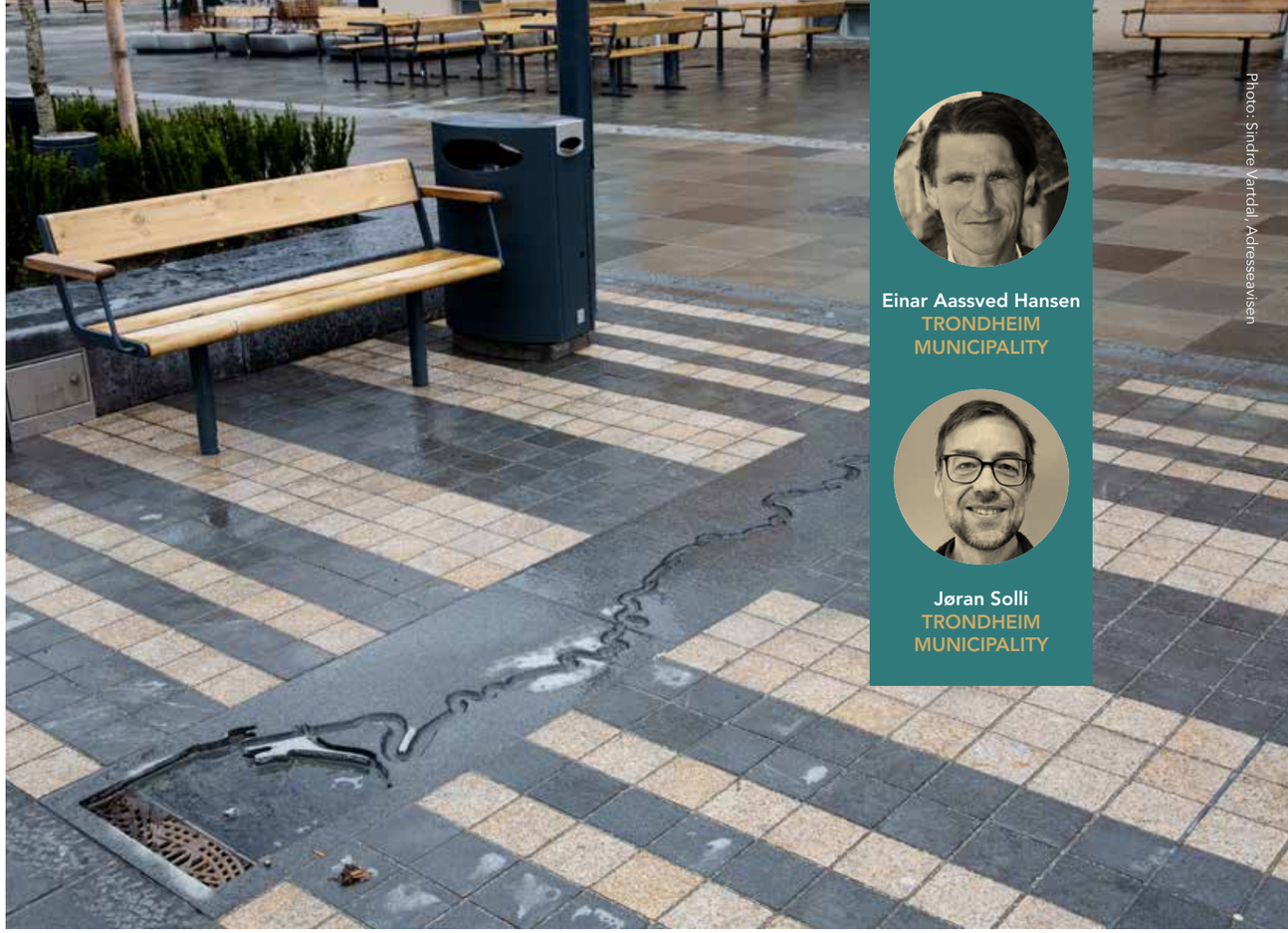
Responsibility

Our Social

Photo: Glen Musk/Trondheim Kommune

Climate adaptation all across the municipality

Climate adaptation must form the basis for all municipal planning. The Klima 2050 Centre has been working together with Trondheim municipality to develop indicators that can measure how far climate adaptation has advanced.



Einar Aassved Hansen
TRONDHEIM MUNICIPALITY

Jøran Solli
TRONDHEIM MUNICIPALITY

Photo: Sindre Vartdal, Adresseavisen

"It's our responsibility as a municipality to ensure that our citizens enjoy safe and healthy living conditions", says Einar Aassved Hansen, who is Director for Urban Development at Trondheim Municipality. "For this reason, it's vital that we consider the impacts of climate change", he says.

Trondheim municipality has long been at the forefront of climate adaptation. In 2017, it took the initiative to form the association 'Network Climate Adaptation Trøndelag' as a means of promoting collaboration and knowledge sharing on climate adaptation throughout the county.

"One of the goals of the network was that all municipalities should include climate adaptation in their risk and vulnerability assessments linked to spatial planning. These assessments are among the most important documents that a municipality has when it comes to climate adaptation", says Aassved Hansen.

Praising collaboration with the Klima 2050 Centre

Aassved Hansen believes that collaboration with the Klima 2050 Centre provides the municipality with valuable knowledge. He highlights the impacts of rising sea levels, and stormwater runoff due to the increasing frequency of torrential downpours, as the two main challenges facing the municipality, and for which they require new and research-based knowledge.

"Trondheim municipality is privileged to have such close collaborative relationships with NTNU and SINTEF. One of the most useful aspects of working together with the Klima 2050 Centre is our involvement in pilot projects where new solutions are being tested.

As part of its collaboration with the Klima 2050 Centre, the municipality has built a diversion system for stormwater management under the new town square. The system incorporates a large surface area that can collect huge volumes of water, thus preventing potential damage to infrastructure and other related problems.

Aassved Hansen is also appreciative of the many Thematic Meetings conducted by the Klima 2050 Centre.

Photo: Glen Musk/Trondheim Kommune

“One of our main strategies is that climate adaptation should be used as the basis for all municipal planning”

Jøran Solli, Trondheim Municipality

New municipal plan for climate adaptation

In February, Trondheim municipality adopted a new strategic plan for climate adaptation. As part of this plan, climate adaptation will not only form the basis for planning and construction case processing, but also for construction management, operation, and maintenance. Project risk and vulnerability assessments constitute an important part of the overall plan, which also includes an action plan containing 60 measures that the municipality intends to implement.

“One of our main strategies is that climate adaptation should be used as the basis for all municipal planning”, says Jøran Solli, who works with climate adaptation at Trondheim municipality, and acts as its main point of contact with the Klima 2050 Centre. “In order to achieve this, it is important that the entire municipality engages with the collaboration”, he says.

“Most of the measures are of a technical nature, addressing issues such as the municipality’s responsibility for spatial planning in flood-prone areas”, says Solli. “But we also want to influence our urban communities in ways that reach out more directly to the population. For example, we can offer advice on how people can adapt their own homes and gardens to the changing climate”, he says.

Indicators that measure climate adaptation

In 2021, the Klima 2050 Centre launched a set of performance indicators with the aim of helping municipalities to monitor their climate adaptation initiatives linked to given spaces, buildings, and infrastructure. The indicators were designed to provide an objective measure of the levels of climate adaptation achieved by municipal initiatives. Trondheim municipality acted as a partner in this project.

“Such indicators tell us how we should be approaching our work towards climate adaptation, and are very useful tools that help us transform our plans into action”, says Solli. “It also makes it easier to focus attention and obtain approvals within our own organisation in relation to the importance of climate adaptation”, he says.

Solli believes that these indicators will be useful for illuminating the financial costs that the municipality will face if climate adaptation is not

Photo: Sindre Vartdal, Adresseavisen

taken seriously. Climate adaptation requires ‘precautionary thinking’, and its importance can quickly be downgraded in the face of political demands to boost municipal budgets for nursing homes and other pressing issues.

“The budget is the municipality’s most important management tool, and our aim is that climate adaptation should be included in the budget”, he says.

Sharing knowledge obtained from the Klima 2050 Centre

Solli is keen to share with other municipalities the knowledge that Trondheim obtains as part of its collaboration with the Klima 2050 Centre. One example is the guidelines developed on the reopening of streams.

“In this project the municipality contributed with its experience from previous projects”, says Solli. “We aim to be an active promoter of sharing our knowledge with the rest of society”, he says.

Solli greatly appreciates critical feedback of his municipality’s work from external sources. One example included a report written by a master’s student working at the Klima 2050 Centre who specifically pointed out that climate adaptation was not adequately covered in spatial planning processes.

“One of the many positive aspects of our collaboration with the Klima 2050 Centre is that we are quickly made aware of where we can improve and of what actions we have to take”, says Solli.

“One of the many positive aspects of our collaboration with the Klima 2050 Centre is that we are quickly made aware of where we can improve and of what actions we have to take.”

Jøran Solli

Climate adaptation is increasingly important in the certification of buildings

BREEAM-NOR is Norway's most widely used environmental certification for construction, and a new user manual is now available. Climate adaptation is an important component of its guidelines for building in compliance with sustainability requirements.

The Norwegian Green Building Council, in collaboration with the Norwegian construction and real estate sector, has developed BREEAM-NOR, which is the construction industry's own tool for measuring environmental performance. On 28 February, it launched a new user manual setting out guidelines for building in compliance with sustainability requirements.

"It's five years since the last user manual was published", says Viel Sørensen, who is certification manager at the Norwegian Green Building Council. "So much is changing in this field that the time had come to update it. For instance, we've dedicated

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Viel Sørensen
Head of BREEAM, Norwegian Green Building Council

Photo: Skanska


Photo: Skanska

much more space than in the previous manual to the importance of climate adaptation. In fact, we invited the Klima 2050 Centre to participate in the reference group during compilation of the manual", she says.

A unique tool for building certification

BREEAM-NOR is the adapted Norwegian version of BREEAM, which is Europe's leading sustainability assessment method for master planning projects, infrastructure and buildings. It is the only method for the certification of sustainable buildings in Norway. The user manual represents a tool for the documentation of high quality building construction, setting out more stringent requirements for environmental, climate-related, and sustainability factors than the minimum requirements stipulated in statutory building regulations.

The manual demonstrates how to complete successful, sustainable and environmentally-friendly building projects based on performance in nine specific areas: management, health and indoor environment, energy, transport, water, materials, waste, land use and ecology, and pollution.

"Climate adaptation has been incorporated into several of the nine areas", says Sørensen, who goes on to explain that there are five different levels of BREEAM-NOR certification; Pass, Good, Very Good, Excellent and Outstanding.

Turning research into practice

Berit Time is Director at the Klima 2050 Centre and has also participated in the reference group, advising on the content of the manual on issues related

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to climate adaptation.

"Those of us who develop the BREEAM-NOR system are keen to emphasise that the certification requirements are founded on sound and professional research", says Viel Sørensen. "We do not have the opportunity to conduct research ourselves, but are developing a tool that demonstrates how research can be turned into practice. Those using the tool will then have the benefit of referring to the work and projects conducted by the Klima 2050 Centre", says Sørensen.

Sørensen hopes that the user manual will contribute towards placing climate adaptation higher on the construction agenda.

"We hear more and more about climate adaptation, but not everyone knows how to put it into practice", she says. "The manual allows practitioners to refer to specific methodologies. For example, all construction projects should ideally begin with a climate risk assessment", says Sørensen.

Risk assessments linked to climate adaptation form part of the minimum requirement for achieving the highest certification levels, Excellent and Outstanding.

"We hear more and more about climate adaptation, but not everyone knows how to put it into practice."

Viel Sørensen, Head of BREEAM, Norwegian Green Building Council

Meeting the Breeam requirements

There is a growing interest in the environmental certification of buildings. Sørensen is aware of several banks and financial institutions that require BREEAM-NOR certification as prerequisite for the provision of loans for construction projects. One reason for this is the increasing number of claims received by insurance companies in the wake of natural disasters. Moreover, several Norwegian municipalities are now stipulating that new buildings must be BREEAM-NOR-certified, while building contractors OBOS have decided that all their new buildings must be certified. The EU, in particular, has also tightened up its requirements.

"The EU's sustainable finance taxonomy contains very specific requirements for climate adaptation", says Sørensen. "In order to prevent greenwashing, it's more important than ever to document that the necessary requirements are being met. We believe that BREEAM-NOR meets a critical need by highlighting current 'best practice' in the Norwegian building industry and serves as a driving force for innovation on issues related to the environment and increased sustainability in planning and construction", she says.

Photo: Skanska

Bjørn Kristoffer Dolva
STATENS VEGVESEN

Photo: Ole Martin Wold / NTB

More co-operation needed in the public sector

The Natural Hazards Forum believes there is a need for a fund to finance preventive measures. "We have to be more forward-looking because the costs of hindsight and repairs are too high", says Bjørn Kristoffer Dolva.

The Natural Hazards Forum (NHF) is a collaboration, established in 2016, between ten public enterprises, including the Norwegian Municipal Sector Organisation (KS). Its aim is to identify shortcomings and any potential for improvement linked to the prevention and management of natural hazards. It is also responsible for proposing appropriate remedial actions.

"Climate change is resulting in more landslides, floods, and other natural events, and the public sector is responsible for safeguarding human life and health, as well as infrastructure", says Bjørn Kristoffer Dolva, who works for the Norwegian Public Roads Administration and is one of four members of the NHF's administrative panel. "The NHF's guiding principle is that we have much to gain from greater co-operation within the public sector in the field of prevention", he says.

Dolva was project manager for an inter-sectorial project called 'Natural hazards, infrastructure, floods and landslides' (NIFS), which was the predecessor to the NHF. The project's final report provided a sound basis for the establishment of the NHF, and offered a roadmap for further co-operation in the field of natural hazard management.

New knowledge from Klima 2050

"Co-operation within the public sector is imperative if society is to prevent and effectively manage natural hazards. It will help us to implement measures to reduce costs and will enable us to learn from each other", says Dolva.

Dolva argues that one of the main challenges we face is in converting knowledge into action. Unfortunately, in many cases there are not enough resources to implement necessary actions.

He praises the Klima 2050 Centre for the systematic and structured ways in which it approaches its projects.

"We always keep an eye on what's happening at Klima 2050, and learn an enormous amount from the knowledge and experiences set out in reports and Thematic Meetings linked to the various projects", says Dolva. "From our point of view, the greatest benefits come from the simplification and improvement of regulations and administrative practices", he says.

Dolva says that members of the NHF are closely involved in various projects being carried out at the Klima 2050 Centre.

"The Klima 2050 Centre feels a sense of ownership in its projects because it engages professionals from all the various government agencies and partners involved", he says. "This makes it easier to rapidly translate project results into change, and to implement improvements that have social significance", says Dolva.

Financing prevention

The NHF initiates and implements projects in fields that exhibit specific needs. In March 2021, it sent a recommendation to follow-up the government report 'NOU 2019: 4 Organisation of Norwegian natural damage insurance – About the Norwegian Natural Damage Pool'. The NHF argues that a Natural Hazards Fund should be established to finance preventive measures

Foto: Erin Lindsay

to mitigate against damage to buildings and infrastructure resulting from natural disasters and other climate-related events.

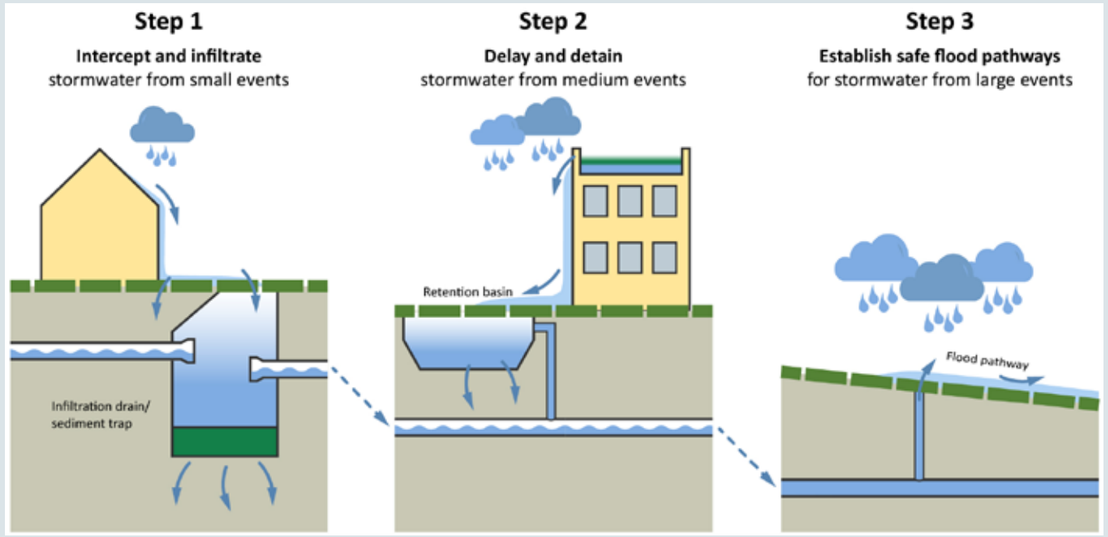
"The idea is that a proportion of these funds can be obtained from mandatory insurance policies", says Dolva. "We believe that such a fund can have a dual function, serving both as a financing method and a financial incentive to implement preventive measures", he says.

The costs of damage must be made more explicit

Dolva believes that the costs that society faces as a result of not implementing preventive measures must be made more explicit, and that it is important to involve decision-makers in this process. In 2015, the NHF presented an economic assessment following the collapse of a bridge in Skjeggestad due to a quick clay landslide. Its analysis showed that the costs to society resulting from lack of accessibility were three times higher than the actual repair costs. In February, the NHF adopted a new strategy by which one of its goals is to promote more long-term activities across the relevant sectors.

3

Glimpses



In Norway the 3-step approach (3SA) is used to manage stormwater, where the day-to-day rain should be handled with infiltration (Step 1) and detention (Step 2), whereas the extreme rainfalls should be handled with safe floodways (Step 3).

New framework for green infrastructure design aligned with the 3-step approach for stormwater management

A recent work in Klima 2050 proposed a new framework named Highly-Informed-Design-Evaluation-Strategy (HIDES) that is based on

i) downscaling of rainfall timeseries and extreme events for both current and future climate,

ii) long-time continuous simulation to estimate retention and day-to-day discharge variation corresponding to step 1 in the 3SA, and,

iii) intensive sampling of local extreme events to estimate reliability and robustness of solutions corresponding to step 2 and 3 in the 3SA.

The proposed framework is paradigm shift in the way infrastructure are designed to manage stormwater infrastructures by studying their behaviour for a wide range of events, including under which events the solutions fail to manage stormwater, and to which extend they can contribute to all objectives of the stormwater management system. The proposed framework is especially relevant in cities subject to increasing urbanization and climate change and will provide a more robust and reliable information about the performance of the green infrastructure solutions compared to the traditional approach.

Nature-based solutions – stream reopening as a climate change adaptation initiative

The reopening of streams currently running in buried pipelines may reduce flooding risk. However, such reopening processes can be complex and fraught with many pitfalls. Stream reopening usually impacts on large areas, and may come into conflict with buildings and infrastructure in densely populated areas. Recently issued guidelines contain a checklist for the entire reopening process, from the concept stage through planning and construction to operation and maintenance. They also provide an overview of factors that require assessment prior to start-up, as well as a list of available tools. Many Norwegian municipalities have shown great interest in the guide and it has already been used as part of Rogaland County Council's framework for the implementation of nature-based solutions.

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Re-opening of Ilabekken in 2008.

ID	Indikator	Skala/enhet	Kilde	Kommentar
R1	Antall husholdningstimer i året i kommunen som er uten strøm som følge av klimarelatert naturhendelser	Antall eller %-vis*	NVE avbruddsstatistikk	
R2	Antall husholdningstimer i året i kommunen som er uten vann som følge av klimarelatert naturhendelse	Antall eller %-vis*	KOSTRA	Rapporteres som uplanlagt nedetid
R3	Antall husholdningstimer i året i kommunen som er uten tilfredsstillende veg som følge av klimarelatert naturhendelse	Antall eller %-vis*	NVDB	NVDB (Nasjonal vegdatabank - Statens Vegvesen) Vegstenging
R4	Antall varslinger (flom, skred, storm, stormflo)	Antall	Kunnskaps-banken	Kan også sjekke med MET eller NVE
R5	Antall innsatser fra brann- og redningsvesen ved klimarelaterte naturhendelser	Antall	Kunnskaps-banken	Brann- og redningsvesenets innsatser og oppdrag
R6	Årlig utbetalinger/antall saker gjennom naturskadeforsikrings-ordningen (Norsk naturskadepool - NASK) (boliger, fritidsboliger og næringsbygg)	Antall eller kr	NASK eller Kunnskaps-banken	
R7	Årlig utbetalinger/antall saker gjennom naturskadeerstatnings-ordningen (Landbruksdirektoratet) (privat infrastruktur)	Antall eller kr	Landbruks-direktoratet	
R8	Årlig utbetalinger/antall saker gjennom skjønnstilskudd utløst av klimarelatert naturhendelse	Antall eller kr	Egne data (Statsforvalteren)	Kommunen kan velge å legge til relevant og tilgjengelig støtteordning, se definisjon
R9	Årlig utbetalinger/antall saker gjennom ekstraordinære skjønnstilskudd utløst av klimarelatert naturhendelse	Antall eller kr	Egne data (Kommunal- og	Kommunen kan velge
R10	Antall nye regresskrav mot kommunen			

Indikator	Skala/enhet	Kilde	Kommentar
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Overvann	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
Elveflom	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
Skred	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
Kvikkleire	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
Havnivåstigning	%-vis		https://www.kartverket.no/til-sjos/ se-havniva/kart
		Egne data	Hører sammen med resultatindikatoren R14

ID	Indikator	Skala/enhet	Kilde	Kommentar
T1	Andel reviderte reguleringsplaner som har inkludert klima-tilpasningstiltak i forhold til totalt antall reviderte reguleringsplaner	%-vis	Egne data	
T2	Andel klimatilpasningstiltak utført iht. plan	%-vis	Egne data	Tiltak kan deles opp til å gjelde for en eller flere risiko/utfordringer
T3	Andel vedlikeholdsplaner for bygg hvor klimatilpasning er nevnt	%-vis	Egne data	
T4	Andel helse- og omsorgsbygg der man har gjort sikringstiltak mot skaderisiko som følge av:		Egne data	Hører sammen med resultatindikatoren R11
a	Overvann	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
b	Elveflom	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
c	Skred	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
d	Kvikkleire	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
e	Havnivåstigning	%-vis		https://www.kartverket.no/til-sjos/ se-havniva/kart
T5	Andel innbyggere som er bosatt i områder der man har gjort sikringstiltak mot skaderisiko som følge av:		Egne data	Hører sammen med resultatindikatoren R12
a	Overvann	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
b	Elveflom	%-vis		https://www.nve.no/flaum-og-skred kartlegging/faresonekart-kommuner/
c	Skred	%-vis		

Indicators for measuring climate change adaptation in Norwegian municipalities

In Norway, the municipalities are responsible for safeguarding buildings, infrastructure and other areas against climate stressors such as flooding, landslides and torrential rain. The Klima 2050 Centre has developed a set of indicators designed to measure the levels of performance achieved by the municipalities. A holistic approach is key to the prevention of damage resulting from climate change. At the same time, there is a need to introduce specific metrics so that those responsible for adaptive measures can succeed in incorporating both quantitative measurement and evaluation of the measures they implement into their everyday work.

The performance indicators developed by the Centre include process, action and result indicators and will be used to provide an objective measure of how well a given municipality is adapting to climate change.

Contaminated stormwater – a literature review

Urban stormwater may be contaminetd due to road transport, industry and other human activities. Typical pollutants include a wide range of dissolved and particulate compounds such as road salts, heavy metals, nutrient salts, organic pollutants and microplastics. To obtain an updated overview of international research on contaminated stormwater and treatment methods, a systematic literature search was conducted, analysed and reported. A total of 171 relevant articles published after 2015 have been identified, and an overall presentation of metadata related to these articles is provided together with a more detailed presentation of the 19 review articles identified. An overview of literature dealing with costs, operation and maintenance of treatment methods and an overview of literature relevant to cold climates are also given.

Foto: NVE

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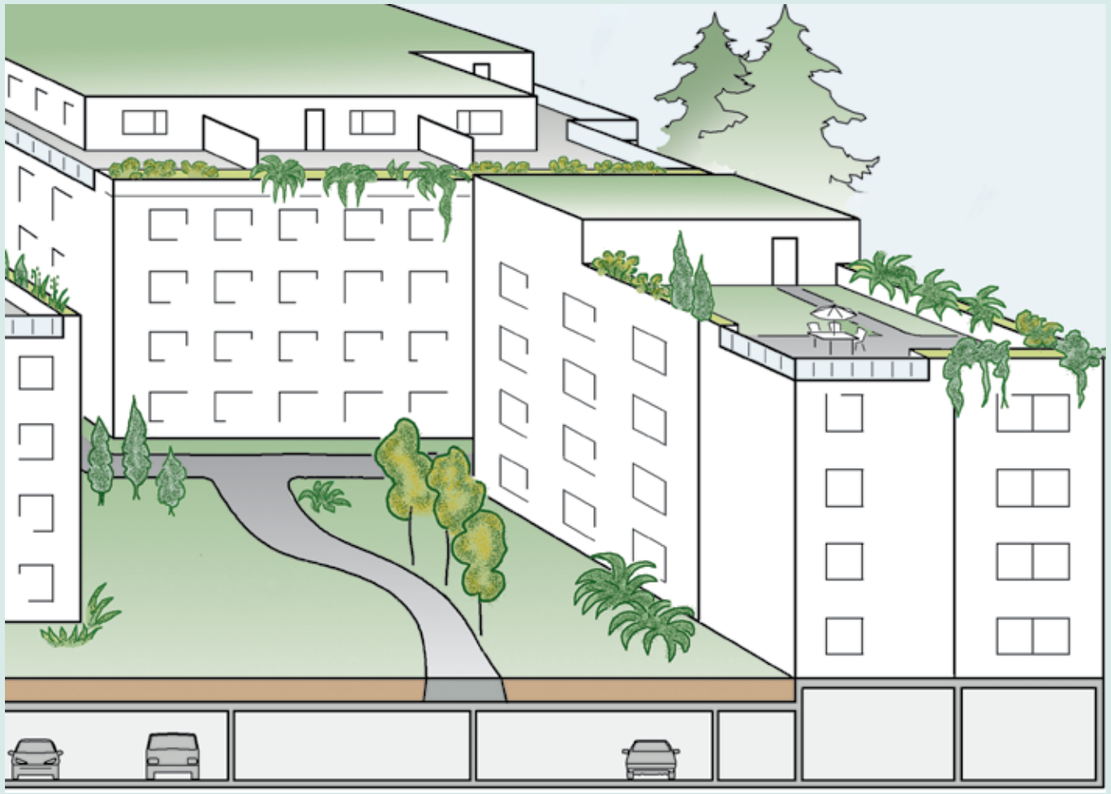


A risk framework for blue-green roofs

The use of blue-green roofs is a stormwater management initiative that is expected to become significantly more common in the future, and the research-driven innovation centre Klima 2050 has prepared a framework for the prevention of building damage using such roofs. Many technical requirements must be met in order to deliver a robust roof construction, and blue-green roofs must be planned to ensure that all such requirements are satisfied without making excessive compromises that may result in building damage because certain technical factors have not been taken into account. The successful coordination of the technical requirements needed to deliver the best possible construction project represents a major challenge. The framework described is the result of a PhD project conducted at the Klima 2050 Centre, and is now being used by centre user partners and other commercial organisations that are planning to build blue-green roofs.

Physical and numerical modelling of debris flow dynamics

Debris flows typically increase in volume by eroding and entraining soil, fluid, rocks and trees along the flow path. Hunnedalen in Norway was significantly eroded after a debris flow on 2nd June 2016. The initial landslide had a volume of approximately 2000 m^3, but following entrainment, it increased 10 times up to 20 000 m3. An empirical model was used to back-calculate the entrainment process. However, most available models do not explain bed soil entrainment in debris flows well enough. Therefore, to progress towards a more rational understanding of entrainment by debris flows, large-scale flume experiments have been carried out in Hong Kong. Hence, a three-dimensional numerical model was used to back-calculate the experiments. The simulations with this model allowed to explain the processes leading to entrainment and simulate the progressive reduction of the bed shear strength due to pore pressure generation. Finally, the case of boulders entrained at the flow front was also modelled: the boulders were observed to slow down the debris flow. In this PhD study both physical and numerical modelling were used to progress our understanding on the debris flow entrainment. If we are able to prevent entrainment high in the debris flow paths, significant damage can be prevented, mitigation measures for doing so have been part of the study.

Photo: Jarle Aasland, Stavanger Aftenblad

ANNUAL REPORT 2021

Cross-Laminated Timber (CLT) elements have had a growing popularity in recent years due to low carbon footprint, low weight and efficient construction time. However, the elements are sensitive to rain- and moisture and prone to organic growth if not treated properly during construction or if used incorrectly.

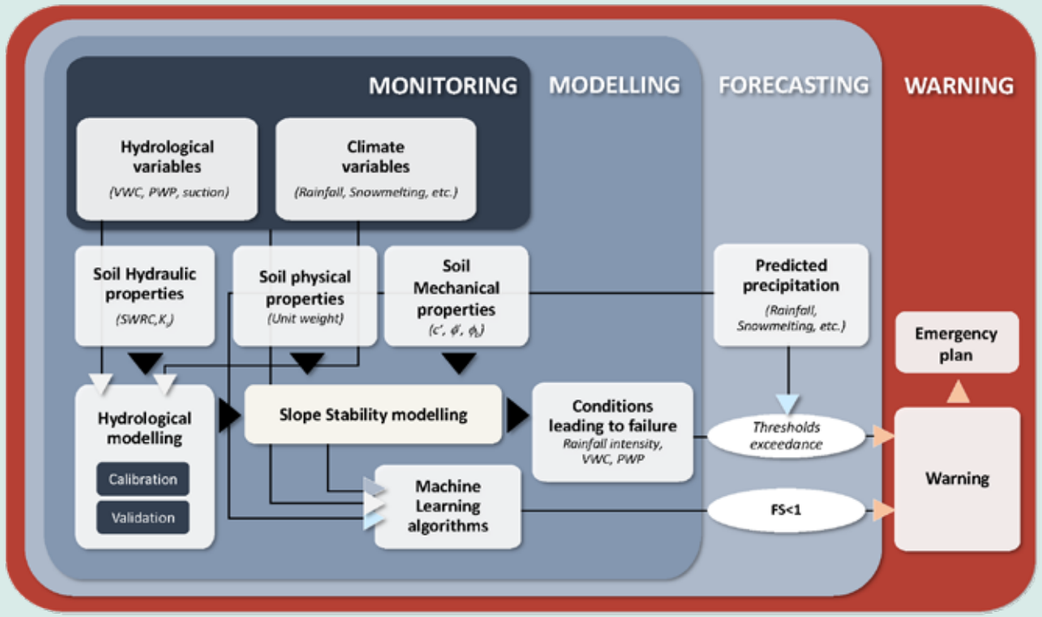
Climate- and moisture robustness of roofs made by Cross-Laminated Timber

Rainy days will increase du to climate change. Roof slabs are particularly exposed, as they have a large area of exposure and the horizontal orientation doesn't allow rainwater run-off. The efforts made, during construction, to protect CLT-roofing elements from rain by Norwegian contractors vary widely, as there are few guidelines and little long-term experience. A field study of CLT-roofs on existing buildings was conducted to investigate the conditions after some years in service. The study, initiated by the Norwegian Roof Producers Research Group, included inspection and moisture measurements of CLT elements from the exterior side in 10 building projects 1-9 years old from two regions of Norway. The contractor of each project was interviewed in order to assess the extent of climate exposure and protection measures during construction. The results indicate a correlation between water content, building age and exposure level during construction. There is a clear indication that the drying time for built-in moisture in CLT roof constructions are slow. Keeping built-in moisture to a minimum is therefore essential and adequate measures for rain protection have to be developed and applied.

Railway corridor at Eidsvoll – early warning system

Climate induced hazards impact the safety and availability of roads and railroads. These problems are expected to increase with more frequent and intense extreme precipitation events. Klima 2050 has several activities with the aim of reducing the climate risk to linear infrastructure.

In the pilot project “Railway Corridors” a prototype of an early warning system is developed. At a steep slope facing the new railway at Eidsvoll, several sensors have recently been installed to measure the water content and suction in the slope. These sensors together with the already installed piezometers provide real-time monitoring data remotely accessible. Furthermore, a weather station is to be installed to monitor rainfall and other meteorological variables. All these data are being used to calibrate and validate a hydrogeological model for real-time stability analyses. The slope stability is now constantly monitored, and the calibration of the model is on-going. The final aim is to develop a fully operational local early warning system for the slope facing the high-speed railway north from Oslo. The near-real time estimates of the slope stability, will enable the train operator to act on time.



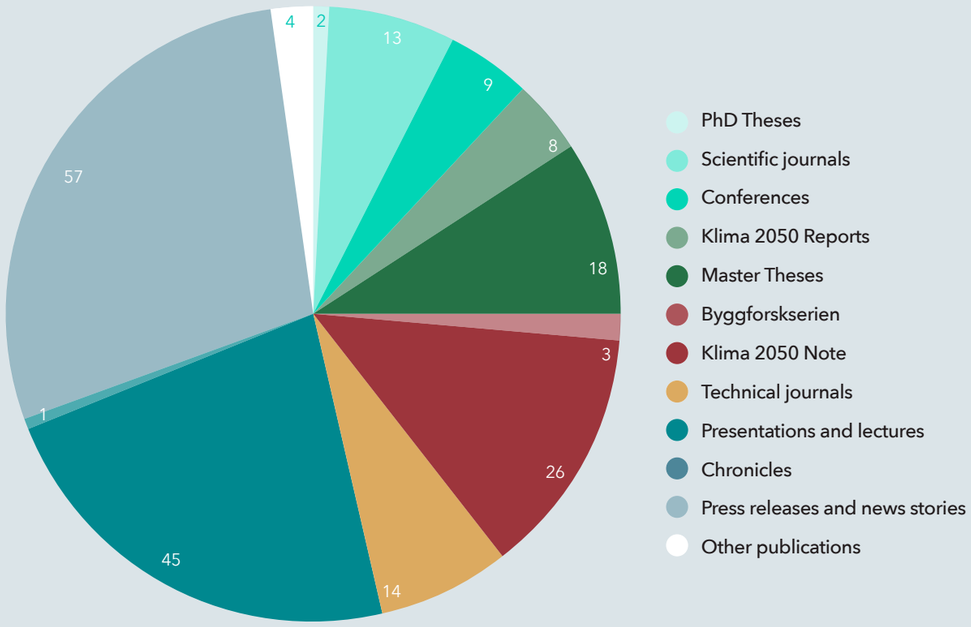
4 Key figures

Photo: Unsplash

Communication and visibility

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

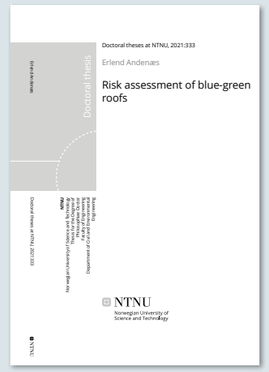
The policy of the Centre is to publish at least one user-oriented/ public-oriented publication for each scientific publication focusing on the practical benefit of the scientific work. The counting by the end of 2021 shows following distribution of publications.



Publications

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

Klima 2050 Report



PhD

Technical journal

Scientific journal

PhD

Defence of PhD-thesis:
Erlend Andenæs

Erlend Andenæs defended his thesis at NTNU with the title "Risk assessment of blue-green roofs".

In the picture:
Professor Rolf André Bohne, NTNU
Erlend Andenæs NTNU, Professor Eva B. Møller, Technical University of Denmark

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 meetings, collecting between 20 and 100 people in 2021 are important in view of knowledge exchange, the researchers receive direct input to the research work and areas of closer collaboration are pointed out. The meetings have been on Teams.

- *Overvann i Breeam-Nor, 19 February*
- *Effektive verktøy og veiledere for betre beslutninger om klimatilpasning, 8 March*
- *Klimanormalar, referanseperiodar & konsekvensar av klimaendringar, 26 May*
- *Masteroppgaver tilknyttet pilotprosjektene på overvann, 4 July*
- *Joint thematic meeting between Klima 2050 and the EU-project EviBAN, 17 August*
- *Sikring mot flom og skred fram mot 2050: Sikrer vi oss til fant? 10 September*
- *Kriterier og indikatorer for klimatilpasning, 19 October*
- *Modelling of rapid mass movements, 22 November*
- *Fuktsikre konstruksjonar mot terreng, 15 December*

Recruitment

Klima 2050's PhD Candidates financed by the Centre:

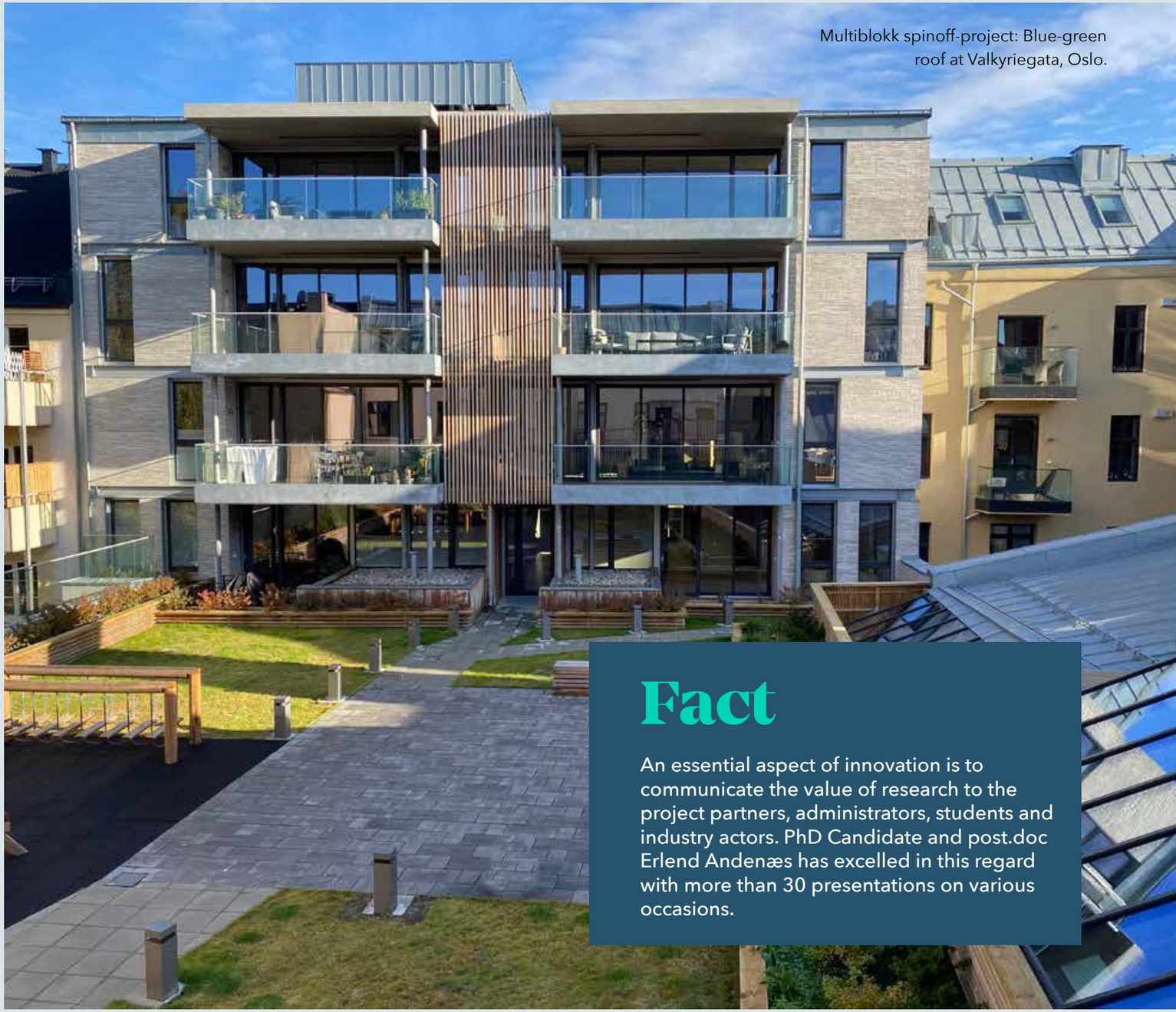
Jørn Emil Gaarder, *NTNU*
Silje Asphaug, *NTNU*
Erlend Andenæs, *NTNU – awarded PhD 5 November*
Erin Lindsay, *NTNU*
Petter Fornes, NTNU
Bridget O'Brien Thodesen, *NTNU*
Hervé Vicari, *NTNU*
Vladimir Hamouz, *NTNU awarded PhD (2020)*
Aynalem Tasachew, *NTNU awarded PhD (2019)*
Lars Gullbrekken, *NTNU awarded PhD (2018)*

Associated PhD Candidates:

Manuel Franco Torres, *NTNU/Multiconsult*
Atle Engebø, *NTNU*
Kaj Pettersson, *Chalmers University of Technology awarded PhD 31 May*
Ashenafi Lulseged Yifru, *NTNU awarded PhD (2020)*
Birgitte Gisvold Johannessen, *NTNU/Trondheim Municipality awarded PhD (2019)*

Post.docs 2021:

Anne Kokkonen, *BI*
Jardar Lohne, *NTNU*
Erlend Andenæs, *NTNU*



Multiblokk spinoff-project: Blue-green roof at Valkyriegata, Oslo.

Fact

An essential aspect of innovation is to communicate the value of research to the project partners, administrators, students and industry actors. PhD Candidate and post.doc Erlend Andenæs has excelled in this regard with more than 30 presentations on various occasions.

Annual account 2021

FUNDING

The Research Council	12 000
SINTEF (host institution)	2 824
Research partners	2 420
Private partners	6 842
Public partners	6 084
Sum	**30 170**

COSTS

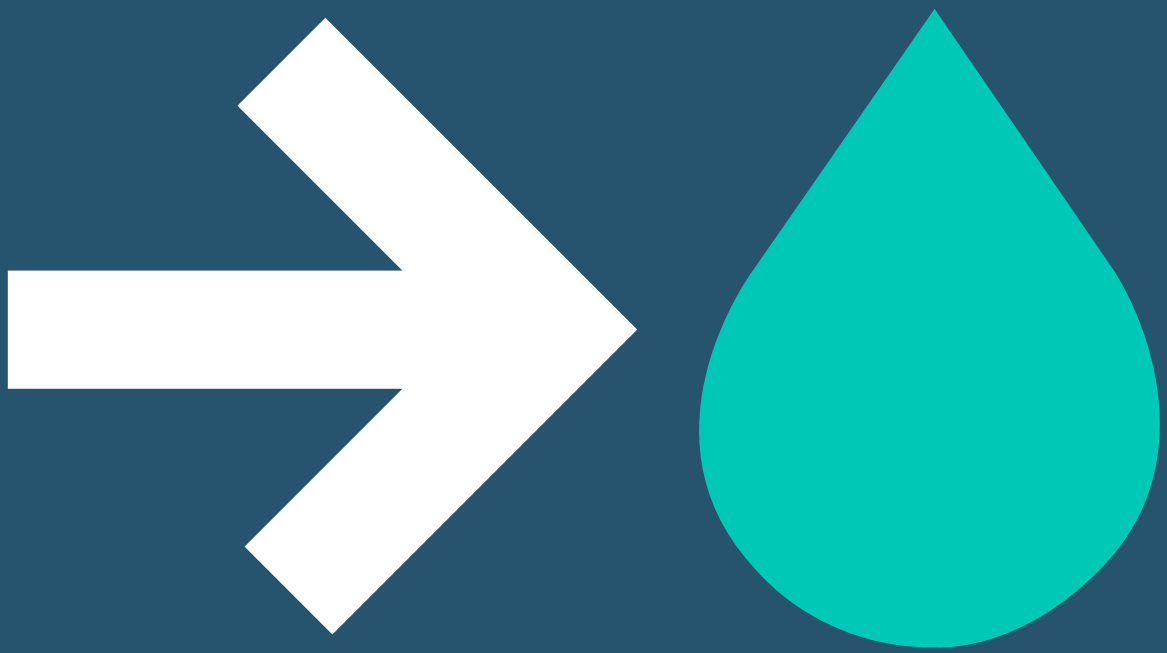
SINTEF (host institution)	12 144
Research partners	12 407
Private partners	5 542
Public partners	77
Sum	**30 170**

All figures in 1000 NOK

Photo: Skanska

For more information about Klima 2050 go to our webpage:

www.klima2050.no



Report no 31 Klima 2050 Annual Report 2021

Berit Time (editor)

Keywords: Klimatilpasning, bygninger, overvann, skred, beslutningsprosesser, samfunnsøkonomi

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